

BEVERAGE CHOICE IMPACT ON HYDRATION AND PERFORMANCE FOR THE  
RECREATIONAL ATHLETE

by

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A DISSERTATION

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## ABSTRACT

Three studies examined hydration and performance for recreational exercisers (REC). Three beverages (flavored caloric (CE) and non-caloric (NCE) electrolyte-containing sport drinks and water (W)) were served to male ( $n = 24$ ) and female ( $n = 14$ ) REC in a counter-balanced order during 1-h of moderate intensity cycling (mean  $\pm$  SD heart rate =  $146 \pm 4$  beats/min) in an environment of  $25^{\circ}$  C wet bulb globe temperature. The volume of beverage served was equal to sweat loss measured (mean  $\pm$  SE =  $834 \pm 59$  mL) in a familiarization trial with no fluid intake during exercise. No differences ( $p > .05$ ) among beverages were found in: performance (peak and mean power) during a set of three Wingate Anaerobic Tests completed after cycling, perceived exertion, or mood states among beverages. After exercise in the familiarization trial with no fluid intake, participants drank *ad libitum* for 30 min with all beverages available. Consumption volume among beverages did not differ ( $p > .05$ ). Participants reported that replacing 100% of sweat loss was an appropriate volume and did not result in stomach discomfort for the majority of individuals in fluid intake during exercise sessions. Total intake in the familiarization session when fluids were consumed in recovery only (mean  $\pm$  SD,  $971 \pm 375$  mL) was less ( $p \leq .001$ ) than when consumed during both exercise and recovery (W ( $1,415 \pm 560$  mL), NCE ( $1,244 \pm 538$  mL,  $p < .001$ ), and CE ( $1,196 \pm 444$  mL), and W was greater than CE ( $p = .01$ )). The survey found decreased performance (69%) and heat-illness (45%) believed to be related to dehydration among runners was very common. Almost all (94%) of participants ( $n = 276$ ) reported drinking during outdoor runs in warm weather. Faster higher volume runners believed that consuming sport beverages would result in

improved performance and better hydration than water. For REC exercising for ~1 h, replacing sweat loss during exercise and drinking *ad libitum* afterwards, should result in a fluid intake level that will return body mass close to pre-exercise level, be tolerable, and result in no decrease in performance when W or CE are used instead of CE.

## DEDICATION

I would like to thank God for bestowing on me a small talent of wisdom, a large amount of pride to be too stubborn to quit, and an endless supply of love and support from individuals who have pushed and believed in me. I am not sure why I was chosen to be blessed with such a great wife, parents, brother, family and friends too numerous to count. I would like to dedicate this dissertation to all of those who have always been there for me.

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## CONTENTS

|   |      |
|---|------|
| ABSTRACT.....   | ii   |
| DEDICATION.....   | iv   |
| ACKNOWLEDGEMENTS.....   | v    |
| LIST OF TABLES.....   | vii  |
| LIST OF FIGURES.....  | viii |
| I. INTRODUCTION.....  | 1    |
| II. CARBOHYDRATE INGESTION DURING 50 MIN OF CYCLING DOES NOT<br>ALTER POWER, MOOD, OR PERCEIVED EXERTION.....                                       | 4    |
| III. INFLUENCE OF 100% FLUID REPLACEMENT DURING EXERCISE ON THIRST<br>SATIETY, STOMACH DISCOMFORT, AND VOLUNTARY FLUID INTAKE<br>POST-EXERCISE..... | 28   |
| IV. HYDRATION PRACTICES AND PERCEPTIONS OF HALF- AND FULL-<br>MARATHON RUNNERS.....   | 54   |
| V. CONCLUSIONS.....   | 77   |

## LIST OF TABLES

### CHAPTER II

|  |    |
|--|----|
| 1. Characteristics of participants (Mean $\pm$ SD, n = 36).....  | 23 |
| 2. Characteristics of exercise sessions by treatment (Mean $\pm$ SD, n = 36).....                                | 24 |
| 3. Responses to questionnaire items as marked on a 100-mm visual analogue scale,<br>(Mean $\pm$ SD, n = 36)..... | 25 |

### CHAPTER III

|  |    |
|--|----|
| 1. Reported Exercise-related Fluid Intake Habits (Mean $\pm$ SE).....  | 46 |
| 2. Responses to post-exercise questionnaire items (Mean $\pm$ SE)..... | 50 |

### CHAPTER IV

|  |    |
|--|----|
| 1. Demographics, Running Habits, and Distance and Predicted Finishing Times<br>(n = 276).....                          | 71 |
| 2. Sources of information for hydration strategies and beverage choice (n = 276).....                                  | 72 |
| 3. Beverage choice and perceptions of ergogenic and hydration qualities of water and sport<br>beverages (n = 276)..... | 73 |
| 4. Incidence of decreased performance and heat illness related to inadequate hydration (n =<br>276).....               | 74 |
| 5. Hydration monitoring and methods incorporated by percentage (n = 276).....  | 75 |
| 6. Reported fluid intake habits during outdoor runs and methods of fluid delivery<br>(n = 275*).....                   | 76 |

## LIST OF FIGURES

### CHAPTER II

1. Mean  $\pm$  SE performance outcomes including peak power for the first  $W_{AnT}$  (WPK1), average power for the first  $W_{AnT}$  (WAVG1), and average power for all 3  $W_{AnT}$  (WAVG1-3). No differences ( $p > .05$ ) were found among beverages for any variable.....26
2. Mean  $\pm$  SE ratings of perceived exertion by time point and beverage. No significant differences ( $p > .05$ ) were found between any beverages.....27

### CHAPTER III

1. Baseline taste test ratings (men = 24, women = 14). Taste test rating scale 0 = extremely dislike, 9 = extremely like. † = Significant difference ( $p < .05$ ) from W for all responses. ‡ = Significant different ( $p < .05$ ) for beverage taste rating between men and women.....48
2. Voluntary consumption by volume following the baseline session with no fluid intake during exercise (men = 24, women = 14).....49
3. Voluntary consumption by percentage of total consumption for 30 min following the baseline session with no fluid intake (men = 24, women = 14).....50
4. Voluntary consumption 30 min post-ride following 100% fluid intake during 50 min cycling sessions (men = 24, women = 14).....51
5. Total consumption across treatments in comparison to mean sweat loss. SL = mean sweat loss for all sessions. BL = total consumption with all beverages for 30 min following baseline ride with no fluid consumption during exercise. ‡ = Significant difference from W, NCE, and CE sessions. † = Significant difference from W.....52
6. Reports of stomach discomfort by beverage. Response to the questionnaire item: “Did you experience any stomach discomfort related to drinking the beverage during the ride?” using a 100 mm visual analogue scale (0 = “Not at all” and 100 = “Very much”).....53

## CHAPTER I

### INTRODUCTION

Guidelines concerning hydration during athletic competitions and training have undergone many changes over the last few decades and continue to evolve. There are examples from the not too distant past in which coaches viewed drinking fluids during practice as a sign of weakness and did not allow it. Today, it is well established that beginning activity in a euhydrated state and fluid consumption during exercise in warm or hot conditions can play a substantial role in improving performance and decreasing risk of heat-related illness incidents. There is much evidence that highly trained and elite athletes will consume sports drinks in greater quantities than water when exercising and that during prolonged exercise, drinking sport beverages can be advantageous with regards to performance and rehydration. However, there is a paucity of information examining performance and hydration in exercise conditions experienced by the average adult recreational athletes or exercisers (REC). This investigation explored performance and hydration effects when three beverages were consumed by REC exercising in warm environment for one hour, and the current hydration practices of recreational runners.

Sport beverages or flavored, carbohydrate-electrolyte beverages (CE) have received much attention and evidence suggests they may offer advantages over water with regards to rehydration and performance during prolonged exercise. However, investigations exploring possible advantages of CE often involve elite level athletes taking part in exercise that does not represent the duration, intensity, or environmental

conditions experienced by most adult exercisers or recreational athletes (REC).

In the last decade multiple groups of investigators have claimed CE consumption can improve aerobic and intermittent high intensity exercise performance for bouts lasting one hour in comparison to water or flavored, non-calorically sweetened placebos. If CE do actually offer advantages for shorter term exercise, many REC could possibly benefit from consuming CE during their normal workouts. However, nearly all investigations showing positive results for CE consumption have tested highly trained athletes performing after twelve or more hours of fasting.

Our first investigation examined differences in performance, mood, and perceived exertion for REC completing one hour of exercise, two hours post-prandial while consuming CE, flavored, non-caloric electrolyte containing sport beverage (NCE), or water (W). We hypothesized that CE compared to NCE or W consumption would result in no differences in performance, mood, or perceived exertion for REC.

Although little information is available, there is evidence that it is common for REC to begin exercising in a hypohydrated condition. These problems have been addressed repeatedly for participants in organized sport environments and many precautions usually involving intervention from coaches or athletic trainers are taken to ensure that athletes begin competition or practices euhydrated. The same preventative measures are unlikely to be undertaken for or by REC. The purpose of our second investigation was to determine if athletes consuming a volume of W, NCE, or CE equivalent to that lost through sweating in a familiarization trial would be well accepted and result in greater total intake including fluid consumed in a 30-min recovery period versus voluntary consumption in recovery only. We hypothesized that the volume served

would be well tolerated and that no preference for flavored beverages (i.e. CE or NCE) would be exhibited for REC, as has been seen for more highly trained athletes.

In our third investigation a questionnaire was administered at a major marathon concerning: 1) where runners get their information from regarding beverage choice and hydration strategies, 2) perceptions of hydration and ergogenic properties of sport beverages versus water, 3) history of performance decrements and heat-related illness believed to be caused by dehydration, 4) methods used to monitor hydration status, and 5) if and how runners provide themselves with fluids during runs. Two-hundred and seventy-six runners registered for the Little Rock half- or full- marathon completed the survey and participants were separated into tertiles based on reported running volume and expected finishing time. We hypothesized that higher volume and faster runners would report greater usage of sport beverages, have more favorable opinions about sport beverages, report a greater prevalence for performance decrements and heat-related illness believed to be caused by dehydration.

Knowledge of issues regarding sport and hydration has greatly expanded, but the needs and experiences of REC have received very little attention. The purposes of this study were to determine: 1) whether a performance advantage would be seen for REC drinking a CE in comparison to a NCE or W; 2) if replacing 100% of predicted sweat loss during exercise and drinking *ad libitum* in recovery would be well received and result in greater total fluid consumption than voluntary consumption during recovery only, and if difference would exist among CE, NCE, and W; and 3) the hydration practices and viewpoints concerning beverage choice of adult recreational distance runners.

## CHAPTER II

### Carbohydrate Ingestion During 50 min of Cycling Does Not Alter Power, Mood, or Perceived Exertion

The purpose of this study was to compare, in recreational aerobic exercisers, mood states and sprint cycling performance after ingesting water (W), a flavored carbohydrate-electrolyte (CE) or a flavored non-caloric electrolyte (NCE) beverage during exercise. Men ( $n = 23$ ) and women ( $n = 13$ ), who reported engaging in between 150 and 450 min of exercise per week, completed four 50-min moderate intensity bouts of cycling (50MR) at ~60-65% of heart rate reserve in a warm environment ( $WBGT = 24.9 \pm 0.5^{\circ}\text{C}$ ) followed by three 30-s Wingate anaerobic tests ( $W_{\text{AnT}}$ ) separated by 2.5 minutes. Participants reported to the laboratory two hours post-prandial and consumed a 24-h standardized diet provided by the investigators. During one of the 50MR, participants drank either W, CE (mean  $\pm$  SD carbohydrate =  $49 \pm 22$  g), or NCE (counterbalanced) equal to the amount of sweat they lost in an initial familiarization session ( $847 \pm 368$  mL). Participants were only informed they would be drinking water and two sport beverages. Blood glucose and a Profile of Mood States Brief questionnaire (POMS) were obtained before each 50MR, and immediately prior to the  $W_{\text{AnT}}$ . No differences ( $p > .05$ ) were found for pre-ride blood glucose, but glucose was higher ( $p < .05$ ) post-50MR for CE ( $110.6 \pm 30.4$  mg/dL) than W ( $88.6 \pm 27.5$ ) or NCE ( $82.3 \pm 21.3$ ). Carbohydrate consumption resulted in no differences in the peak or average power output for the first  $W_{\text{AnT}}$  or overall average for all three  $W_{\text{AnT}}$ . No differences among beverages were found in RPE at any point during the ride or for session RPE. There was a significant increase ( $p < .001$ ) in POMS fatigue from pre- to post-

50MR, but there were no differences among beverages. The results of the present study suggest that recreational athletes do not experience differences in mood, level of perceived exertion, or  $W_{AnT}$  performance following 50 min of moderate intensity exercise while consuming W or a NCE versus a CE.

**Keywords:** recreational exercisers, non-caloric sport beverage, RPE, mood states

## **Introduction**

It is commonly accepted that consuming carbohydrate-electrolyte beverages (CE) in a range of 30-60 g of carbohydrate/hour during prolonged exercise (> 2 h) will enhance late exercise performance (Coyle, 2004). (Coyle, 2004; 2004) However, the percentage of exercisers who actually train for two or more hours in a single bout is small, and comprises only a small percentage of CE consumers. There is evidence that ingesting CE can provide performance benefits for high intensity endurance activity lasting ~1 h (Anantaraman, Carmines, Gaesser, & Weltman, 1995; Ball, Headley, Vanderburgh, & Smith, 1995; Below, Mora-Rodriguez, Gonzalez-Alonso, & Coyle, 1995; el-Sayed, Balmer, & Rattu, 1997; A. Jeukendrup, Brouns, Wagenmakers, & Saris, 1997; Millard-Stafford, Roszkopf, Snow, & Hinson, 1997; Neuffer, et al., 1987; I. W. Rollo, C, 2009) and intermittent high intensity protocols simulating sports such as soccer or basketball (Welsh, Davis, Burke, & Williams, 2002; Winnick, et al., 2005) lasting ~1 h.

The above mentioned studies support the position that CE consumption could possibly increase performance in a broad range of exercise conditions. However, applying findings from laboratory settings involving CE consumption and highly trained athletes to more recreationally focused exercisers is difficult. In an excellent review concerning the efficacy of commercially available CE and performance (Coombes & Hamilton, 2000), the authors point out that in four of

the most often cited studies in support of CE for performance improvement, participants reported to exercise after a minimum of a 12-h fast and consumed beverages with carbohydrate concentrations as high as 50% (6.5 times greater than the concentration of current commercial sport beverages that are intended to be consumed during exercise). Similar criticisms could be made for the ~1-h duration studies cited above, because seven of the nine studies used protocols with subjects who had fasted 10-15 hours prior to exercise and one study (Welsh, et al., 2002) had participants consume beverages with carbohydrate concentrations as high as 18% whereas current carbohydrate concentrations for sport beverages are typically around 6%.

The proposed mechanisms for performance improvements in shorter bout activity from CE consumption remain unclear. The traditional proposed peripheral mechanism for the ergogenic effects of CE is that exogenous glucose sources spare hepatic and muscle glycogen stores allowing for greater oxidative carbohydrate availability late in exercise (Coyle & Montain, 1992). When glucose is infused versus ingested, these findings have been evident in long bouts of exercise (Coggan & Coyle, 1987) but not during a 1-h cycling time trial (Carter, Jeukendrup, Mann, & Jones, 2004). More novel proposed mechanisms that could potentially explain performance improvement during 1-h performance are linked to central mediated factors. Carter et al., (2004) found riders completed a one-h cycling time trial faster when rinsing and spitting (i.e. not ingesting) a CE versus water.

Using functional magnetic resonance imaging, Chambers, Bridge and Jones (2009) have provided compelling evidence supporting this hypothesis. The authors found increased brain activity in regions associated with reward and locomotion during rest with glucose or maltodextrin in comparison to a saccharin-sweetened solution. The authors followed up the functional magnetic resonance imaging testing with the same participants completing an ~1-h

performance ride. Performance was improved in comparison to the saccharin-sweetened beverage when either form of carbohydrate was swilled around in the mouth and spit out. However, the positive results described in the previous study came from participants who were fasted for 6 hours if they rode in the afternoon or 12 hours if they rode in the morning. CE mouth rinse has also been shown to improve 1-h running performance when participants were fasted (I. Rollo, Cole, Miller, & Williams, 2009), but performance was not improved when runners were fed (Whitham & McKinney, 2007), or for cyclists with CE mouth rinse (Beelen, et al., 2009).

Lowered blood glucose levels during exercise may also influence mental drive. Work by Davis et al. (1992), revealed exercisers consuming a CE had longer rides to exhaustion accompanied by significantly lower levels of free tryptophan (the rate limiting factor in serotonin production) than those drinking a placebo. Two studies (Welsh, et al., 2002; Winnick, et al., 2005) in which CE and placebos were administered to athletes completing intermittent high intensity exercise for one hour both noted trends of less fatigue and more vigor late in exercise with CE feedings. Both studies used a protocol requiring a 12-h fast before exercise, and in the first study participants consumed  $127.5 \pm 4.9$  g of sugar. Backenhouse et al., (2005) reported higher levels of pleasure beginning and continuing at the 15 min mark of a 2-h ride when endurance trained cyclists following an overnight fast drank a CE verses a placebo.

Over the past four decades sport beverages have undergone many changes in regards to the types and concentrations of carbohydrates used (Coombes & Hamilton, 2000). Interestingly, one of the latest trends is to offer as a sport beverage non-caloric electrolyte beverages (NCE), which were once considered a placebo in sport beverage research. Lower calorie or even NCE

have become increasingly popular in the United States for exercisers who are concerned with caloric intake (Scott, 2009).

The purpose of this study was to determine if individuals, who regularly exercise for recreation but not as highly competitive athletes, would exhibit improved performance late in exercise, perceive exercise as less difficult, or report lower levels of fatigue and increased vigor when consuming a CE during exercise versus a NCE or W in a fed state. We hypothesized that no difference would be exhibited among beverages for performance, level of perceived exertion, or mood state sub-components in non-fasted recreational athletes.

## **Methods**

### **Participants**

Men (n = 23) and women (n = 13) ages 19-30 who reported participating in a minimum of 150 but no more than 450 minutes of aerobic exercise per week for the previous 3 months were recruited to participate in this study. Participants were excluded if: they reported having a fluctuation of more than 10 pounds in body weight during the previous 3 months, had a body mass index score less than 18.5 or greater than 29.9, were currently using medication of any type excluding birth control, had an initial random blood glucose test < 70 mg/dL or > 145 mg/dL, a systolic blood pressure > 140 mm Hg or diastolic blood pressure > 90 mm Hg, or were considered at risk based on health questionnaires. This study was approved by the university's institutional review board and participants gave written informed consent prior to participation. Participants were recruited through word of mouth and flyers posted and handed out to individuals engaging in aerobic exercise at the student recreation center of a major university in the southeastern United States.

Weight and height were measured on a balance beam scale and stadiometer (Detecto, Webb City, MO) to determine Body Mass Index. Three-site skinfold measurements (Lange Caliper, Beta Technology Inc., Deer Park, NY) were recorded in accordance with ACSM guidelines (Whaley, 2006) to estimate body fat percentage (Jackson & Pollock, 1985). Participants also completed a short questionnaire describing their current exercise habits. A description of the participants is displayed in Table 1. Thirteen of the twenty-six participants reported that they engaged in indoor or outdoor cycling weekly ( $2.3 \pm 1.4$  times per week). Only three participants reported engaging in organized endurance competitions in the last 6 months. None of the reported finishing times would classify these participants as elite endurance athletes.

#### *Beverage Content and Administration*

Bottled water (W), a 6% carbohydrate-electrolyte (CE), and a non-calorically-sweetened beverage containing electrolytes (NCE) served as independent variables. The CE and NCE were grape flavored. Each beverage used was sold commercially and their composition was not altered for this study. Grape flavoring was used in both sport beverages. Data collection assistants and exercisers were blinded to caloric and non-caloric beverages but it was not possible to blind them to the water.

Blood glucose was taken pre- and post- the 50-minute ride (50MR). One investigator conducted all glucose analyses but was not actively involved in the performance tests. All other data collectors were unaware of the differences in the sport beverages. In the initial screening session, participants were presented with a single list of all ingredients that could potentially be in the beverages and were asked if they were aware of allergies to any ingredients. Participants were only informed that they would be receiving water and two sport beverages. It is possible that some participants recognized the presence of non-caloric sweeteners or identified the

beverage, but no description of the caloric versus non-caloric factors were discussed by investigators. The lead investigator was also the only member of the data collection team who was aware of the caloric versus non-caloric treatments. Participants were instructed not to comment in any manner on the characteristics of the beverages to other participants.

Participants brought two sets of shirts, shorts, and undergarments and were weighed before and after exercise, wearing the same dry pair for both measurements in the familiarization session in which no fluid was provided. Sweat loss was determined from weight change adjusted for urinary voids, and for ingested beverage weight for the experimental beverage sessions. Volume of consumption for fluid intake trials was based on the maximal level of recommended intake as suggested by the most recent ACSM (Sawka, et al., 2007) fluid replacement position stand (i.e. 100% of sweat loss).

In separate trials (sessions 2-4), a volume of W, CE, or NCE equivalent to the sweat loss during the familiarization session was served in three equal aliquots to participants, chilled and in a tinted unmarked bottle at minutes 0, 20, and 40 of the 50MR. Participants were instructed to consume all content within a 10-minute period from the time beverage was received. Only participants who lost a minimum of 300 ml of sweat during the familiarization trial were allowed to continue to the experimental sessions. The average sweat loss during the familiarization session was  $847 \pm 368$  ml (mean  $\pm$  SD). Participants consumed  $49.4 \pm 21.5$  g (mean  $\pm$  SD) of carbohydrates during the CE trial.

#### *Familiarization Session*

Participants were instructed to drink ~500 ml of water between their last meal and the time they went to bed and a second 500 ml of water during the 2 hours before reporting to the laboratory 1-3 hours post-prandial. Participants were instructed not to consume alcohol or

caffeine during the 24-h period prior to any experimental trial. Following explanation of the study, completion of the consent form, and completion of the medical and the exercise history questionnaires, a resting capillary blood glucose measurement was taken via a finger stick. Whole blood was collected in a 100  $\mu$ L fluoride/heparin/nitrite-containing capillary tube (Analox Instruments, Lunenburg, MA) mixed for 3 min and analyzed in triplicate (PGM7 Analyzer, Analox Instruments, Lunenburg, MA). The average of the two closest measurements was recorded. The same method was used for all subsequent blood glucose measurements.

Participants were then instrumented with a heart rate (HR) monitor (Team System Monitor, Polar Electro Oy, Kempele, Finland) and were instructed to remain seated without major movement for 15 min in a dimly lit and quiet room. HR was recorded continuously in 5-s intervals and resting HR was reported as the average rate from minutes 5 to 15. After resting HR was recorded, duplicate seated blood pressure measurements were taken according to ACSM guidelines (Whaley, 2006). Height, weight, and the sum of three skinfolds (as described above) were then measured and recorded.

Prior to each exercise session, participants completed a Profile of Mood States-Brief questionnaire (POMS) (McNair et al. 1989). The POMS is a 30-item pencil and paper test that evaluates levels of anger, tension, fatigue, confusion, vigor and depression. After pre-exercise weight was recorded and participants changed into ride attire, participants put on a heart rate monitor and fitted themselves to an indoor spin bike (Johnny G's Spinner Pro, Star Trac, Irvine, CA). Seat and handlebar height were recorded to duplicate the set-up in each subsequent trial. The low, high, and middle HR counts for 60-65% of HR reserve based on resting HR and age-predicted maximal heart rate ( $208 - (\text{age} \times 0.7)$ ) (Wilmore, Costill, & Kenney, 2008) were posted on the wall in front of the stationary bikes. Investigators instructed riders to select the

pedal cadence they wished to use and gradually increase the resistance on the bike until they reached an intensity level that would allow them to maintain a HR as close as possible to the target HR on the wall in front of them. HR monitor watches were placed on the handlebars of the bike to give the rider a visual and audible signal (watches beeped when participants were outside of target HR range). The HR range was chosen to represent a moderate intensity workout. After five minutes of riding in the pre-determined HR range, participants were asked if they felt the intensity was below or above their normal exercise intensity. If participants perceived the intensity to be too low, the HR range was increased by five to ten beats per minute until a more closely matched their normal exercise intensity. Participants reported having no problem maintaining the prescribed intensity level and average HR differed less than one beat per minute between trials among beverage types (Table 4). Subsequent sessions for individuals took place at the same time of day, day of the week, and with the same cohort of riders as the initial session. Up to three participants rode at the same time. Participants were instructed not to change their current exercise routines.

The 50MR took place in an environmental chamber with a wet bulb globe temperature (WBGT) of approximately 25°C. At minutes 10, 20, 30, 40, and 50, a 2-min rest period took place so sweat could be collected from a patch on the participants' lower backs as part of a separate investigation. There was 50 minutes of actual cycling for the initial exercise phase.

Immediately following the final sweat collection, five min of rest was given to collect blood for the blood glucose measurement and administration of a second POMS. Participants then transferred to an electronically-braked cycle ergometer (Velotron, RacerMate Inc., Seattle, WA) to complete three, 30-s Wingate Anaerobic Tests ( $W_{AnT}$ ) with a resistance equal to ~7% of their body weight. Peak power and mean power were recorded for each test. Two and half

minutes of recovery were given between each  $W_{AnT}$ . Participants continued pedaling at a resistance level and cadence of their choice during recovery. Participants were given strong verbal encouragement by at least two investigators during performance testing. After a short cool down, participants dried off, changed back into their original dry clothes, and had post-exercise weight measured so sweat loss could be calculated.

### *Beverage Consumption Sessions*

Three meals including beverages and two snacks were provided to participants by investigators prior to each session. Participants recorded the time each item was consumed in the 24-h period leading up to the first beverage consumption session and replicated the time meals were eaten in the following 2 sessions to standardize nutritional intake. The last meal was eaten 2-3 hours prior to the commencement of exercise and only water was consumed in the 2-hour period before reporting to the laboratory. Participants were required to consume all items they had been provided and no additional food or beverages (except for water) were permitted during the 24 hours before testing.

Test sessions were held throughout the day beginning no earlier than 07:00 and ending no later than 21:00 local time. Different final meals were eaten before trials held at different times of the day, but food was consumed in the same order and the same pre-exercise meal was constant between trials for individuals. The total caloric value of the 24-h diet provided to participants was ~1975 kcal (carbohydrate = 67.0%, fat = 23.7%, and protein = 9.3%) and included no meat products.

Following the familiarization session, participants completed three identical exercise sessions (excluding beverage administered) each separated by 7 or 14 days over the following four weeks (if participants were unavailable for one session, they completed the session the

following week). RPE (Borg 6-20 scale) (Borg, 1998) was recorded at minutes 20, 40, and 60 during the 50MR. Following the post-exercise weight measurement, participants provided a session RPE and completed two questionnaire items in which they were asked to rate the difficulty of the ride compared to their normal workouts and if they felt drinking the beverage improved their performance ability. Participants also completed a questionnaire in the health screening portion of the first session addressing the regularity in which they drank sport beverages in exercise environments and rated factors that influenced their motivation to exercise. A 100-mm visual analogue scale was used for the questionnaire items.

### **Statistical Analyses**

Differences in response to questionnaire items concerning motivational factors for exercise and current sport beverage consumption habits between men and women were compared using independent sample *t* tests. Doubly repeated measures analysis of variance was used to determine if there were main effects for treatment or time or an interaction for beverage and time (pre- post- 50MR) for blood glucose levels and POMS sub-component scores. If a main or interaction effect was found, repeated measures analysis of variance was used to determine if differences existed among beverages for pre- or post- values. Repeated measures analysis of variance was used to determine if there were differences for 50MR WBGT and average HR, peak power for the first  $W_{AnT}$  (WPK1), average power for the first  $W_{AnT}$  (WAVG1), overall average power for all three rides (WAVG3), session RPE (S-RPE), and post-exercise questionnaire items among beverages trials. Bonferroni post-hoc tests were used in all applicable analyses. All hypothesis tests used an alpha level of .05. All data are reported as mean  $\pm$  SE unless otherwise noted.

Missing data resulted when a pedal came unscrewed during one participant's  $W_{AnT}$ , two individuals did not complete their post-ride evaluation questions after a session, and blood glucose could not be obtained due to a mechanical problem with the analyzer during one day of testing for a few participants. A series mean method was used to replace missing data points. No variable had more than two missing data points per beverage. All statistical analyses were conducted using SPSS package, version 18.0 (SPSS Inc., Chicago, IL).

## Results

No differences in WBGT (overall average =  $24.9 \pm 0.5^{\circ}\text{C}$ ) or average HR (overall average =  $146 \pm 4$ ) were found among trials. A main effect for time ( $p = .03$ ) and interaction for treatment by time ( $p < .001$ ) was found for blood glucose. No differences were found for pre-exercise blood glucose among beverages, but post-50MR blood glucose was higher for CE than W ( $p = .015$ ) and NCE ( $p = .001$ ). The fatigue rating was the only POMS component which had a significant main effect or time x beverage interaction. A main effect for time ( $p < .001$ ) and interaction for treatment and time ( $p = .04$ ) was found for differences in pre- and post-50MR POMS fatigue component, but no differences were found among beverages for pre- or post-conditions for the POMS fatigue component. Values for WBGT, HR, blood glucose, and POMS fatigue by treatment are shown in Table 2. Men reported lower levels of agreement to “exercising because it is an enjoyable activity” ( $p = .04$ ), and higher levels of agreement to “exercising to improve performance during competitive athletics” ( $p = .03$ ) than women (Table 3). Men also reported greater ( $p = .004$ ) “consumption of sport beverages in exercise environments” than women (Table 3).

No differences among beverages were found for any of the  $W_{AnT}$  performance measures (Figure 1). No differences were found for S-RPE among beverages (overall =  $15.0 \pm 0.3$ ) or at

any time during the ride (Figure 2). When asked to rank how difficult each session was compared to their normal workouts, responses for all beverages were closer to the “Much more difficult” anchor. When asked if they felt drinking the beverages improved their workout performance ability, averages for all beverages were below 50 mm on 100-mm scale with “Not at all” as the 0 anchor (Table 3).

## **Discussion**

The health benefits of regular physical activity are well documented. However, exercise for the purpose of weight management and improved physical appearances have been noted as strong motivational factors for women (Prichard & Tiggemann, 2008) and men (Strelan & Hargreaves, 2005). Weight management as a strong source of motivation for exercise was reflected by our participants regardless of gender (Item 2, Table 3). Not surprisingly, lower- and non-caloric sport beverages have become increasingly popular alternatives to traditional sport beverages. Current recommendations (Rodriguez, DiMarco, & Langley, 2009; Sawka, et al., 2007) suggest that the addition of carbohydrates should not affect performance lasting less than an hour. However, investigations using highly trained endurance athletes (Anantaraman, et al., 1995; Ball, et al., 1995; Below, et al., 1995; el-Sayed, et al., 1997; A. Jeukendrup, et al., 1997; Millard-Stafford, et al., 1997; Neuffer, et al., 1987; I. W. Rollo, C, 2009) or protocols involving intermittent high intensity (Welsh, et al., 2002; Winnick, et al., 2005) tasks have provided contrary evidence.

Although not conclusive, it appears improvement may be linked to central, rather than peripheral mechanisms for improvements during shorter time spans. Regardless of mechanisms that might elicit such changes, the intentions of this investigation were to determine if adults who regularly engage in aerobic exercise for reasons other than endurance sport competition

improvement, would experience any differences in perceived exertion levels, performance capability, or mood states associated with three different beverages during a 50-min bout of moderate intensity exercise followed by three maximal effort anaerobic power output tests.

Data from the current investigation suggest that the addition of carbohydrates in a flavored electrolyte containing beverage had no impact on performance, mood, or perceived level of exertion. It is possible that our findings of no impact of carbohydrate on mood, perceived exertion, or performance were due to relatively lower intensity levels of our testing (i.e. the 50MR at 60-65% of HR reserve) compared to the time-trial protocols used in studies with highly trained cyclists. Another explanation might be that the intermittent high intensity investigations (Welsh, et al., 2002; Winnick, et al., 2005) used very different exercise protocols from ours (i.e. other protocols involved sprinting, shuttle runs, vertical jumps and tempo runs). However, our participants reported the difficulty of the trials overall was higher than their normal workouts.

Another explanation for the difference between our findings and similar studies in which performance was improved with CE consumption or mouth rinse, can possibly be attributed to differences in the dietary condition of our protocol. Desbrow et al. (2004), Beelen et. al., (2009), Whitham and McKinney (2007), and the present study, all chose to conduct investigations in which a pre-activity meal was consumed within two to four hours of the start of exercise rather than in a fasted state. None of these four studies found any increases in performance with carbohydrate consumption or mouth rinse during activity.

Feeding participants more closely represents the actual habits of athletes. Pre-feeding provides contrasting results (i.e. no improvement versus improvement) to nearly all published investigations using a fasting protocol. We support the conclusions of Desbrow et al. (2004) and

Beelen et al., (2009) that mixed-nutrient feeding within a few hours prior to testing may have mostly mitigated the ergogenic effects of carbohydrate ingestion or mouth rinse during exercise seen in past investigations with fasted participants.

A final consideration in interpreting the results of sport beverage-performance studies is the fact that some participants may have had biased expectations of the beverage being consumed in un-blinded studies. Clark et al. (2000) found highly trained cyclists improved 40-km (~1-h) time trial performances by ~4% from a baseline ride with water when told they were consuming a CE and actually given a placebo, while riders given CE and told they were receiving a placebo only increased their subsequent performance by 0.5%.

O'Neal et al., (2010) found that consumption of CE was significantly greater for the top third of half- and full- marathon runners separated into tertiles by expected race finish time and average miles run per week. The fastest and highest training-volume runners also reported significantly higher agreement with the statement that "CE can improve performance during runs of 1+ hours", than the lower two tertiles. It is possible that more highly trained competitive endurance athletes, through experience and greater average use of sport beverages, have more positively-biased opinions concerning the ergogenic capabilities of sport beverages in comparison to non-competitively-focused and less highly-trained exercisers. Regular consumption of sport beverages was not commonly reported by the participants in our study sample, and markedly less sport beverage consumption was noted by women than men ( $p < .05$ ) (Table 3). The mean responses concerning participants' perceptions that drinking any of the beverages improved performance were all below the halfway mark with 0 representing "not at all" on post-ride questionnaires (Table 3).

Non-competitive exercisers are often motivated to engage in physical activity to lose or manage weight. Many of these individuals will participate in exercise sessions that last ~1 h and involve combinations of moderate and intense exercise such as a spin class. Past investigations have suggested that CE may be able to attenuate fatigue and increase performance in such conditions. However, for exercisers who have weight loss or weight management as a goal, consuming large quantities of CE may negate much of the caloric expenditure attained during the workout. Substitution of W or a NCE would result in a workout with a greater caloric deficit if performance ability was not diminished and fatigue perception did not increase resulting in a shorter, or lower-intensity, workout session. In addition, consumption of NCE would provide the same rehydration advantages of a CE, and there is much evidence that flavored beverages are voluntarily consumed in greater quantities by active individuals in warm or hot environments (Clapp, Bishop, Smith, & Mansfield, 2000; Passe, Horn, & Murray, 2000; Rivera-Brown, Gutierrez, Gutierrez, Frontera, & Bar-Or, 1999).

Although the intensity and environment of this study were moderate, more than 1/3 of the participants lost a liter or more of sweat in the familiarization session and two participants lost more than 2% bodyweight. In conclusion, the findings of this study suggest that non-fasted aerobic exercisers should expect no decrease in performance capacity or perceive exercise as more difficult when W or a NCE is substituted for a CE, under conditions similar to those of this study.

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Table 1 Characteristics of participants (Mean  $\pm$  SD).

| <u>Descriptor</u>                           | <u>Men (n = 23)</u> | <u>Women (n = 13)</u> | <u>Total (n = 36)</u> |
|---|---------------------|-----------------------|-----------------------|
| Age (years)                                 | 23.2 $\pm$ 3.1      | 23.5 $\pm$ 3.2        | 23.3 $\pm$ 3.1        |
| Height (cm)                                 | 177.4 $\pm$ 6.9     | 164.6 $\pm$ 5.2       | 172.8 $\pm$ 8.8       |
| Weight (kg)                                 | 77.6 $\pm$ 8.9      | 60.5 $\pm$ 9.1        | 71.4 $\pm$ 12.1       |
| BMI (kg/m <sup>2</sup> )                    | 24.6 $\pm$ 2.2      | 22.3 $\pm$ 2.9        | 23.8 $\pm$ 2.7        |
| BF (%)                                      | 10.3 $\pm$ 4.8      | 18.2 $\pm$ 4.6        | 13.2 $\pm$ 6.0        |
| Aerobic Exercise Sessions (per week)        | 3.8 $\pm$ 1.1       | 4.5 $\pm$ 1.0         | 4.1 $\pm$ 1.1         |
| Average Exercise Session Duration (minutes) | 48.2 $\pm$ 20.5     | 57.3 $\pm$ 19.0       | 51.6 $\pm$ 20.1       |

Table 2 Characteristics of exercise sessions by treatment (Mean  $\pm$  SD, n = 36).

| Variable                             | <u>W</u>         | <u>NCE</u>      | <u>CE</u>                  |
|--------------------------------------|------------------|-----------------|----------------------------|
| WBGT ( $^{\circ}$ C)                 | 25.0 $\pm$ 0.6   | 25.0 $\pm$ 0.5  | 24.8 $\pm$ 0.2             |
| Average HR (beats/min)               | 145 $\pm$ 4      | 146 $\pm$ 4     | 146 $\pm$ 4                |
| Blood Glucose Pre-ride (mg/dL)       | 100.9 $\pm$ 28.9 | 95.3 $\pm$ 28.5 | 98.5 $\pm$ 23.7            |
| Blood Glucose End of 50MR (mg/dL)    | 88.6 $\pm$ 27.5  | 82.3 $\pm$ 21.3 | 110.6 $\pm$ 30.4 $\dagger$ |
| POMS Fatigue Pre-Exercise $\ddagger$ | 1.3 $\pm$ 2.0    | 1.9 $\pm$ 2.7   | 2.0 $\pm$ 2.1              |
| POMS Fatigue Post-50MR               | 4.0 $\pm$ 3.3    | 4.1 $\pm$ 2.9   | 3.4 $\pm$ 2.4              |

$\dagger$  = Significantly different ( $p < .05$ ) from W and NCE.  $\ddagger$  = Main effect ( $p < .001$ ) found for time (pre- post- for POMS Fatigue component).

Table 3 Responses to questionnaire items as marked on a 100-mm visual analogue scale, (Mean  $\pm$  SD, n = 36).

| Item  | Response Anchors    |                     | Beverage | Men              | Women           | Total           |
|---|---------------------|---------------------|----------|------------------|-----------------|-----------------|
|   | 0                   | 100                 |          |                  |                 |                 |
| 1. I exercise because it is an enjoyable activity.  | Strongly disagree   | Strongly agree      |          | 77.1 $\pm$ 21.6† | 90.8 $\pm$ 11.0 | 82.2 $\pm$ 19.4 |
| 2. I exercise to lose/maintain a healthy body weight.                                       | Strongly disagree   | Strongly agree      |          | 77.0 $\pm$ 29.2  | 81.8 $\pm$ 18.5 | 78.8 $\pm$ 25.5 |
| 3. I exercise to improve my performance during competitive athletics.                       | Strongly disagree   | Strongly agree      |          | 71.3 $\pm$ 22.5† | 51.5 $\pm$ 29.5 | 63.9 $\pm$ 26.8 |
| 4. I exercise to reduce chronic disease risks such as diabetes and heart disease.           | Strongly disagree   | Strongly agree      |          | 60.2 $\pm$ 35.0  | 59.2 $\pm$ 29.3 | 59.8 $\pm$ 32.6 |
| 5. I regularly drink sport beverages before, during or immediately after exercise.          | Always              | Never               |          | 63.0 $\pm$ 31.0‡ | 90.7 $\pm$ 9.3  | 73.0 $\pm$ 28.5 |
| 6. How difficult was the ride compared to one of your normal workouts?                      | Much less difficult | Much more difficult | W        | 62.4 $\pm$ 16.8  | 57.1 $\pm$ 17.7 | 60.5 $\pm$ 17.1 |
|   |                     |                     | NCE      | 55.8 $\pm$ 14.6  | 53.1 $\pm$ 20.5 | 54.9 $\pm$ 16.7 |
|   |                     |                     | CE       | 55.7 $\pm$ 14.4  | 55.3 $\pm$ 16.8 | 55.6 $\pm$ 15.0 |
| 7. Do you feel drinking this beverage during your workout improved you performance ability? | Not at all          | Very much           | W        | 50.0 $\pm$ 20.0  | 36.4 $\pm$ 18.9 | 45.1 $\pm$ 20.4 |
|   |                     |                     | NCE      | 41.2 $\pm$ 24.7  | 36.8 $\pm$ 24.1 | 39.7 $\pm$ 24.2 |
|   |                     |                     | CE       | 46.4 $\pm$ 26.7  | 41.6 $\pm$ 32.6 | 44.7 $\pm$ 28.6 |

Anchors for scale are listed in the second column. Items 1-5 were reported in the health screening portion of the first session. † = significant difference ( $p < .05$ ) from women. ‡ = significant difference ( $p < .01$ ) from women. Items 6 and 7 were collected at the end of each session 2-4. No significant differences ( $p > .05$ ) were found among beverages on items 6 and 7.

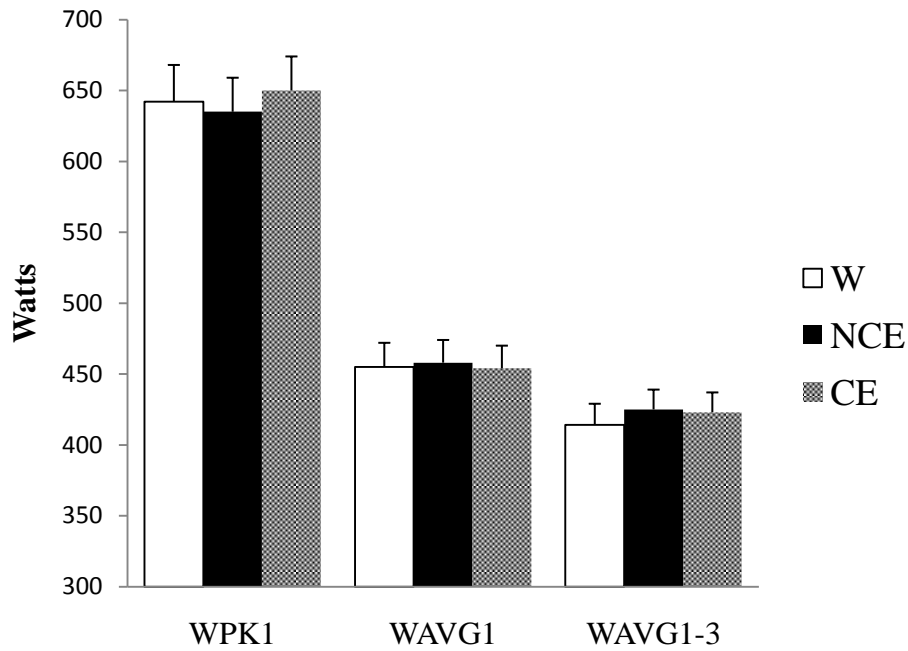


FIGURE 1— Mean  $\pm$  SE performance outcomes including peak power for the first  $W_{AnT}$  (WPK1), average power for the first  $W_{AnT}$  (WAVG1), and average power for all 3  $W_{AnT}$  (WAVG1-3) . No differences ( $p > .05$ ) were found among beverages for any variable.

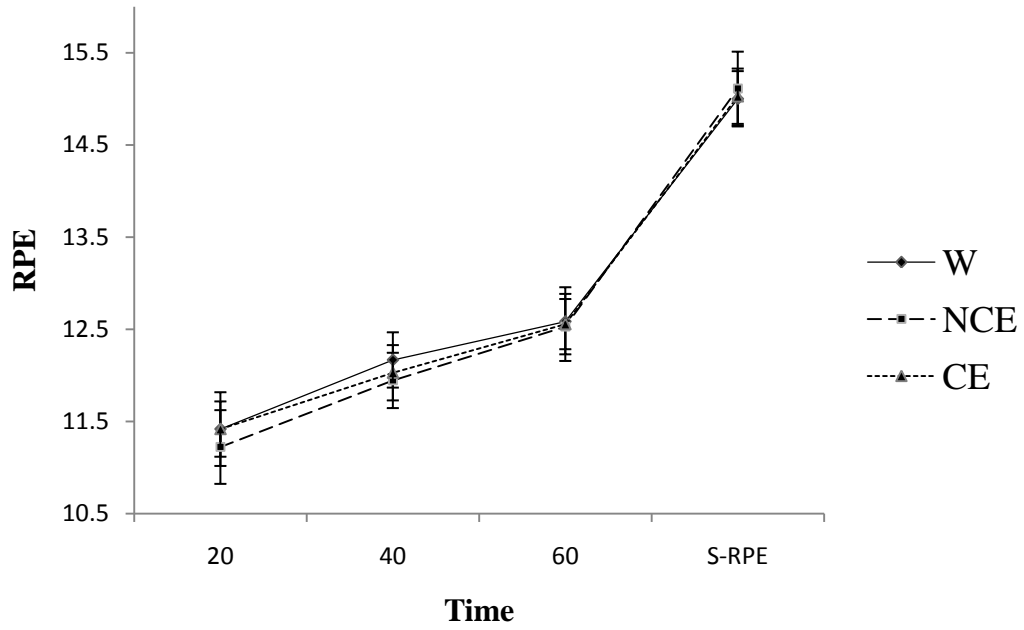


FIGURE 2- Mean  $\pm$  SE ratings of perceived exertion by time point and beverage. No significant differences ( $p > .05$ ) were found between any beverages.

### CHAPTER III

#### Influence of 100% Fluid Replacement During Exercise on Thirst Satiety, Stomach Discomfort, and Voluntary Fluid Intake Post-Exercise

The primary purpose of this study was to evaluate the effects of replacing all sweat loss during exercise with a carbohydrate-electrolyte sport beverage (CE), non-caloric electrolyte sport beverage (NCE), or water (W) on thirst, stomach discomfort, and post-exercise fluid consumption of recreational exercisers. Men ( $n = 24$ ) and women ( $n = 14$ ) (age mean  $\pm$  SD =  $23.6 \pm 3.2$ ) recruited from a fitness center completed ~60 minutes of moderate and high intensity cycling in a warm environment (WBGT  $\sim 25.0^{\circ}\text{C}$ ). Sweat loss was determined during a familiarization session with no fluid consumption (mean  $\pm$  SE =  $834 \pm 59$  mL) and did not differ ( $p = .35$ ) between experimental sessions in which a volume of W, NCE, and CE equal to sweat loss in the familiarization session were consumed in a counter-balanced order during exercise. Following exercise, participants drank *ad libitum* (all beverages available for familiarization session, beverage consumed during ride for sessions 2-4) during a 30-min recovery period. Fluid replacement matching sweat loss was reported to be an appropriate intake amount (mean score  $\pm$  SE on 100-mm scale =  $53.0 \pm 2.8$ ; with 0 = “not enough” and 100 = “too much”) with no differences ( $p = .29$ ) among beverages. Seventy-five percent of participants marked below the 25% mark on a 100-mm scale (0 = “not at all”, 100 = “very much”) when asked if they felt any stomach discomfort perceived to be related to exercise beverage consumption. Replacing fluid during the ride and *ad libitum* during recovery resulted in greater ( $p < .05$ ) total consumption

than consumption during recovery only. Replacement of sweat loss by drinking in recovery only and no fluid intake during exercise was 113% compared to W (140%), NCE (132.1%), and CE (129.4%) trials with 100% replacement of sweat loss during exercise and 30-min recovery consumption *ad libitum*.

**Keywords:** voluntary fluid consumption, non-caloric sport beverages, recreational exercisers, hydration

## **Introduction**

The following recommendation was made in a previous position stand by the American College of Sports Medicine (ACSM) (Convertino, et al. 1996), “During exercise, athletes should start drinking early and at regular intervals in an attempt to consume fluids at a rate sufficient to replace all the water lost through sweating (i.e., body weight loss), or consume the maximal amount that can be tolerated.” (p. i). These recommendations for large volumes of fluid ingestion during exercise did not go without criticism (Noakes 2007). Current ACSM guidelines (Sawka, et al. 2007) reflect a more conservative approach with minimum fluid consumption to permit body fluid loss of no more than 2% of body weight, and for maximum consumption to not exceed sweat loss. However, even these recommendations may not always be most appropriate as athletes may often begin bouts in a hypohydrated condition (Maughan and Shirreffs 2008).

In one of the few studies investigating hydration of recreational exercisers in a natural environment, Stover et al. (2006) found that 46% of participants entering fitness facilities had a urine specific gravity (USG) level of 1.020 or greater and 3% had a level of 1.030. The National Athletic Trainers Association classifies USG levels of 1.020 as significant dehydration and 1.030 as serious dehydration for athletes (Casa, et al. 2000). Data collection for that study took place in March at fitness centers in Chicago and Los Angeles where the average ambient temperatures

were -5 °C and 20.6 °C, respectively. It is possible that individuals exercising and living in warmer environments may begin exercise in an even less hydrated condition. Bergeron et al. (2006) reported that youth tennis players training during late spring in the southeastern U.S. had pre-exercise USG levels of  $1.025 \pm 0.005$  before reporting to a voluntary hydration study.

Based on predicted sweat rates under a variety of conditions that include body mass, exercise intensity, and environmental conditions, the majority of exercisers would be unlikely to experience sweat loss equal to or greater than 2% body mass (Montain, et al. 2006). However, as demonstrated by Stover et al. (2006) many exercisers will begin exercise in a less than optimal hydration status. Whereas there are a wide range of methods to measure pre-activity hydration status (Oppliger and Bartok 2002; Shirreffs 2003), the majority of these methods would be unlikely to be utilized by recreational exercisers (O'Neal, 2010b).

Voluntary beverage consumption also plays an important role with regards to hydration status during exercise and rehydration between bouts of exercise. For highly trained adult endurance athletes, flavored sport beverages have been shown to be consumed in greater quantities during exercise than water even when least-liked flavors were used (Passe, et al. 2000). Similar observations have been made in well trained team sport athletes (Minehan, Riley et al. 2002), young male cyclists (Wilk and Bar-Or, 1996; Rivera-Brown, Gutierrez et al. 1999), and for men simulating long bouts of work in a hot industrial environment (Clapp, et al. 2000). In addition to increasing ad libitum fluid intake, the addition of electrolytes and particularly sodium can also enhance fluid retention (Maughan, et al. 1997; Sharp, 2006). However, the participants, protocols, and environments in many of the previously cited investigations do not represent the physical fitness levels or exercise condition characteristics for the majority of adult recreational athletes.

The first purpose of this study was to investigate voluntary consumption of male and female recreational athletes (REC) when a carbohydrate-electrolyte beverage (CE), a non-calorically sweetened electrolyte beverage (NCE), and water (W) were made available after engaging in ~1 h of stationary cycling in a warm environment (WBGT = 25.0° C) with no fluid intake. The second purpose of this study was to determine if REC would experience differences in stomach discomfort, satiety, and post-exercise fluid consumption when consuming a volume of CE, NCE, or W equal to sweat loss during a baseline exercise session. Based on results concerning gender difference in ad libitum hydration with older adults (Baker, et al. 2005) and well trained adolescents athletes (Rivera-Brown, et al. 1999; Rivera-Brown, Ramirez-Marrero et al. 2008) and comments by recreational exercisers serving as participants in our laboratory in previous studies, we also explored if differences in taste preferences and current exercise beverage type consumption habits would be exhibited between men and women. We hypothesized that men would consume more NCE and CE than W based as a percentage of total consumption than women, and that men would display a more favorable disposition to CE than women with regards to taste and current consumption of sport beverages.

## **Methods**

### **Participants**

For the purpose of this study and the inclusion criteria of our participants, the term recreational athletes (REC) was defined as adults (19+ years of age) who regularly engaged in physical activity (3+ sessions per week), including a minimum of 150 and maximum of 450 minutes of aerobic exercise per week, who were not members of professional or collegiate sport teams, and who were not considered elite level endurance athletes based on reported finishing race times, when applicable.

Potential participants partaking in spin classes or aerobic activity (treadmill running and stationary cycling) at a student recreation center at a major southeastern university were approached about interest in a hydration and performance study comparing water and two sport beverages. Men (n=24) and women (n=14) (mean  $\pm$  SD age  $23.6 \pm 3.2$  years) who would be classified as REC, as defined by this study, passed all inclusion criteria and were able to complete all required trials. Weight and height were measured on a balance beam scale and stadiometer (Detecto, Webb City, MO) to determine Body Mass Index. Three-site (tricep/mid-thigh/suprailiac for women, chest/umbilicus/mid-thigh for men) skinfold measurements were recorded (Lange Caliper, Beta Technology Inc., Deer Park, NY) in accordance with ACSM guidelines (Whaley, 2006) to estimate bodyfat percentage (Jackson and Pollock, 1985). The mean  $\pm$  SD for body mass, body mass index, and body fat percentage for men were  $76.8 \pm 9.6$  kg,  $24.3 \pm 2.4$  kg/m<sup>2</sup>,  $10.3 \pm 4.7\%$  and for women were  $60.8 \pm 8.8$  kg,  $22.4 \pm 2.8$  kg/m<sup>2</sup>,  $18.4 \pm 4.5\%$ . Participants reported engaging in  $4.1 \pm 1.1$  aerobic exercise sessions per week, each lasting  $54 \pm 23$  minutes.

### *Beverages*

Water (W), a 6% calorically-sweetened beverage containing electrolytes (CE), and a non-calorically-sweetened beverage containing electrolytes (NCE) were treatment variables. Each beverage used was sold commercially and composition was not altered in any way for this study. Grape flavoring was used in both sport beverages. Researchers and exercisers were blinded to CE and NCE, but not to water. Participants were only informed that they would be receiving water and two sport beverages to compare. It is possible that some participants recognized the presence of non-caloric sweeteners or the type of beverage, but no description of the caloric versus non-caloric factors were discussed by investigators. Participants were also instructed not

to comment in any manner on the characteristics of their beverage to other participants. All beverages were served in unlabeled paper cups or plastic bottles.

## **Exercise Protocols**

### *Baseline Session*

Testing began in mid-November and ended in early December. Participants completed four separate exercise sessions in a warm environment (mean  $\pm$  SD WBGT = 25.0  $\pm$  0.4 °C). The first session was used to determine baseline measurements for sweat loss (determined by change in body mass from pre- to post- exercise) and to familiarize participants with the procedures. The first phase of exercise included a 60-min session of moderate-high intensity spinning (Johnny G's Spinner Pro, Star Trac, Irvine, CA). Participants rode at a self-selected cadence and resistance level that elicited an intensity of ~60-65% of heart rate reserve (mean  $\pm$  SD HR = 146  $\pm$  4) based on age-predicted maximum heart rate and resting heart rate (determined by average heart rate measured from minutes 5-15, during 15 minutes of seated rest in a quiet room). Heart rate was continually displayed on a heart rate monitor watch (F6, Polar Electro Oy, Kempele, Finland) that beeped to alert participants when they were out of the prescribed range. The actual time spent cycling was 50 minutes. Five, two-min breaks were given at 10-min intervals so sweat could be collected for a separate investigation. At the end of the ride, five minutes of recovery were given so that a mood state questionnaire could be administered and blood glucose could be collected for a separate investigation. Following these procedures, three, 30-sec Wingate anaerobic power tests took place with 2.5 min between tests. Wingate test resistance was set as 7% of body weight. After an initial Wingate test in the baseline session, two participants felt the intensity was too uncomfortable and did not complete any additional Wingate tests. The Wingate performances produced additional sweat loss but were required as

part of separate study. Results for performance tests can be found in (O'Neal, 2010a). This protocol was replicated for sessions 2-4 excluding the beverage type being consumed.

Diet before the baseline session was not controlled, but participants were instructed to eat a light meal in the 2-4 hour period before they reported to the laboratory and were also instructed to consume ~500 ml of water between their last meal and going to bed on the night prior to each session and in the hour prior to arriving for each exercise session. Participants completed the exercise protocol described above with no fluid intake. Participants brought 2 sets of shirts, shorts, and undergarments and were weighed before and after, wearing the same dry pair for both measurements to determine sweat loss. After drying off, changing clothes, and having a second weight measurement recorded, a taste test rating was recorded for all three beverages using a nine-point hedonistic scale (Peryam, 1957) commonly used in sport beverage studies. The taste scale ranged from 1 (extremely dislike) to 9 (extremely like). Beverage tasting order was counterbalanced with a Latin-square design with participants sampling a small volume of beverage before giving a taste rating. Between taste tests, participants rinsed their mouths with water for ~10-seconds before spitting.

After the taste tests, participants were provided with a ~591 ml bottle of each beverage and allowed to freely drink as much or little as they desired for a 30-minute period. No directions were given on how much or which type of beverage to drink, and participants were informed they had access to as many bottles as they would like if they finished any of the bottles given to them. All beverages were served chilled. Bottles were measured on a balance (Dial-O-Gram 1600, Ohaus, Pine Brook, NJ) before and after to determine total consumption for each beverage.

### *Beverage consumption during exercise sessions (2-4)*

For the beverage consumption sessions (sessions 2-4), participants were provided with three meals, two snacks, and beverages for the 24-h period before each beverage consumption session (total calories = 1,975: carbohydrate = 67.0%, fat = 23.7% protein = 9.3%). Participants recorded the time each meal or snack was eaten and repeated the diet for each following session. The last meal was consumed between two and four hours prior to reporting to the laboratory. Participants were also instructed to continue consuming ~500 ml of water between their last meal and bed and in the 1-h period prior to reporting to the laboratory. No alcohol or caffeine consumption was allowed in the 24-h period prior to testing, and participants only ate and drank the items provided to them. Participants were allowed to drink as much water as they wished.

Beverages were served in three aliquots with a volume equal to 1/3 of sweat loss determined during the baseline ride at each of three time points: 0, 20, and 40 minutes (i.e. 100% replacement). All beverages were served chilled and in tinted sport bottles. Participants were instructed to consume all content within a 10-minute period from the time beverage was received. Following exercise, drying off, and having weight measured, participants were allowed to drink that session's beverage ad libitum until the end of the session (30 minutes) and were provided with as much beverage as they requested. Participants were frequently reminded not to discuss any aspects concerning the taste properties of the beverages with other participants.

### *Beverage Questionnaires*

A questionnaire with items concerning current use of sport beverages and water was administered prior to any exercise testing during the first session. A post-exercise beverage evaluation was completed during the 30-min recovery period in sessions two to four. A 100-mm

visual analogue scale was also used for six items addressing participants' satisfaction of the volume of fluid consumed, taste qualities of the beverage, feelings of stomach discomfort, and likelihood the participant would drink that beverage during or after a workout.

## **Statistical Analyses**

Paired sample *t* tests were used to determine if differences existed between responses for current sport beverage and water consumption patterns in exercise environments (Items 1-6, Table 1). Independent sample *t* tests were used to determine if differences existed between genders for the same six items and the general use of sport beverages in exercise environment questionnaire item (Item 7, Table 3). Repeated-measures analysis of variance (RM-ANOVA) was used to determine if differences existed among beverages for baseline session taste test ratings, baseline choice consumption by volume and percentage, post-exercise consumption in sessions two to four, sweat loss by session, total consumption across all four sessions, and post-ride questionnaire responses among beverages with a between-subjects comparison for gender. When main effects were found for beverage or treatment sessions, Bonferroni post-hoc tests were used to determine where the differences occurred. If a between-subjects effect was found for gender, independent sample *t* tests were used. An alpha level of .05 was deemed as significant for all analyses. Data in tables, figures, and script are presented as mean  $\pm$  SE unless otherwise noted.

## **Results**

### *Current Exercise Environment Hydration Habits*

Participants reported lower regular consumption of sport beverages in comparison to water before, during, and after exercise ( $p < .001$ ). No differences ( $p > .05$ ) in water consumption habits were found between genders for water before, during, and after exercise, or between

genders for sport beverages during exercise. Men reported higher levels of drinking sport beverages in comparison to women before ( $p < .001$ ), after ( $p = .01$ ), and overall consumption in exercise environments ( $p = .002$ ) based on the visual analogue scale measurements. Responses for all questionnaire items are listed in Table 1.

#### *Sweat Loss, Baseline Taste Test Ratings, and Consumption*

Average sweat loss differed no more than 80 mL ( $< 10\%$ ) among exercise sessions, and there was no difference ( $p = .35$ ) in sweat loss across sessions by time (mean  $\pm$  SE: Baseline =  $834 \pm 59$  mL, Session 2 =  $887 \pm 64$ , Session 3 =  $854 \pm 48$ , Session 4 =  $807 \pm 43$ ). A main effect for baseline taste test ratings was found for beverage ( $F = 3.6$ ;  $p = .038$ ). Post-hoc analyses found differences between taste test scores for W ( $7.3 \pm 0.3$ ) and CE ( $6.2 \pm 0.3$ ) for scores for the sample (both genders) (Figure 1). The only taste test rating that differed between genders ( $p = .03$ ) for beverages was for CE with women ( $5.6 \pm 0.4$ ) reporting lower ratings than men ( $6.8 \pm 0.4$ ). No differences were found among beverages based on total consumption (Figure 2) or percentage of total consumption (Figure 3) during the baseline recovery session. There were also no differences in post-ride consumption among beverages in sessions when sweat loss was replaced with fluid intake (Figure 4). Mean total consumption exceeded average total sweat loss for all sessions (Figure 5). A main effect ( $F = 32.4$ ;  $p < .001$ ) for total consumption was found between the baseline session ( $971 \pm 61$  mL) and W ( $1415 \pm 91$  mL), NCE ( $1244 \pm 87$  mL), and CE ( $1197 \pm 72$  mL). Total consumption was greater ( $p = .01$ ) for W than CE.

#### *Post-Exercise Beverage Questionnaire Responses*

There were no differences in taste ratings among beverages during recovery (Item 1, Table 2). A main effect was found for “after taste” of beverage ( $F = 6.1$ ;  $p < .01$ ) with W ( $76.1 \pm 4.1$  on 100-mm scale) rating more favorable than NCE ( $53.4 \pm 6.0$ ,  $p = .02$ ) and CE ( $54.2 \pm 5.2$ ,  $p$

= .01). When participants were asked how they felt about the volume of beverage they drank during the ride, mean responses were near the neutral mark for W ( $50.4 \pm 3.7$ ), NCE ( $51.8 \pm 3.1$ ), and CE ( $56.8 \pm 3.4$ ) with no differences among beverages. No differences were found among beverages for stomach discomfort ratings. A categorical distribution of stomach discomfort rating is displayed in Figure 6. A main effect for likelihood to choose to drink a particular beverage during a workout ( $F = 14.2; p < .001$ ) or after a workout ( $F = 11.6; p < .001$ ) was found for beverage type. When asked if they would choose to drink the beverage given to them during the current session, W was reported to be more likely to be consumed during ( $68.7 \pm 4.9$ ) or after a workout ( $78.9 \pm 4.5$ ) compared to NCE ( $36.5 \pm 5.6$  and  $42.7 \pm 6.2$ ) and CE ( $36.4 \pm 4.7$  and  $43.1 \pm 5.5$ ). An interaction for beverage by gender ( $F = 3.4; p = .04$ ) was also found for likelihood to drink after a workout. Men ( $52.9 \pm 6.4$  mm on 100 mm scale) reported a level twice as high compared to women ( $26.3 \pm 8.6; p = .02$ ) for likelihood to drink CE after a workout.

## **Discussion**

The hydration needs of physically active adults not involved in competitive athletics, endurance racing events, or military/industrial settings have not received a large share of attention. However, there is a large population of REC who, like the aforementioned populations, do engage in frequent bouts of moderate to high intensity exercise in warm or hot environments. The hydration needs and habits of these individuals are not well studied and may differ substantially from the elite athletes often used as participants in past investigations. The primary aims of this investigation were to compare voluntary fluid consumption post-exercise among W, NCE, and CE and between genders when either no fluid was consumed during exercise or when sweat losses were replaced with fluid intake during exercise.

The participants in this study reported by questionnaire lower levels of sport beverage consumption when compared to W before, during, and after exercise. Women reported lower levels of regular consumption of sport beverages than men ( $p < .01$ ). When half and full marathon runners were asked this same question, no differences were seen between genders (O'Neal, 2010b). CE received lower taste ratings than water ( $p = .04$ ) during an initial taste test following the baseline exercise session. It is clear that the substantial differences in preferences for W over CE by women was the reason there were overall differences in taste tests when scores of both genders were included, as scores for men were almost identical among beverages (Figure 1). A female preference for W compared to calorically sweetened sport beverages is not unique. Greater consumption of W than sports beverage has been exhibited for older women (Baker, et al. 2005) and young girls (Rivera-Brown, et al. 1999; Rivera-Brown, et al. 2008) when voluntary fluid intake took place between bouts of exercise and rest in hot environments.

van Nieuwenhoven et al. (2005) found W consumption during an 18-km run resulted in less gastrointestinal distress than CE. Comparing van Nieuwenhoven et al. (2005) and the present study, there were differences in the forms of exercise used (cycling vs. running), measurement scales (100-pt global scale for stomach discomfort vs. multiple 10-pt sub-scales), and volume served (100% sweat loss vs. standard 600 mL). These differences make it difficult to compare results. Although stomach discomfort ratings among beverages were not statistically significant ( $p > .05$ ) in the current study, a similar trend was found in the current investigation with W and NCE showing almost identical scores and complaints of stomach discomfort for CE slightly higher (Table 2). Very few participants made verbal complaints to the investigators about stomach discomfort. A limitation of the current study is that only one exercise modality

was incorporated, and stomach discomfort may differ with other types of exercise such as running.

An important finding of this study was that 100% fluid replacement during exercise, regardless of beverage was reported, appeared to be an appropriate intake amount for the majority of participants (Table 2, Item 3). In addition, when 100% fluid replacement took place based on sweat loss in the baseline session, a much greater volume ( $p < .001$ ) of total consumption (exercise plus recovery) was seen than when consumption occurred in recovery only. Total W consumption (exercise plus recovery) with 100% replacement during exercise, resulted in 140.3% sweat loss replacement compared to NCE (132.1%) and CE (129.4%). In the baseline trial with no consumption during exercise, final total consumption was 113% of weight lost (Figure 5). There was no difference in average sweat loss over the four-week period that testing took place and this suggests that an initial measurement in body weight loss is a reliable method for estimating sweat loss when workload and environment remain stable.

Recommendations for fluid intake for physically active individuals have undergone many changes, and some suggest there is no need for established guidelines, but instead that thirst should be relied upon as the best guide (Noakes & Speedy, 2007). However, the majority position is that athletes should begin exercise in a well hydrated state, consume fluid during exercise sufficient to prevent no more than 2% loss in body weight but to not gain weight during exercise, and drink to return to pre-exercise body weight before the next bout of exercise (Casa, et al. 2000; Armstrong, et al. 2007; Maughan & Shirreffs 2008; Rodriguez, et al. 2009). Evidence suggests that thirst away from exercise is often not sufficient to result in euhydration in natural environments prior to subsequent exercise for many physically active individuals (Bergeron, et al. 2006; Stover, et al. 2006).

On the basis that athletes should develop individualized drinking strategies and measuring changes in body mass from pre- to post-exercise is the most reliable and practical method for athletes in the field, we recommend the following simple guidelines for REC based on the results of the present study. REC participating in regular physical activity of similar intensity in relatively stable environmental conditions (indoor or outdoor) should establish normal sweat loss volumes by weighing themselves before and after exercise with considerations for fluid intake and urine excretion. Consuming a volume of fluid during exercise similar to expected sweat loss rates and having additional fluids available for *ad libitum* fluid consumption during recovery should result in consumption rates of 130-140% of sweat losses. REC should be made aware that these volumes may differ with acclimatization and changes in exercise intensity, duration, or seasonal temperature changes and that additional body mass change measurements should be used to monitor these changes.

Although average consumption slightly exceeded sweat loss in the baseline session, based on observations in the current and previous investigations in our laboratory, such practices often seem to result in bolus consumption immediately following exercise in warm environments. Consuming large volumes quickly, instead of over time, can lead to increased urine output and less retention of the same amount of ingested fluid (Jones et al., 2010). Based on our findings, when conditions remain similar and REC replace fluid loss over the course of exercise and drink fluid *ad libitum* post-exercise, complete rehydration should occur (accounting for voids) without gastrointestinal distress for the majority of individuals. After the exercise and immediate recovery phase (~30 min), normal hunger and thirst mechanisms should dictate fluid intake. Beverage type should be based on personal preferences, and the results of this study do

not indicate that flavored beverages will increase voluntary consumption for REC exercising in warm environments.

Hydration during physical activity in warm environments is a consideration by many REC. O'Neal et al. (2010b) found that even in one of the most difficult exercise environments to obtain fluids (outdoor running), 42.4% of runners reported always drinking during outdoor runs in warm or hot weather and less than 6% reported never drinking in the same conditions. Passe et al. (2007) found runners underestimated their sweat losses by 42% during a 75 minute run in a relatively cool environment. However, to the other extreme, endurance athletes overly concerned with hydration may take in such large quantities of fluids they become hyponatremic during competition (Almond, et al. 2005). Our recommendations are not meant to serve as a blanket set of guidelines for all athletes, but are directed to REC exercising in warm to hot conditions for ~1 h or less who may be unsure about how much they should be drinking. Future investigations are warranted to see if these recommendations are applicable in exercise environments utilizing different intensities and modalities.

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Table 1 Reported Exercise-related Fluid Intake Habits (Mean  $\pm$  SE).

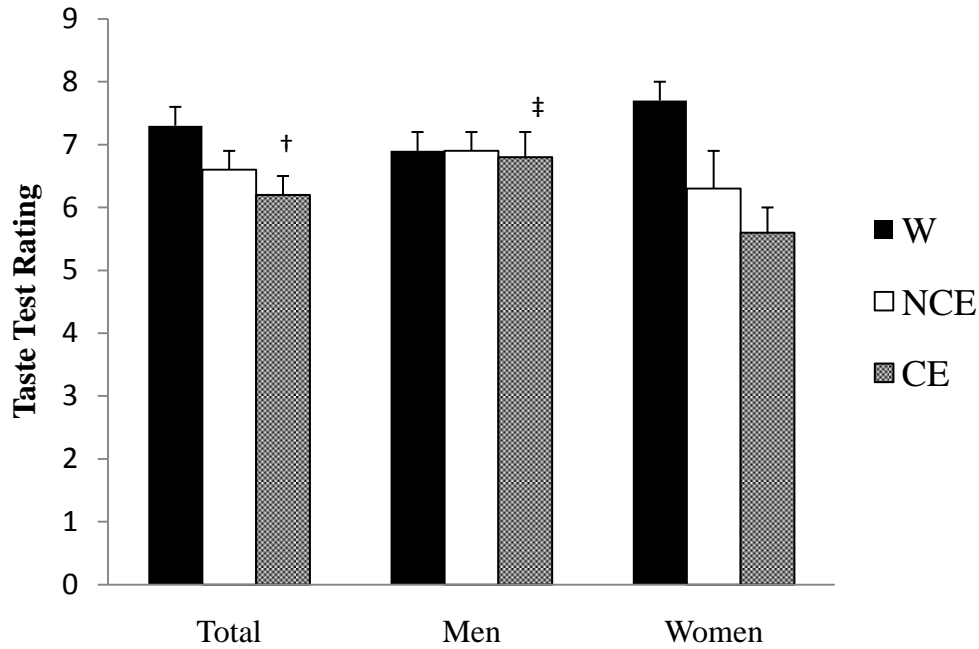
| Item  | Men (n = 24)   | Women (n = 14)  | Total           |
|---|----------------|-----------------|-----------------|
| 1. I drink sport beverages before exercising.                                       | 34.2 $\pm$ 4.8 | 6.4 $\pm$ 2.2†  | 24.0 $\pm$ 3.8‡ |
| 2. I drink water before exercising.   | 73.5 $\pm$ 5.4 | 64.7 $\pm$ 9.4  | 70.3 $\pm$ 4.8  |
| 3. I drink sport beverages during exercise.   | 29.4 $\pm$ 5.7 | 15.1 $\pm$ 4.9  | 24.1 $\pm$ 4.1‡ |
| 4. I drink water during exercise.   | 74.6 $\pm$ 5.0 | 71.6 $\pm$ 9.0  | 73.5 $\pm$ 4.5  |
| 5. I drink sport beverages after exercise.  | 43.7 $\pm$ 5.7 | 21.9 $\pm$ 5.0† | 35.7 $\pm$ 4.4‡ |
| 6. I drink water after exercising.  | 88.0 $\pm$ 3.3 | 87.5 $\pm$ 7.1  | 87.8 $\pm$ 3.3  |
| 7. I regularly drink sport beverages before, during, or immediately after exercise. | 36.5 $\pm$ 6.2 | 8.9 $\pm$ 2.4†  | 26.3 $\pm$ 28.8 |

Scores represent response level marked on a 100-mm visual analogue scale (0 mm anchor = never and 100 mm = always). † = significantly different ( $p < .05$ ) from men. ‡ = significantly different response ( $p < .001$ ) than water for same item.

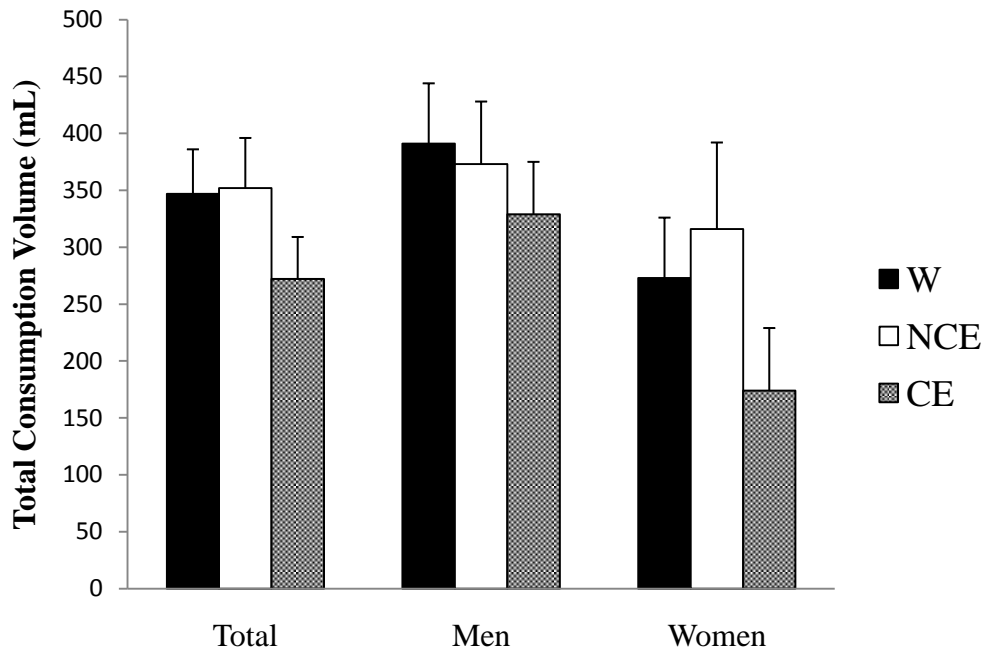
Table 2 Responses to post-exercise questionnaire items (Mean  $\pm$  SE).

| Item   | Response Anchors      |                        | Beverage | Men (n = 24)   | Women (n = 14)              | Total                       |
|--|-----------------------|------------------------|----------|----------------|-----------------------------|-----------------------------|
|  | 0                     | 100                    |          |                |                             |                             |
| 1. How was the taste of the beverage?  | Very bad taste        | Very good taste        | W        | 64.4 $\pm$ 5.4 | 60.4 $\pm$ 8.0              | 62.9 $\pm$ 4.5              |
|  |                       |                        | NCE      | 49.8 $\pm$ 5.4 | 52.7 $\pm$ 9.0              | 50.9 $\pm$ 4.7              |
|  |                       |                        | CE       | 62.6 $\pm$ 4.8 | 44.7 $\pm$ 8.1              | 56.0 $\pm$ 4.4              |
| 2. How was the after-taste of the beverage?  | Strong/bad aftertaste | No/pleasant aftertaste | W        | 73.5 $\pm$ 5.8 | 80.7 $\pm$ 5.1              | 76.1 $\pm$ 4.1              |
|  |                       |                        | NCE      | 48.4 $\pm$ 7.5 | 61.9 $\pm$ 9.8              | 53.4 $\pm$ 6.0 <sup>†</sup> |
|  |                       |                        | CE       | 58.3 $\pm$ 6.2 | 47.3 $\pm$ 9.3              | 54.2 $\pm$ 5.2 <sup>†</sup> |
| 3. How did you feel about the amount of the beverage you drank during the 60-minute ride?      | Not enough            | Too much               | W        | 49.0 $\pm$ 4.9 | 52.7 $\pm$ 5.8              | 50.4 $\pm$ 3.7              |
|  |                       |                        | NCE      | 54.3 $\pm$ 3.9 | 47.5 $\pm$ 5.3              | 51.8 $\pm$ 3.1              |
|  |                       |                        | CE       | 59.3 $\pm$ 4.0 | 52.3 $\pm$ 6.1              | 56.8 $\pm$ 3.4              |
| 4. Did you experience any stomach discomfort related to drinking the beverage during the ride? | Not at all            | Very much              | W        | 16.3 $\pm$ 5.1 | 13.7 $\pm$ 7.6              | 15.4 $\pm$ 4.2              |
|  |                       |                        | NCE      | 18.4 $\pm$ 4.9 | 10.6 $\pm$ 4.7              | 15.6 $\pm$ 3.5              |
|  |                       |                        | CE       | 21.7 $\pm$ 6.0 | 26.2 $\pm$ 8.1              | 23.4 $\pm$ 4.7              |
| 5. How likely would you be to choose to drink this beverage during a workout?                  | Very unlikely         | Very likely            | W        | 72.1 $\pm$ 6.1 | 62.8 $\pm$ 8.5              | 68.7 $\pm$ 4.9              |
|  |                       |                        | NCE      | 37.4 $\pm$ 6.9 | 34.9 $\pm$ 9.8              | 36.5 $\pm$ 5.6 <sup>†</sup> |
|  |                       |                        | CE       | 43.5 $\pm$ 5.4 | 36.5 $\pm$ 7.8              | 36.4 $\pm$ 4.7 <sup>†</sup> |
| 6. How likely would you be to choose to drink this beverage after a workout?                   | Very unlikely         | Very likely            | W        | 77.7 $\pm$ 5.7 | 80.9 $\pm$ 7.4              | 78.9 $\pm$ 4.5              |
|  |                       |                        | NCE      | 41.9 $\pm$ 7.3 | 43.9 $\pm$ 11.4             | 42.7 $\pm$ 6.2 <sup>†</sup> |
|  |                       |                        | CE       | 52.9 $\pm$ 6.4 | 26.3 $\pm$ 8.6 <sup>‡</sup> | 43.1 $\pm$ 5.5 <sup>†</sup> |

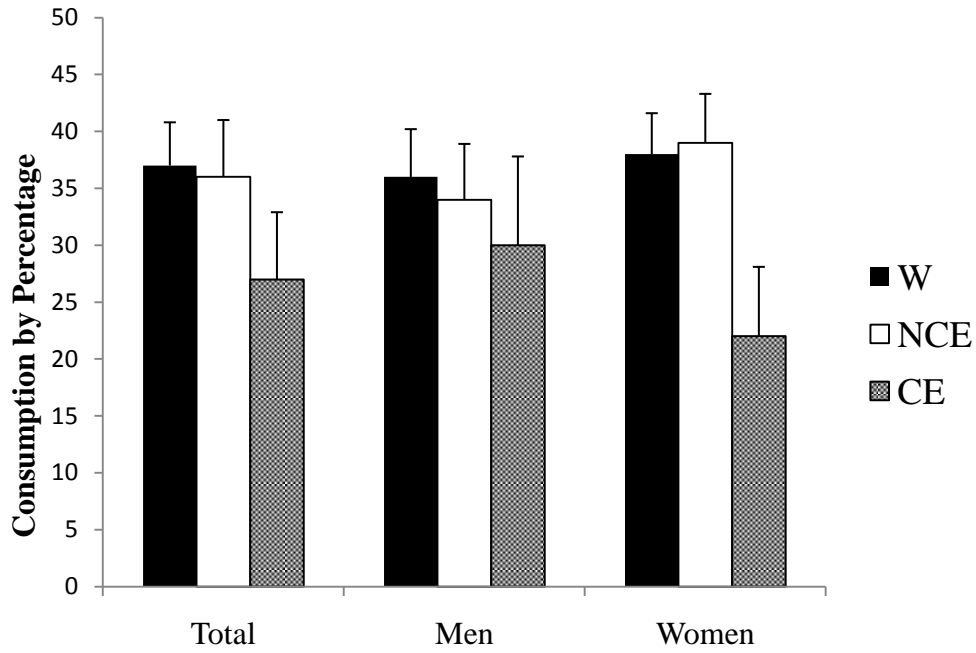
Responses = position marked on a 100 mm visual analogue scale by participants. Anchors for scale are listed in the second column. <sup>†</sup> = significantly different than W. <sup>‡</sup> = Women significantly different from men.



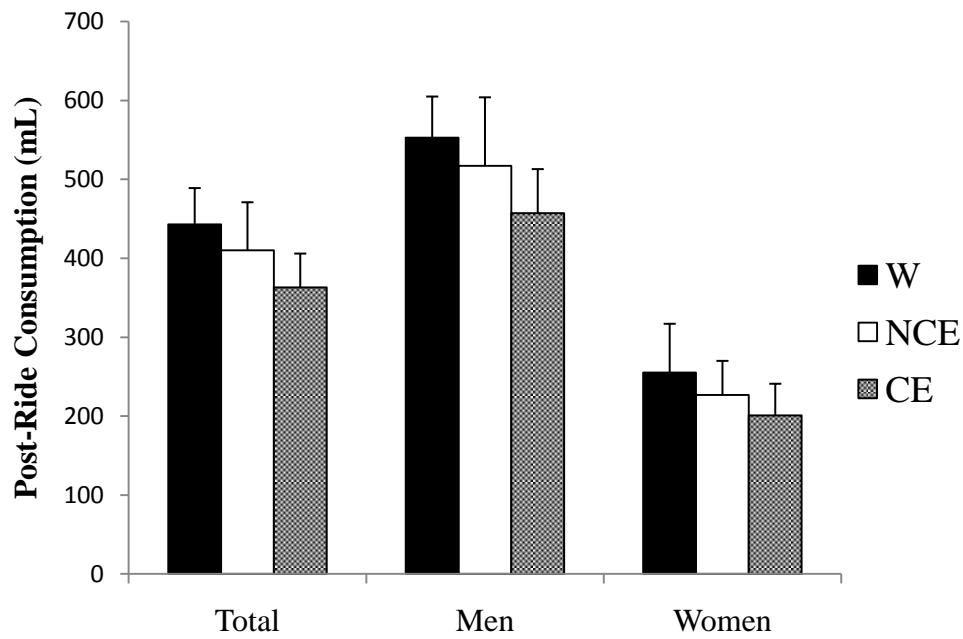
**Figure 1** -- Baseline taste test ratings (men = 24, women = 14). Taste test rating scale 0 = extremely dislike, 9 = extremely like. † = Significant difference ( $p < .05$ ) from W for all responses. ‡ = Significant different ( $p < .05$ ) for beverage taste rating between men and women.



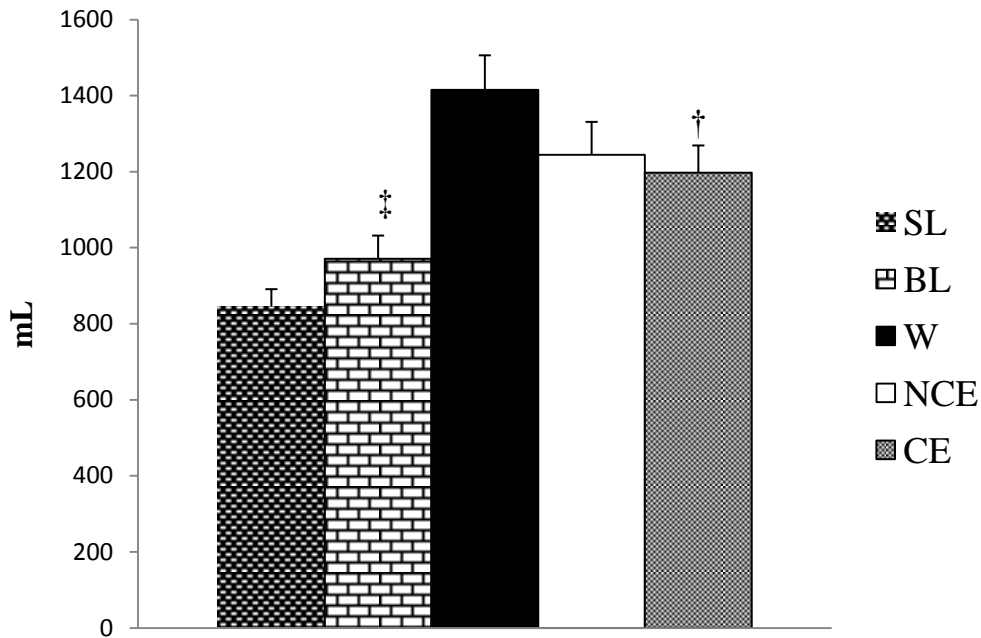
**Figure 2** -- Voluntary consumption by volume following the baseline session with no fluid intake during exercise (men = 24, women = 14).



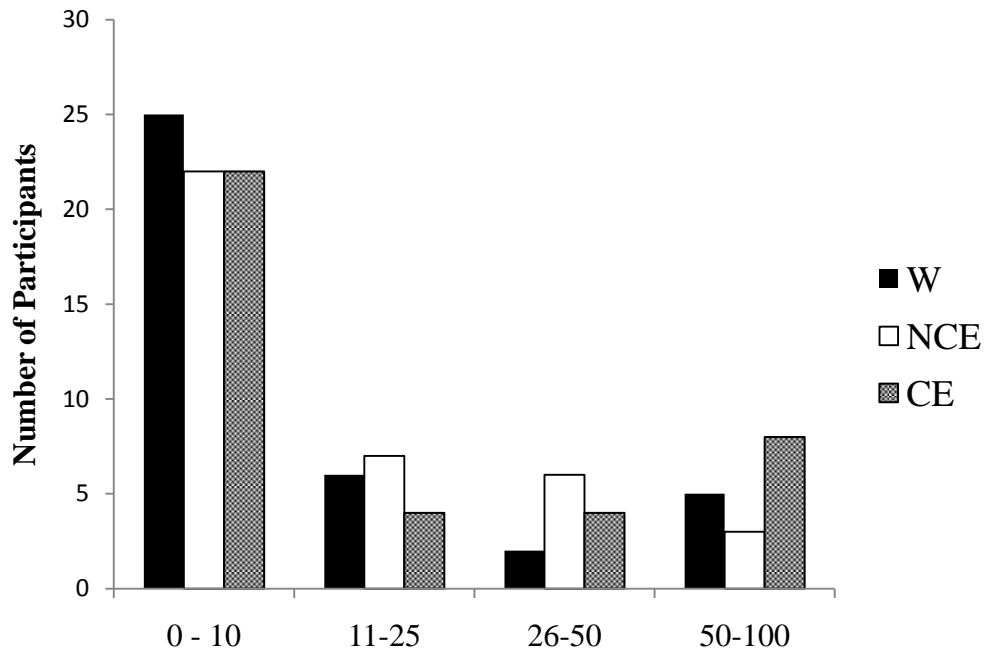
**Figure 3 --** Voluntary consumption by percentage of total consumption for 30 min following the baseline session with no fluid intake (men = 24, women = 14).



**Figure 4 --** Voluntary consumption 30 min post-ride following 100% fluid intake during 50 min cycling sessions (men = 24, women = 14).



**Figure 5** -- Total consumption across treatments in comparison to mean sweat loss. SL = mean sweat loss for all sessions. BL = total consumption with all beverages for 30 min following baseline ride with no fluid consumption during exercise. ‡ = Significant difference from W, NCE, and CE sessions. † = Significant difference from W.



**Figure 6 --** Reports of stomach discomfort by beverage. Response to the questionnaire item: “Did you experience any stomach discomfort related to drinking the beverage during the ride?” using a 100 mm visual analogue scale (0 = “Not at all” and 100 = “Very much”).

## CHAPTER IV

### Hydration Practices and Perceptions of Half- and Full- Marathon Runners

Runners ( $n = 276$ ) registered to compete in the 2010 Little Rock half- or full- marathon completed a 23-item questionnaire addressing the impact of fluid intake on hydration and performance. Runners were separated into tertiles based on reported running volume and expected race performance level (RVP) to determine if RVP influenced responses. RVP low (RVPL) and RVP moderate (RVPM) reported significantly lower levels ( $p < .001$ ) of “drinking sport beverages in exercise environments” than RVP high (RVPH). RVPH also reported that sport beverages were “superior in meeting the need of exercisers” in contrast to RVPL and RVPM ( $p < .05$ ), and that “sport beverages consumed before or during runs of  $>1$  h would improve performance” ( $p < .01$ ). The most often reported source of information concerning hydration strategies and exercise beverage choice (63% major influence) was “other runners”. Almost 70% of participants reported they had suffered a major decrease in run performance that they believed was due to dehydration and 44% believed they had suffered heat-related illness symptoms during a run because of dehydration. Only 20% of participants reported monitoring their hydration status, and urine color was the most often cited method used (7%). Only 2% of runners reported using changes in body mass as a means of measuring hydration status.

**Keywords:** dehydration, urine color, hydration monitoring, sweat loss

## **Introduction**

During organized endurance events such as marathon running, much emphasis is placed on hydration and opportunities for fluid intake are usually ample. These conditions often result in runners who actually gain weight from the beginning to the end of a race and in some cases ingest fluid to the point that they develop hyponatremia (Almond, et al., 2005). However, during training, runners are responsible for providing their own fluids and consequently hydration opportunities may be more limited.

Shendell et al. (2010) reported that almost 90% of marathon runners completed their long runs outdoors. Highly trained runners are unlikely to replace the majority of fluid losses during training even if fluids are accessible (Passe, Horn Stofan, et al., 2007). Although there are exceptions, most marathons are held in cooler seasons of the year, but many runners will continue to train through warmer seasons. These factors create conditions in which large body water losses during running are possible. Dehydration is known to impair cognitive function (Grandjean & Grandjean, 2007) and is associated with increased risk of heat illness and decreased aerobic performance for physically active individuals in warm environments (Armstrong, et al., 2007; Casa, et al., 2000; Sawka, et al., 2007). Running is often a solitary endeavor and individuals may be alone and far from support when faced with impairments of heat stress and dehydration.

Recommendations for what, when, and how much fluid intake is needed for athletes are continually evolving. Past hydration guidelines (Convertino, et al., 1996) encouraged athletes to replace sweat losses during competition. These recommendations received much scrutiny from Tim Noakes (Noakes, 2007), a major influence in the running community, who believed such

messages encouraged overdrinking and increased incidence of hyponatremia in marathoners in the United States (Noakes & Speedy, 2007).

More recent position stands for athletes have been more conservative and fairly similar regardless of the governing body sponsoring them (Casa, et al., 2000; Rodriguez, DiMarco, & Langley, 2009; Sawka, et al., 2007). These guidelines emphasize the need for fluid intake before and after exercise sufficient to minimize loss of body weight between bouts and recommend that consumption during exercise not exceed sweat loss but be sufficient to avoid body weight reduction greater than 2%.

All three position stands also promote the addition of carbohydrates and electrolytes to fluids when exercise will be prolonged and large sweat losses are expected, and recommend incorporation of various methods to measure hydration status (e.g. urine specific gravity, urine color, and acute and day to day changes in body mass). In contrast, the International Marathon Medical Directors Association (IMMDA) (2006), with much influence from Dr. Noakes, has adopted a different stance, advocating thirst to be used as the primary gauge for fluid intake and have deemphasized the relevance of sodium ingestion during events.

Distance running has become increasingly popular with American adults with over 397 marathons taking place in the United States in 2009 resulting in over 468,000 finishing times reported in the USA alone, a 10% increase from 2008 (marathonguide.com, 2010). The majority of these participants most likely serve as their own coach and are unlikely to be supervised by health professionals.

There is currently not a consensus for hydration guidelines even within the scientific community and consequently information runners encounter perhaps varies greatly. Little is

known about the hydration practices of these runners and the degree of influence that guidelines have had on their behaviors.

The purposes of this investigation were to determine: 1) runners' sources for information concerning hydration and beverage choice, 2) what they drink, 3) how they view water versus sport beverages regarding performance and hydration, 4) if they have experienced decreases in performance or heat related-illness symptoms believed to be caused by dehydration, and 5) how they monitor their hydration status. Differences in responses based on the running volume and performance level (RVP) for the areas listed above were also examined.

## **Methods**

### *Participants*

Investigators set up a table with two signs describing the survey at the doorway to the entrance of the registration site and Runners' Expo at the 2010 Little Rock Marathon. All runners were required to pick up their race bib and timing chip at this site. Investigators approached interested race participants entering and leaving during all hours the expo was open in the two days prior to the race. The Little Rock Marathon is an open race with no qualification times required for entry. A total of 2,908 runners completed the half-marathon and 1,550 runners completed the marathon. The only inclusion criteria for this study were that participants were 18 years of age and registered to run the half or full Little Rock Marathon. Investigators verbally informed participants of the purpose of the study and inclusion criteria, and participants completed a consent form before taking the survey. This investigation was approved by our local Institutional Review Board.

Three hundred runners completed a survey, but 24 were discarded because they contained incomplete items or were completed incorrectly. A total of 146 men and 130 women were

included in the final sample (mean  $\pm$  SD, age = 38.3  $\pm$  11.3 years). Fifty-seven percent of participants were from the state of Arkansas and less than 1% were from foreign countries. The remaining participants claimed 27 different home states. Eighty-five percent of participants indicated regularly engaging in exercise in hot or warm environments. Twenty-seven participants (10%) reported running half-marathon distance or longer for less than a year. Only 11% of runners reported training under the supervision of a coach or medical staff. A description of exercise habits and history are presented in Table 1. Consent forms and surveys were turned in separately making all responses anonymous to investigators.

Participants were separated into tertiles based on running volume and expected performance (RVP). RVP was determined from a weighted  $z$ -score based on expected categorical finishing time (35%), average miles per week (35%), participation in organized running events over the last 24 months (10%), years of running experience of half-marathon distance or longer (10%), and aerobic exercise sessions per week (10%). Runners were separated into tertiles based on  $z$ -scores (low = RVPL,  $n = 92$ ; moderate = RVPM,  $n = 92$ ; and high = RVPH,  $n = 92$ ). Demographics by group are presented in Table 1.

### *Instrument*

The questionnaire consisted of 23 items. The first item was a 100-mm visual analogue scale asking participants if they regularly drank sport beverages before, during, or immediately after exercise, with anchors of “Never” (0) and “Always” (100). A definition for sport beverage, “*For the purpose of this study sport beverages will be defined as flavored beverages containing carbohydrates and electrolytes.*”, was provided in bold print immediately above this item.

The second section asked participants how much six different information sources influenced their exercise-related beverage choices and hydration strategies. Participants could

choose between responses of “None”, “Minor”, and “Major”. The next section included 10 items addressing beverages consumed by participants and viewpoints on the ergogenic and hydration properties of water and sport beverages. Response choices for this section included “Strongly Disagree”, “Disagree”, “Agree”, “Strongly Agree”, and “Not Applicable or Do Not Know”.

Participants were also asked if they had ever experienced a major decrease in running performance or experienced heat-related illness symptoms during a run they believed was caused from being dehydrated with response choices of “Yes (Once)”, “Yes (More Than Once)”, “No”, or “Do Not Know”. Participants were also asked if they used any method to monitor their hydration status, followed by an open-ended response section to list any monitoring methods used. The final question asked participants if they drank during their outdoor runs in warm or hot environments. Response choices were “Never”, “Sometimes”, “Very Often”, or “Always”. This was followed by an open-ended section for participants to describe how they supplied themselves with fluids during runs.

### **Statistical Analyses**

Quantitative data values are presented as mean  $\pm$  SD for continuous variables or as frequencies by percentages for nominal variables. One-way analysis of variance (ANOVA) was used to determine if differences existed among responses of RVPL, RVPM, and RVPH for demographic and visual analogue scale responses. Expected finishing times were given numerical representation with one representing the slowest finishing time category and six representing the fastest predicted categorical finishing time. Categorical questionnaire responses for the section concerning sources of information that influence beverage choice and hydration strategies (Table 2) were converted to ordinal responses with “None” = 1, “Minor” = 2, “Major”

= 3. For items in Table 3 categorical responses were converted to “Strongly disagree” = 1, “Disagree” = 2, “Agree” = 3, and “Strongly Agree” = 4. “Not Applicable/Do Not Know” responses were removed for comparisons. For items in Tables 5 categorical responses were converted to “No” = 1, “Yes (Once)” = 2, and “Yes (More than once)” = 3. One-way ANOVA was also used for these items, and Tukey’s post-hoc tests were used when main effects were found for RVP level. Open-ended response items were evaluated and placed into categories determined by members of the investigation team. An alpha level of .05 was utilized for all hypothesis tests.

## **Results**

### *Demographics*

Table 1 details participants’ training histories, lists the race for which they registered for based on distance and expected finish time by RVP level and totals. There was a main effect ( $p < .001$ ) for RVP level for all continuous variables (miles per week, years of running experience of half-marathon distance or longer, aerobic exercise sessions per week, and number of competitions of half-marathon distance or longer) and for predicted finishing time. There were differences between RVPL and RVPH for all continuous variables and between RVPL and RVPM for all continuous variables with the exception that there was no difference ( $p > .05$ ) for the number of running competitions of half-marathon distance or longer in the last 2 years.

### *Sources of information for hydration strategies and beverage choice*

“Advice from other runners” was the most often cited source of information for hydration strategies and beverages choice. Only 6% participants responded that other runners were not an influential source to some degree. Health professionals such as athletic trainers or doctors received the second most responses as an influence (minor = 36%, major = 47%).

Similar responses were obtained for the item concerning advice from former/current coaches and fitness professionals” (minor = 30%, major = 47%). The only difference among the three RVP levels was for “Articles about hydration and beverages in magazines, books, or newspapers” ( $F = 5.1, p < .01$ ) with RVPL ( $1.8 \pm 0.7$ ) reporting these sources were significantly less of an influence on beverage choice and hydration strategies than those reported by RVPM ( $2.1 \pm 0.7$ ) and RVPH ( $2.1 \pm 0.7$ ). Results for all items are listed in Table 2.

#### *Impact of exercise environment beverage choice on hydration and performance*

High levels of agreement (86%) were reported when runners were asked if they intentionally increase their volume of fluid intake in non-exercise environments during periods of warm or hot weather. A main effect for RVP level ( $F = 4.4, p = .01$ ) with RVPL ( $2.6 \pm 0.9$ ) and RVPM ( $2.6 \pm 0.9$ ) reporting less agreement than RVPH ( $2.9 \pm 0.7$ ) that “sport beverages are superior to water in meeting hydration needs of exercisers”.

RVPM ( $2.9 \pm 0.9$ ) reported a higher agreement that they “preferred the taste of water over sport beverages in exercise environments” than RVPH ( $2.6 \pm 0.9$ ) (Item 10,  $F = 3.5, p = .03$ ). Thirty-one percent of runners agreed with the statement that they avoided drinking sport beverages because of their caloric content, and 50% reported that they drank low or non-caloric sport beverages. A fairly large percentage (38%) of runners reported drinking high percentage carbohydrate beverages or carbohydrate and protein beverages. RVPM ( $2.5 \pm 0.9$ ) reported less agreement than RVPH ( $2.8 \pm 0.7$ ) that “drinking a sport beverage instead of water would result in better recovery and improved performance for subsequent workouts” ( $F = 3.9, p = .02$ ).

A main effect ( $F = 9.3, p < .001$ ) based on RVP level was found with RVPH ( $3.4 \pm 0.6$ ) reporting higher agreement that “drinking sport beverages with carbohydrates and electrolytes

before or during exercise would improve runs of greater than 1 hour” compared to water versus RVPL ( $3.0 \pm 0.7$ ) or RVPM ( $2.9 \pm 0.7$ ).

#### *Incidence of performance decreases and heat illness due to dehydration*

Almost 70% of participants believed that they had experienced a major decrease in performance (44% reported multiple incidents) due to dehydration (Table 4). A higher ( $p = .001$ ) rate of performance decrement was reported by RVPH ( $2.4 \pm 0.8$ ) than RVPL ( $2.0 \pm 0.8$ ). Fifty-four percent of RVPH reported suffering from heat-related illness symptoms they believed were caused from dehydration during a run compared to 42% for RVPL and 37% for RVPM, but no statistical differences were found among RVP levels.

One out of five runners reported that they monitored their hydration status by some method (Table 5). Using urine color was the most often reported (20 runners) method of determining hydration status. While technically not a method to measure hydration status, nine participants listed that they determined the amount and or time intervals during their pre-run that they would drink. Nine participants (3%) also listed frequency or volume of urination as a marker of hydration, followed by eight runners (3%) reporting that they “listened to their bodies” or used thirst as a guide. Only five participants (2%) listed measuring changes in body weight as a method used.

One-hundred and seventeen runners (42%) reported they always drink during their outdoor runs in warm or hot environments while 16 runners (6%) reported they never drink during outdoor runs in warm or hot environments (Table 6). Carrying bottles in hand or in a waist belt or using a backpack type hydration system was the most reported (170 runners, 62%) means of providing fluid during a run, followed by “placing bottles on routes prior to run” (58 runners, 21%), and “drinking from public water fountains or faucets” (32 runners, 12 %).

## **Discussion**

Dehydration during strenuous physical activity particularly in warm or hot environments is believed to increase the risk of heat exhaustion, heat stroke, and cramping (Armstrong, et al., 2007; Casa, et al., 2000; Sawka, et al., 2007), and while still debated by some (Sawka & Noakes, 2007), dehydration > 2% loss of bodyweight is considered to result in reduced performance capacity for many individuals (Sawka, et al., 2007). The scientific community has devoted much attention to what type, when, and how much fluid athletes should consume. As the popularity of distance running for adults increases there is a growing population of individuals who may face the negative performance or health outcomes stemming from inadequate or lack of any hydration strategies. The purpose of this investigation was to explore the prevalence of such occurrences and the actual hydration practices of recreational runners.

The purposes of this investigation were to determine: 1) runners' information sources for information concerning hydration and beverage choice, 2) what they drink, 3) how they view water versus sport beverages on performance and hydration, 4) if they have experienced decreases in performance or heat related-illness symptoms believed to be caused by dehydration, and 5) how they monitor their hydration status. Differences in responses based on the running volume and performance level (RVP) for these areas were also examined.

### *Information sources of influence*

The first key finding of this study was that interpersonal contacts were the primary reported sources of information regarding hydration strategies and exercise-related beverage choices. As expected, other runners were cited as the source of most influence (Table 2). However, doctors, athletic trainers, coaches, personal trainers, and fitness instructors were listed as a "major" source of influence by nearly half of all participants. This interpersonal relationship

chain emphasizes the importance of these individuals being informed of the most current and evidence-based information available and clearly disseminating recommendations to athletes.

Few studies designed to examine the effects of promoting hydration strategies have been conducted, but Hagger and Monasem (2009) found that when cyclists were asked to devise a drinking strategy without direction from investigators, they consumed 35% more of a sports drink than a group cycling under the same conditions not asked to develop a hydration plan. Advice from coaches and health professionals to a single runner may reverberate throughout much of the running community. Almost 80% of runners listed popular media sources such as magazines and books as an influence on their hydration strategies and behavior choices. These statistics emphasize the importance of experts in the fields using such outlets to keep runners updated and informed in addition to publications in peer-reviewed papers in scientific journals.

#### *Beverage choice and views on water and sport beverages*

RVPH reported significantly greater use of sport beverages in exercise environments than RVPL and RVPM (Table 1). Beliefs concerning rehydration properties and ergogenic effects of sport beverages may account for these differences. RVPH reported greater levels of agreement with statements that “sport beverages are superior to water in meeting the hydration needs of exercisers” and “drinking sport beverages before or during runs of greater than one hour can improve performance compared to water” (Table 3).

A partiality for sport beverages for RVPH may be partially based on taste preference. RVPH had a lower level of agreement than RVPM ( $p < .05$ ) to the statement, “I prefer the taste of water over sport beverages in exercise environments.” Experienced endurance athletes have been shown to drink more sport beverage (even when a least-liked flavor is given) than water

during prolonged exercise when both beverages are continuously available (Passe, Horn, & Murray, 2000) and when drinking opportunities are limited (Passe, Horn, Stofan, et al., 2004).

The greater level of agreement for sport beverages containing carbohydrates to improve performance during runs of one h or greater for RVPH compared to RVPL and RVPM, is supported by scientific evidence (Coyle, 2004; Jeukendrup, 2004). The differences between these groups could be a result of RVPH running longer distances at higher intensities, past experiences, or greater exposure to information supporting the use of carbohydrate beverages. The belief that carbohydrate-containing beverages will improve performance has been seen in highly trained endurance athletes. Clark, Hopkins, et al., (2000) found lower levels of improvement in a subsequent time-trial when highly trained cyclist were misled into believing they were drinking an artificially-sweetened sports drink and actually given a carbohydrate sport beverage in comparison to those given a placebo and told they were receiving a carbohydrate sport beverage.

One of the most recent trends in the sport beverage industry is to offer low or non-caloric electrolyte containing beverages. The addition of electrolytes (particularly sodium) as found in these beverages can increase the retention of ingested fluid through reduction of diuresis compared to water (Maughan, Leiper, & Shirreffs, 1997; Sharp, 2006). Nearly 55% of participants reported agreement to drinking low or non-caloric sport beverages, and 43% reported diluting sport beverages with water. RVPL reported near statistically significantly ( $p = .070$ ) higher levels of agreement that they avoided drinking sport beverages because of their caloric content than RVPH, and the mean for RVPM was halfway between the two groups. The higher performance groups may feel that they expend enough calories in training such that calories are not a concern for these athletes.

Anecdotal observations would suggest a heightened sense of focus on nutrition and hydration takes place in the days leading up to a race, and that runners would likely begin a competition in a euhydrated state. This may not often be the case during training when runs are often scheduled around work and other activities. One of the most important aspects of hydration when fluid may not be readily available as in a race, is pre-hydration status (Casa, et al., 2000; Maughan & Shirreffs, 2008; Sawka, et al., 2007). Twenty percent of runners reported monitoring their hydration status and no differences were seen among RVP levels. Urine color was the most (20 runners) reported method used (Table 5). Using urine color as an indication of hydration status is a simple technique that highly correlates to urine specific gravity and urine osmolality (Armstrong, et al., 1998) and is a practice supported by the National Athletic Trainers Association (Casa, et al., 2000).

When asked if they monitored their hydration status, only a few participants in our survey reported having a specific hydration plan (e.g. “Measure out water”, “I just rehydrate every 20-30 minutes in cold runs – every 10-15 minutes in hot weather”, “Drink fluid on my belt and depending on weather drink every 2 miles (Garmin (GPS) tells me)”). It is unknown how runners determined how much and when they should consume fluids. Eight runners (3%) listed “thirst or listening to my body”. Unfortunately no item was used to determine if these individuals’ responses were based on IMMUDA (2006) recommendations.

Measuring changes in body mass is the most accurate way to determine acute changes in hydration level (Armstrong, 2007) and is a key component for developing individual hydration strategies (Armstrong, et al., 2007; Maughan & Shirreffs, 2008). However, only 5 (4 were from RVPH) out of 276 runners (2%) reported measuring changes in body weight. This is an area that

should receive much more attention. Five runners (2%) mentioned using a skin turgor test and two runners (< 1%) reported using bioelectrical impedance watches or scales.

The most important findings of this study are the rates of self-reported beliefs concerning performance decrements, and heat-related illness symptom occurrences that runners believed were caused by inadequate fluid intake (Table 4). Decreases in running performance believed to have been caused by dehydration were common (70% of participants) and incident rate increased with RVP level (Table 4). Multiple experiences of major decreases in performance were noted 30% more by RVPH (59%) than RVPM (41%) and almost twice as often as RVPL (33%). It is possible this trend was seen because of increased distances, frequencies, and intensity levels of runs undertaken by those in higher RVP levels. A limitation of this study was no definition for “major decrease in performance” was provided, and response rates were based on subjective interpretations made by participants. However, it is apparent that the majority of runners believed that they have experienced a decrease in performance because of inadequate fluid intake.

Future investigations concerning why athletes reached a point of dehydration that resulted in decreased performance (e.g. inadequate intake before or during the run, lack of fluid availability, pre-run hydration strategy inaccurately accounting for actual fluid deficit, unexpected change in weather, etc.) is warranted. Forty-five percent of participants reported they had suffered heat-related illness symptoms they felt were caused by being dehydrated. The relationship between environmental conditions, intensity of physical activity, and fluid intake on heat illnesses is complex and individual athletes may have different responses to similar conditions. However, dehydration is believed to exacerbate the symptoms of heat-related illness and fluid intake is a preventative measure suggested by the American College of Sports

Medicine (Armstrong, et al., 2007). The results of this study indicate that the majority of runners agreed that hydration during runs in the heat is particularly important and reported that they frequently take steps to make sure they can access fluids during runs by a variety of means (Table 6). Whether this impetus comes from personal negative experiences or trusting in advice given by a variety of influential sources is unknown. Regardless, at some point the majority of these runners felt inadequate fluid intake led to less than optimal performance or impairment of normal functioning during a run.

Running is a sport in which gaining access to fluids during a run often requires preparation by the runner, particularly if the run takes place outdoors, which is common. Much effort has been undertaken to develop hydration guidelines for athletes, but the experiences and viewpoints of runners themselves is not well understood. This investigation attempted to explore the hydration practices of runners, and whether they believed they had experienced negative consequences from not hydrating themselves adequately. Upon completing this survey numerous participants shared traumatic personal stories with the investigators about their own negative experiences with running and dehydration. Their ideas on the proper way to stay hydrated varied greatly. Many runners had firmly entrenched beliefs about what, when, and how much they should drink. However, many were unsure about their hydration habits and interested in our personal views on what they should be doing. Future investigations are warranted that cover these topics in more depth than the current investigation.

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Table 1 Demographics, Running Habits, and Distance and Predicted Finishing Times (n = 276).

| Item  | <u>RVPL</u>    | <u>RVPM</u>  | <u>RVPH</u> | <u>Total</u> |
|---|----------------|--------------|-------------|--------------|
| Age (years)   | 35.8 ± 10.5‡   | 38.9 ± 12.0  | 40.2 ± 11.3 | 38.3 ± 11.3  |
| Gender (Men - Women)  | 31 – 61        | 51 – 41      | 64 – 28     | 146 – 130    |
| Aerobic exercise sessions per week  | 4.0 ± 1.2†‡    | 4.7 ± 1.5‡   | 6.0 ± 2.3   | 4.9 ± 1.9    |
| Exercise sessions per week lasting longer than 1 h  | 2.7 ± 1.6‡     | 3.0 ± 1.6‡   | 4.4 ± 2.3   | 3.4 ± 2.0    |
| Running miles per week  | 13.2 ± 4.9†‡   | 22.9 ± 3.5‡  | 39.5 ± 11.1 | 25.2 ± 13.1  |
| Frequently train in hot or warm environment<br>(% reporting yes)                              | 80.0           | 90.9         | 90.1        | 83.8         |
| Years of running half-marathon distance or longer   | 2.9 ± 4.7†‡    | 5.3 ± 5.7‡   | 7.5 ± 6.8   | 5.2 ± 6.1    |
| Running competitions of half-marathon distance<br>or longer completed in last 24 months       | 2.1 ± 2.6‡     | 3.5 ± 4.1‡   | 8.8 ± 10.2  | 4.8 ± 7.1    |
| Participants reporting “Yes” to training under the<br>supervision of a coach or medical staff | 14             | 8            | 9           | 31           |
| Registered race distance (Half-Marathon – Full-<br>Marathon)                                  | 71 – 21        | 58 – 34      | 29 – 63     | 158 – 118    |
| Predicted finishing time (h) (Half / Full)†‡  |                |              |             |              |
| < 1.5 / < 3.0   | 0              | 0            | 8           | 8            |
| 1.5 – 1.75 / 3 – 3.5  | 1              | 6            | 25          | 32           |
| 1.75 – 2.0 / 3.5 – 4.0  | 11             | 21           | 20          | 52           |
| 2 – 2.25 / 4 – 4.5  | 26             | 40           | 21          | 87           |
| 2.25 – 2.5 / 4.5 – 5.0  | 25             | 17           | 9           | 51           |
| > 2.5 / > 5.0   | 29             | 8            | 9           | 46           |
| Regularly drink sport beverages in exercise<br>environments (0 = Never, 100 = Always)         | 42.2 ± 35.4 3‡ | 38.8 ± 31.7‡ | 57.7 ± 30.9 | 46.2 ± 33.6  |

† = Significantly different than RVPM, ‡ = Significantly different than RVPH.

Table 2 Sources of information for hydration strategies and beverage choice (n = 276).

| Item  | <u>RVPL</u>         |     |     | <u>RVPM</u>      |     |     | <u>RVPH</u>      |     |     | <u>Total</u>     |     |     |
|---|---------------------|-----|-----|------------------|-----|-----|------------------|-----|-----|------------------|-----|-----|
|   | None                | MIN | MAJ | None             | MIN | MAJ | None             | MIN | MAJ | None             | MIN | MAJ |
|   | M ± SD              |     |     | M ± SD           |     |     | MAJ<br>M ± SD    |     |     | M ± SD           |     |     |
| Advice of other runners about beverages and hydration strategies  | 7                   | 28  | 65  | 4                | 32  | 64  | 7                | 32  | 62  | 6                | 31  | 64  |
|   | <u>2.6 ± 0.6</u>    |     |     | <u>2.6 ± 0.6</u> |     |     | <u>2.5 ± 0.6</u> |     |     | <u>2.6 ± 0.6</u> |     |     |
| Advice of health professionals such as athletic trainers or doctors about beverage choice and hydration strategies                                  | 15                  | 33  | 52  | 23               | 35  | 42  | 12               | 41  | 47  | 17               | 36  | 47  |
|   | <u>2.4 ± 0.7</u>    |     |     | <u>2.2 ± 0.8</u> |     |     | <u>2.3 ± 0.7</u> |     |     | <u>2.3 ± 0.7</u> |     |     |
| Advice of former/current coaches or fitness professionals such as personal trainers or fitness instructors about beverages and hydration strategies | 21                  | 30  | 49  | 24               | 29  | 47  | 24               | 30  | 46  | 23               | 30  | 47  |
|   | <u>2.3 ± 0.8</u>    |     |     | <u>2.2 ± 0.8</u> |     |     | <u>2.2 ± 0.8</u> |     |     | <u>2.2 ± 0.8</u> |     |     |
| Article about hydration and beverages in magazines, books, or newspapers  | 33                  | 51  | 16  | 19               | 52  | 29  | 17               | 55  | 29  | 23               | 53  | 25  |
|   | <u>1.8 ± 0.7</u> †‡ |     |     | <u>2.1 ± 0.7</u> |     |     | <u>2.1 ± 0.7</u> |     |     | <u>2.0 ± 0.7</u> |     |     |
| Peer-reviewed research journal articles about beverages and hydration strategies  | 36                  | 42  | 22  | 35               | 28  | 37  | 23               | 43  | 34  | 31               | 38  | 31  |
|   | <u>1.9 ± 0.7</u>    |     |     | <u>2.0 ± 0.9</u> |     |     | <u>2.1 ± 2.0</u> |     |     | <u>2.0 ± 0.8</u> |     |     |
| Advertisements about beverages and hydration strategies from commercials or in magazines  | 37                  | 57  | 7   | 40               | 55  | 4   | 45               | 49  | 7   | 41               | 54  | 6   |
|   | <u>1.7 ± 0.6</u>    |     |     | <u>1.6 ± 0.6</u> |     |     | <u>1.6 ± 0.6</u> |     |     | <u>1.7 ± 0.6</u> |     |     |

MIN = Minor, MAJ = Major, NR = No Response. Top row of numbers represents responses by percentage. Bottom number (underlined) = ordinal response mean ± SD with None = 1, MIN = 2, MAJ = 3. † = Significantly different than RVPM, ‡ = Significantly different than RVPH.

Table 3 Beverage choice and perceptions of ergogenic and hydration qualities of water and sport beverages (n = 276).

| Item  | <u>RVPL</u> |                   |    |    | <u>RVPM</u> |                   |    |    | <u>RVPH</u> |                  |    |    | <u>Total</u> |                  |    |    |
|---|-------------|-------------------|----|----|-------------|-------------------|----|----|-------------|------------------|----|----|--------------|------------------|----|----|
|   | SD          | D                 | A  | SA | SD          | D                 | A  | SA | SD          | D                | A  | SA | SD           | D                | A  | SA |
|   | NA/DNK      | M ± SD            |    |    | NA/DNK      | M ± SD            |    |    | NA/DNK      | M ± SD           |    |    | NA/DNK       | M ± SD           |    |    |
| I intentionally increase the volumes of fluids I drink in <u>non-exercise environments</u> during periods of warm or hot weather.                                       | 3           | 2                 | 52 | 36 | 4           | 12                | 47 | 34 | 3           | 9                | 63 | 25 | 4            | 8                | 54 | 32 |
|   | 7           | <u>3.3 ± 0.7</u>  |    |    | 3           | <u>3.1 ± 0.8</u>  |    |    | 0           | <u>3.1 ± 0.7</u> |    |    | 3            | <u>3.2 ± 0.7</u> |    |    |
| Sport beverages are superior to water in meeting hydration needs of exercisers.   | 11          | 23                | 34 | 13 | 7           | 33                | 42 | 10 | 0           | 30               | 45 | 21 | 6            | 31               | 40 | 15 |
|   | 13          | <u>2.6 ± 0.9‡</u> |    |    | 9           | <u>2.6 ± 0.8‡</u> |    |    | 4           | <u>2.9 ± 0.7</u> |    |    | 8            | <u>2.7 ± 0.8</u> |    |    |
| I prefer the taste of water over sport beverages in exercise environments.  | 10          | 32                | 26 | 27 | 4           | 28                | 34 | 30 | 10          | 35               | 39 | 13 | 8            | 32               | 33 | 24 |
|   | 5           | <u>2.7 ± 1.0</u>  |    |    | 3           | <u>2.9 ± 0.9‡</u> |    |    | 3           | <u>2.6 ± 0.9</u> |    |    | 4            | <u>2.8 ± 0.9</u> |    |    |
| I avoid drinking sport beverages because of their caloric content.  | 19          | 37                | 21 | 15 | 23          | 44                | 22 | 9  | 27          | 39               | 23 | 4  | 23           | 40               | 22 | 9  |
|   | 9           | <u>2.4 ± 1.0</u>  |    |    | 3           | <u>2.2 ± 0.9</u>  |    |    | 7           | <u>2.0 ± 0.9</u> |    |    | 6            | <u>2.2 ± 0.9</u> |    |    |
| I dilute regular sport beverages with water.  | 30          | 19                | 24 | 9  | 21          | 28                | 17 | 24 | 29          | 24               | 20 | 21 | 27           | 24               | 20 | 18 |
|   | 19          | <u>2.1 ± 1.0</u>  |    |    | 10          | <u>2.5 ± 1.1</u>  |    |    | 6.5         | <u>2.3 ± 1.1</u> |    |    | 12           | <u>2.3 ± 1.1</u> |    |    |
| I drink low or zero calorie sport beverages.  | 15          | 21                | 35 | 17 | 17          | 24                | 37 | 13 | 28          | 20               | 30 | 17 | 20           | 21               | 34 | 16 |
|   | 12          | <u>2.6 ± 1.0</u>  |    |    | 9           | <u>2.5 ± 1.0</u>  |    |    | 4           | <u>2.4 ± 1.1</u> |    |    | 8            | <u>2.5 ± 1.0</u> |    |    |
| I drink beverages marketed as “recovery” beverages that contain high percentages of carbohydrates or a carbohydrate and protein combination.                            | 14          | 27                | 36 | 4  | 25          | 35                | 19 | 10 | 17          | 28               | 34 | 12 | 19           | 30               | 29 | 9  |
|   | 19          | <u>2.4 ± 0.8</u>  |    |    | 12          | <u>2.1 ± 1.0</u>  |    |    | 9           | <u>2.4 ± 0.9</u> |    |    | 13           | <u>2.3 ± 0.9</u> |    |    |
| Drinking a sport beverage instead of water after exercise will result in better recovery and improved performance for my next exercise session.                         | 7           | 25                | 39 | 7  | 11          | 32                | 34 | 10 | 2           | 26               | 47 | 15 | 7            | 28               | 40 | 11 |
|   | 23          | <u>2.6 ± 0.8</u>  |    |    | 14          | <u>2.5 ± 0.9‡</u> |    |    | 10          | <u>2.8 ± 0.7</u> |    |    | 16           | <u>2.6 ± 0.8</u> |    |    |
| Drinking sport beverages with carbohydrates and electrolytes before or during exercise can improve performance during runs of <u>less than 1hour</u> compared to water. | 9           | 37                | 30 | 4  | 13          | 40                | 32 | 1  | 7           | 44               | 29 | 1  | 9            | 40               | 30 | 2  |
|   | 20          | <u>2.4 ± 0.8</u>  |    |    | 14          | <u>2.2 ± 0.7</u>  |    |    | 20          | <u>2.3 ± 0.6</u> |    |    | 18           | <u>2.3 ± 0.7</u> |    |    |
| Drinking sport beverages with carbohydrates and electrolytes before or during exercise can improve performance for runs of <u>greater than 1hour</u> compared to water. | 3           | 10                | 49 | 19 | 3           | 19                | 52 | 20 | 0           | 7                | 45 | 41 | 2            | 12               | 49 | 26 |
|   | 20          | <u>3.0 ± 0.7‡</u> |    |    | 7           | <u>2.9 ± 0.7‡</u> |    |    | 8           | <u>3.4 ± 0.6</u> |    |    | 11           | <u>3.1 ± 0.6</u> |    |    |

SD = Strongly Disagree, D = Disagree, NA/DNK = Not Applicable/Do Not Know, A = Agree, SA = Strongly Agree. Numbers represent responses by percentage. Underlined numbers = ordinal response mean ± SD with SD = 1, D = 2, A = 3, SA = 4. ‡ = Significantly different than RVPH.

Table 4 Incidence of decreased performance and heat illness related to inadequate hydration (n = 276).

| Item   | <u>RVPL</u> |                          |     | <u>RVPM</u> |                        |     | <u>RVPH</u> |                        |     | <u>Total</u> |                        |     |
|--|-------------|--------------------------|-----|-------------|------------------------|-----|-------------|------------------------|-----|--------------|------------------------|-----|
|  | NO<br>DNK   | Y1<br>M ± SD             | Y1+ | NO<br>DNK   | Y1<br>M ± SD           | Y1+ | NO<br>DNK   | Y1<br>M ± SD           | Y1+ | NO<br>DNK    | Y1<br>M ± SD           | Y1+ |
| Have you ever experienced a major decrease in running performance that you feel was caused from being dehydrated?  | 36<br>2     | 29<br><u>2.0 ± 0.8</u> ‡ | 33  | 27<br>5     | 26<br><u>2.1 ± 0.8</u> | 41  | 17<br>3     | 21<br><u>2.4 ± 0.8</u> | 59  | 27<br>4      | 25<br><u>2.2 ± 0.8</u> | 44  |
| Have you ever suffered heat-related illness symptoms during a run (severe muscle or stomach cramping, light-headedness, dizziness, nausea, or loss of ability to think clearly) while running that you feel were caused from being dehydrated? | 58<br>1     | 21<br><u>1.6 ± 0.8</u>   | 21  | 62<br>1     | 16<br><u>1.6 ± 0.8</u> | 21  | 45<br>0     | 28<br><u>1.8 ± 0.8</u> | 26  | 55<br>1      | 22<br><u>1.7 ± 0.8</u> | 23  |

Y1 = Yes (Once), Y1+ = Yes (More Than Once), DNK = Do Not Know. Non-underlined numbers represents responses by percentage. Underlined numbers = ordinal response mean ± SD with No = 1, Y1 = 2, Y1+ = 3. ‡ = Significantly different than RVPH.

Table 5 Hydration monitoring and methods incorporated by percentage (n = 276).

| Item   | <u>RVPL</u> |    |     | <u>RVPM</u> |    |     | <u>RVPH</u> |    |     | <u>Total</u> |    |     |
|--|-------------|----|-----|-------------|----|-----|-------------|----|-----|--------------|----|-----|
|  | YES         | NO | DNK | YES         | NO | DNK | YES         | NO | DNK | YES          | NO | DNK |
| Do you use any method to monitor you hydration status? (Responses by %)  | 15          | 80 | 4   | 21          | 71 | 9   | 23          | 73 | 4   | 20           | 74 | 6   |
| Methods derived by category (number of times reported)   |             |    |     |             |    |     |             |    |     |              |    |     |
|  | <u>RVPL</u> |    |     | <u>RVPM</u> |    |     | <u>RVPH</u> |    |     | <u>Total</u> |    |     |
| Urine color  | 6           |    |     | 7           |    |     | 7           |    |     | 20           |    |     |
| Pre-planning amount of fluid to be consumed or intervals at which to drink   | 3           |    |     | 3           |    |     | 3           |    |     | 9            |    |     |
| Frequency and/or volume of urination   | 3           |    |     | 4           |    |     | 2           |    |     | 9            |    |     |
| Thirst and listening to body   | 2           |    |     | 2           |    |     | 4           |    |     | 8            |    |     |
| Dehydration induced symptoms (examples given by participants: “lack of sweating”, “calf cramps”, dry skin, chapped lips, “hand moisture” | 1           |    |     | 3           |    |     | 3           |    |     | 7            |    |     |
| Sweat rate   | 0           |    |     | 2           |    |     | 4           |    |     | 6            |    |     |
| Skin turgor test   | 3           |    |     | 1           |    |     | 1           |    |     | 5            |    |     |
| Body weight  | 0           |    |     | 1           |    |     | 4           |    |     | 5            |    |     |
| Total body water measurement predictor tool  | 0           |    |     | 1           |    |     | 1           |    |     | 2            |    |     |
| Total  | 18          |    |     | 24          |    |     | 29          |    |     | 71           |    |     |

DNK = Do Not Know.

Table 6 Reported fluid intake habits during outdoor runs and methods of fluid delivery (n = 275\*).

| Item   | <u>RVPL</u>           |    |    |    | <u>RVPM</u>           |    |    |    | <u>RVPH</u>           |    |    |    | <u>Total</u>            |    |    |    |
|--|-----------------------|----|----|----|-----------------------|----|----|----|-----------------------|----|----|----|-------------------------|----|----|----|
|  | N                     | S  | VO | A  | N                     | S  | VO | A  | N                     | S  | VO | A  | N                       | S  | VO | A  |
| Do you drink during your outdoor runs in warm or hot environments?<br>(Responses by %) | 10                    | 22 | 27 | 40 | 4                     | 30 | 24 | 41 | 3                     | 19 | 33 | 46 | 6                       | 24 | 28 | 42 |
| Methods derived by category (number of times reported)                                 |                       |    |    |    |                       |    |    |    |                       |    |    |    |                         |    |    |    |
|  | <u>RVPL</u><br>n = 67 |    |    |    | <u>RVPM</u><br>n = 79 |    |    |    | <u>RVPH</u><br>n = 84 |    |    |    | <u>Total</u><br>n = 230 |    |    |    |
| Running belt with fluid bottles, carry bottle in hand, backpack hydration system       | 49                    |    |    |    | 60                    |    |    |    | 61                    |    |    |    | 170                     |    |    |    |
| Place bottles on route prior to run  | 13                    |    |    |    | 24                    |    |    |    | 21                    |    |    |    | 58                      |    |    |    |
| Drink from public fountains or faucets   | 8                     |    |    |    | 5                     |    |    |    | 19                    |    |    |    | 32                      |    |    |    |
| Have someone bring fluids to runner during run   | 4                     |    |    |    | 7                     |    |    |    | 6                     |    |    |    | 17                      |    |    |    |
| Run loops past home or car with fluids prepared fluids                                 | 4                     |    |    |    | 1                     |    |    |    | 3                     |    |    |    | 8                       |    |    |    |
| Purchase beverages at stores along running route                                       | 2                     |    |    |    | 1                     |    |    |    | 3                     |    |    |    | 6                       |    |    |    |
| Total responses  | 80                    |    |    |    | 98                    |    |    |    | 113                   |    |    |    | 291                     |    |    |    |

N = Never, S = Sometimes, VO = Very Often, A = Always. \* 1 runner in the RVPL group gave did not give a response to this question.

## CHAPTER V

### CONCLUSIONS

REC are a population often overlooked in hydration and performance research. Guidelines for fluid consumption and performance are generally based on data collected on elite level athletes performing at intensity levels and durations unlikely to be experienced by the majority of REC. These investigations explored the performance and rehydration effects for REC completing one hour of exercise in a warm environment while consuming three different beverages and evaluated the hydrations practices and perceptions of sport beverage and water consumption on performance and hydration for recreational runners. In our first investigation participants were served a volume of CE equivalent to the maximum recommended level of fluid intake during exercise (i.e. 100% of fluid loss). Total carbohydrate intake during CE trial was  $49 \pm 22$  g (mean  $\pm$  SD). Consumption of CE did not result in lower ratings of fatigue ( $p > .05$ ) or perceived exertion ( $p > .05$ ) after 50 minutes of moderate intensity cycling or subsequent peak or average power output for Wingate tests following the 50 minutes of moderate intensity cycling in comparison to NCE or W. Participants rated the intensity of exercise sessions as being comparable to their normal workouts.

We propose that one of the main differences in our results (no improvement) compared to opposing investigations that have found improvement in performance and lesser fatigue when CE are consumed, is that the participants in this study consumed a meal two hours prior to exercise diminishing any possible ergogenic effects of consuming CE during exercise. Our study is the fourth of four recent investigations finding no improvements when CE were given to

non-fasted participants, and suggests that REC athletes will receive no benefits in performance compared to NCE and W during their workouts. Motivation to exercise for the purposes of weight management rated as a high priority for our participants. Based on the volume of beverage voluntarily consumed (~900 ml) during recovery only in a familiarization trial with no fluid intake during exercise would result in an intake of ~200 kcal which could be a relatively large percentage of the caloric expenditure during exercise. In conclusion, fed REC who choose to consume NCE or W during exercise should expect to see no differences in performance in comparison to consuming a CE.

Measuring changes in body mass is the most accurate method to determine acute changes in hydration status and can be assessed by any individual with a reliable scale. Our second investigation explored how replacing all predicted sweat loss with CE, NCE, or W during exercise would be received and how the volume of fluid intake would differ from replacing all sweat loss during exercise plus voluntary consumption in a 30-min recovery session in comparison to recovery consumption only. Our first finding was that sweat losses remained stable (mean  $\pm$  SE for all sessions = 834  $\pm$  59 ml) across session differing less than 10%, suggesting that an initial measurement of weight change should be a reliable guide for the volume of fluid intake needed when intensity, duration, and environment are consistent. The volume served (100% of sweat loss from familiarization session) was also reported as an appropriate amount and resulted in few stomach discomfort complaints. The total volume consumed was greater ( $p < .001$ ) for W (mean  $\pm$  SE = 1415  $\pm$  91 mL), NCE (1244  $\pm$  87 mL), and CE (1197  $\pm$  72 mL) than ad libitum consumption in recovery only (971  $\pm$  61 mL). Although data is limited, the few investigations measuring pre-exercise hydration for REC have found nearly half of REC will begin exercise in a hypohydrated state in natural environments. We propose

that 100% fluid replacement based off predicted sweat loss during exercise and voluntary consumption in recovery will result in: 1) a diminished negative effect of dehydration for individuals beginning exercise in a hypohydrated state; 2) an increased return to pre-exercise hydration status due to greater total consumption and metered versus bolus intake resulting in greater retention of ingested fluids and less urinary losses than fluid intake in recovery only; and 3) will be an acceptable amount of intake for most REC. In addition beverage type does not appear to influence consumption, and REC should drink the beverage of their choice.

The objective of our third investigation was to gain insight on the opinions and practices of REC athletes concerning hydration and exercise environment beverage choice. Runners were chosen as they represent a population that would theoretically be one of the most at risk groups of REC to suffer negative effects from dehydration. Runners often exercise outdoors in warm or hot environments and fluid accessibility may be more limited than during exercise taking place in a single location such as on a tennis court or in a fitness facility.

One of our most important findings was that the majority (69%) of runners felt that dehydration had resulted in performance decrements and almost half (45%) responded they believed they had experienced heat-related illness symptoms stemming from dehydration. The expected finishing times reported by our participants do not represent times that would be expected by highly trained or elite level runners. Such high reports of negative consequences associated with dehydration warrants an increase in attention to the needs of this sub-group of REC.

The majority (85%) of participants reported regularly running in warm or hot environments. Hydration was obviously a concern during these runs as only 6% of runners reported never drinking and 44% reporting always drinking during runs in hot or warm

environments. However, only 20% of participants reported monitoring their hydration status. Less than 2% of runners used the method of measuring changes in body mass from pre- to post-run. This is the least subjective and accurate method for participants to determine changes in acute hydration status, a critical factor in prescribing a hydration plan, and its use is highly advocated by the major governing bodies in sports medicine and athletic training. The lack of awareness and use of this technique warrant more promotion within the running community.

The lower two tertiles of runner reported lower levels ( $p < .01$ ) of consuming sport beverages in exercise environments than the highest tertile of runners based on running volume and expected finishing time. Our results were also in agreement with our hypotheses, finding higher volume and faster runners did report greater levels of agreement that sport beverages were more advantageous than water for performance and hydration, and the highest tertile of runners reported greater incidents of performance decrement in comparison to the lowest tertile. However, there were no differences between groups in regards to incidents of heat-related illness symptoms believed to be caused by dehydration.

In conclusion, these investigations have provided evidence that in exercise environments REC may not demonstrate a preference for sport beverages as has been seen in more highly trained athletes. This may be partially due to lower expectations REC and less highly trained athletes may have of sport beverages abilities to improve performance or offer an advantage in terms of hydration. Consumption of CE failed to improve performance, reduce fatigue, or level of perceived exertion during an hour long workout in comparison NCE or W. Negative incidents related to dehydration during exercise were fairly common among recreational adult runners and may be caused in part by inadequate hydration strategies. A key step in reducing these types of occurrences could be to more actively promote the hydration monitoring method of measuring

changes in body mass. Preparing and consuming a volume of fluid comparable to predicted sweat loss during exercise and drinking *ad libitum* in recovery is an effective method of ensuring proper hydration, and the beverage chosen to be consumed should be based on taste preference of the individual.