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PERCEPTIONS AND PRACTICES OF HYDRATION IN TRIATHLON

Corey S. O'Connor

59 Pages May 2014

Purpose: To examine where triathletes obtain information regarding hydration, their beverage choice, perceptions of the difference between water and sport beverages, if their performances have been affected by dehydration, and how they monitor their hydration status. **Methods:** Two hundred and two participants were recruited from various triathlon groups in Illinois. Each participant was asked to complete an electronic survey. The survey was composed of twenty-seven items and was developed by O'Neal (2011). The survey was modified for triathletes and seven questions were added in order to categorize different triathlon groupings. The survey targeted training background, sources of information on hydration, beverage perceptions and if dehydration negatively impacted performance. **Results:** Seventy-seven percent of the triathletes reported that peer reviewed research played a minor or no role as sources of information on hydration. Eighty-one percent of the triathletes experienced at least one instance where their performance was decreased as a result of dehydration. Sixty-percent of the triathletes suffered at least one instance of heat related illness symptoms caused by dehydration. Seventy-seven percent of participants reported monitoring their hydration status with

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seventy-six percent of the people who monitor their hydration will use thirst and listening to their body. **Conclusions:** Triathletes may need to use a variety of techniques to monitor hydration status because a majority of participants experienced decreases in performance as a result of dehydration. Triathletes might also need to utilize scientific resources on hydration in order to properly understand correct hydration guidelines.

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PERCEPTIONS AND PRACTICES OF HYDRATION IN TRIATHLON

COREY S. O'CONNOR

A Thesis Submitted in Partial
Fulfillment of the Requirements
for the Degree

MASTER OF SCIENCE

Department of Kinesiology and Recreation

ILLINOIS STATE UNIVERSITY

2014

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PERCEPTIONS AND PRACTICES OF HYDRATION IN TRIATHLON

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CHAPTER I

PERCEPTIONS AND PRACTICES OF HYDRATION IN TRIATHLON

Participation in triathlons has become popular in all age groups, especially in the age range of thirty to forty-nine (34). The number of sanctioned races in the United States has nearly tripled over the last seven years, going from 1,541 to 4,310 races per year (34). Along with the increase in races, there has also been a rise in participation from 1,702,000 to 1,992,000 participants who completed at least one triathlon in 2011 (34). The growth of triathlon can be attributed to several different factors. The 2000 Olympic Games, triathlon's first appearance at this international event, elevated the publicity of the sport on the national level (34). Through the first weekend, NBC's coverage of the 2000 Sydney Olympic Games, which included coverage of the women's triathlon, was the most watched non-U.S. Summer Games in history with 111 million people tuned-in to all or part of the broadcasts, according to NBC Sports research (34). Additionally, after the 2004 Olympic Games in Athens, Greece, USA Triathlon and its elite athletes appeared in such publications as the New York Times, the L.A. Times, Vanity Fair, Washington Post, USA Today and a host of others (34). However, with the increase in participation comes the risk of endurance related illnesses such as dehydration and hyponatremia.

With triathlon being a relatively new sport, there is little information available on

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hydration recommendations or guidelines for triathletes. Triathletes are frequently left to experiment with hydration practices on their own. Dehydration is defined as the loss of body water, with or without salt, at a rate greater than the body can replace it (30). It can be measured by changes in body weight, urine color, various questionnaires, as well as blood tests. It is recommended that an athlete should aim to lose no more than 2% of body weight during exercise; however, exercise sometimes continues up to a 7% loss of body weight with severe symptoms beginning to show in most people at 4-6% (1). In Ironman racing (Ultra-endurance event) some of the most successful athletes complete the race with a high percentage of body weight loss (30).

An athlete losing 2-3% of their body weight is at risk of complications stemming from dehydration. An athlete who is dehydrated has many risks including compromised thermoregulatory homeostasis, unless fluids are replenished at a rate near equal to the volume of fluid lost in sweat (37). The challenge for dehydration management is trying to replace all of the fluids that are lost, especially during a triathlon. During activities like running, swimming and cycling, it is difficult to rehydrate since in swimming the only fluid intake occurs before or after the exercise is completed. Likewise, in running and cycling it may be difficult to gauge how much fluid has been lost during the activity, especially if the individual is new to the sport.

Triathlons can range from sprint distances all the way to an Ironman which is an ultra-endurance event, and they can occur throughout the entire calendar year. Triathlons that are Ironman distance have food and fluid stations throughout the bike and run

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portions of the competition that supply water, carbohydrate beverages, and often times various food items. The other races distances however do not have this luxury except during the run portion, and it is solely up to the athlete to determine how much food and fluid they will need throughout the other two segments of the race. The common problem among triathletes is trying to develop a plan of how they will hydrate before and during the competition. For these types of triathlons where food and fluid are not readily available, it might be important for triathletes to completely hydrate prior to competition because during the event they will create a fluid deficit. Therefore, methods designed to optimize pre-exercise hydration are important and have become the focus of a large body of current research (37). More specifically, attempting to hyper-hydrate prior to exercise is being emphasized in an effort to optimize pre-exercise hydration regimens (37). With a majority of triathlons not providing food and fluid during two of the three segments of the race, it is important that triathletes begin to formulate a hydration plan that they can utilize while they are racing.

Hypotheses

The purpose of the study was to investigate triathletes' perceptions of the importance of hydration and their hydration practices while they are training and racing during a triathlon. The goals were to see how triathletes practice hydration and what their views on the subject of hydration are. Additionally, we wanted to determine what distance of racing includes triathletes who demonstrate the best hydration practices and knowledge.

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Methods

The investigation was approved by the University's Institutional Review Board. A wide and diverse population of triathletes was targeted for the study. The investigator contacted triathlon groups with an explanation of the study and asked them to distribute the survey to their members. The investigator also asked permission to post the survey on the triathlon groups' social media websites. When the survey was posted on the triathlon groups' social media sites, an explanation of the study was provided.

The inclusion criteria for the study required that all participants had completed a triathlon race prior to completion of the survey and be at least 18 years old. There were no other restrictions. The purpose of the study and the inclusion criteria were included as the first page of the electronic survey. Along with the purpose of the study and inclusion criteria, informed consent was outlined on the first page of the survey.

Participants were separated into groups based on their responses to the questions on the first page of the survey. Gender and race distance were used in order to develop different groupings that could be analyzed with the responses to the questions.

Survey Instrument

The survey instrument was originally created and used in a previous research study that looked at hydration among half marathon and marathon runners (25). The survey was developed by people with research experience in nutrition and performance, environmental physiology, and thermoregulation (25). A review panel that reviewed the

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content and readability of the questions also consisted of experienced runners and a registered dietitian (25). Several questions were added in order to obtain background information on the participants, and some of the wording was modified in order for it to be appropriate for triathletes.

The first seven questions of the survey targeted different demographics of the participants as well as information regarding their training and career in triathlon. The next part of the survey asked participants whether six different sources of information on hydration played a role in their hydration practices (Figure 1). The participants chose either Major, Minor or No Role. The next section included ten questions that targeted the participants beverage choices and their perceptions of the difference between water and sport beverages (Table 1). Response choices for this section include strongly disagree, disagree, agree, strongly agree, and not applicable/do not know

The final section asked participants whether they had experienced decreased performance as a result of inadequate hydration as well as heat-related illness symptoms that they felt were caused by being dehydrated. The participants chose from either no, once, more than once, or do not know. The last two questions inquired about the triathlete's use of methods to monitor hydration status, and if they did, they were then asked to select one of the methods that they use while training or racing.

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Data Analysis

Descriptive statistics (means, standard deviations, cross-tabs, and percentages) were calculated. Data from participants who had incomplete surveys were kept in the study, but the missing data was not analyzed for that specific question. Descriptive statistics that were utilized were percentages as well as cross-tabs. Percentages were used for every question in order to see how different populations responded to various questions. Cross-tabs were used in order to interpret how gender and specific race distance responded to the section 4 questions on performance and dehydration.

Results

Two hundred and two triathletes completed the electronic surveys. Surveys that were incomplete were not discarded; they were withheld from data analysis if the unanswered item was being analyzed. A total of 100 men and 101 women were included in the final sample; 93% (n=189) predominately trained in the Midwest with the remaining 13 participants predominately training in the south, west coast or east coast. Sixty-one percent of the participants (n=123) had been competing in triathlons for one to five years. Thirty-seven percent of the participants (n=75) were training for more than one race distance. Sixty-three percent of the participants (n=128) were training ten to twenty hours per week. Twenty-nine percent of the participants (n=59) had completed between five to ten triathlon races in their career.

The survey questions that targeted where triathletes received their information on hydration and the decreased performance as a result of inadequate hydration questions

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provided several items that require future research. Advice of former or current coaches or fitness professionals played the biggest role (major= 52.7%) in the participant's sources of information on hydration. On the other hand, the advice of health professionals and peer-reviewed research were reported as playing a minor or no role (minor=41%; no role=24%) (minor=45%; no role=33.2%) respectively. The responses to the questions on where triathletes obtain their information on hydration can be seen in figure 1.

Close to 82% of participants reported experiencing a major decrease in performance that they felt was caused from being dehydrated. Of those participants, 58% had experienced that major decrease in performance more than once. Almost half of the subjects who experienced a major decrease in performance (49.5%), have been in the sport for 1-5 years. Males reported that 69% had experienced a decrease in performance from dehydration more than once whereas females only reported 48%. Sixty-one percent of the participants reported that they suffered heat-related illness symptoms that they felt were caused from being dehydrated. Of those participants, 39% reported that they suffered from heat-related illness symptoms more than once. The performance and hydration responses can be seen in figure 2.

Seventy-seven percent of triathletes reported monitoring their hydration status. Thirst and listening to their body were the highest reported methods for monitoring hydration status among those who monitor their hydration (76.5%). The other methods used to monitor hydration can be seen in figure 3. When comparing males and females, males reported using thirst the most (62%), whereas females used frequency of urination (51%). When comparing the questions in the final section that asked if the participants

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ever experienced a decrease in performance as a result of dehydration and if they ever suffered heat-related illnesses as a result of dehydration, the sprint (shorter) distance had the highest percentage (37%) of triathletes who reported that they never experienced it.

Discussion

The most important findings came from the questions that were posed regarding decreased performance as a result of inadequate hydration. A majority of triathletes (82.1%) had experienced a major decrease in performance that they felt was caused from being dehydrated. Half of the triathletes in the study had completed 10-20 races and nearly 75% trained 10-30 hours per week, so the decrease in performance might not be uncommon. Future studies will be needed to clarify if the decrease in performance happened during a training session or a race.

Seventy-seven percent of participants (n=155) reported that they used various methods to monitor their hydration status. Of those one hundred and fifty-five participants, ninety-eight participants (63.2%) reported that they experienced a major decrease in performance that they felt was caused from being dehydrated more than once. It is again hard to distinguish how uncommon these results are because "more than once" could be interpreted as just two or three times when the triathlete's performance faltered, or it could mean ten or more. Speculating about the statement "more than once", the results still show that more than half of the participants who monitor their hydration have had decreases in performance multiple times.

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Triathletes may be having problems with dehydration because they do not know how to recognize the symptoms. The basic symptoms given by USA Track and Field for dehydration are irritability, and general discomfort, then headache, weakness, dizziness, cramps, chills, vomiting, nausea, head or neck heat sensations (e.g. pulsating sensation in the brain), disorientation and decreased performance (5). The problem with recognizing these symptoms for a triathlete is that when performing three different events, they may see some of these signs but they are not always a result of dehydration, but rather the stress of completing three intense events in the same race. By the time the triathlete gets to chills and vomiting, they are already too dehydrated to reverse its impact on performance. It is worth investigating whether or not triathletes can recognize signs and symptoms of dehydration in order to see if that is where the problem originates.

By far, the method used to monitor hydration the most was thirst and listening to their bodies (76.5%). Proper hydration becomes a difficult task because the endurance community is aware of hyponatremia and consuming too much fluid, but on the other hand, thirst is used as a general indicator of dehydration (5). The point is that both dehydration and hyponatremia have terrible consequences, but should a triathlete use thirst as a monitoring tool when it clear that it is already a sign of dehydration? There may be other methods like sweat rate or changes in body weight which may be able to eliminate both hyponatremia and dehydration. In the future, it is important to pose more hydration monitoring questions in order fully understand what the triathletes are using as their tool to monitor hydration.

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The triathletes were asked where they received their information on hydration, and by far the two that played the biggest role were the advice of former or current coaches (52.7%) and other triathletes (46%). The study of half marathon and marathon runners had similar results for these questions, with the advice of other runners being around 65% and the advice of former coaches being around 48% (25). These numbers are worth looking at more closely in the future in order to understand why triathletes put more stock in what a coach or triathlete says, rather than someone who maybe more qualified in the field of hydration. The coach or triathlete may have experience with this field, so an explanation as to why they use this information rather than listening to health professionals or peer-reviewed research is needed. The triathletes in the study said that the advice of health professionals (65%) and peer-reviewed research (78.2%) played a minor or no role in their hydration habits. O'Neal again had similar results with his runners, the health professionals' advice (48%) and peer-reviewed research (78%) (25). More investigation is needed as to why runners and triathletes use similar advice about hydration.

A limitation of the study was that 61.2% of the triathletes had been competing in the sport for one to five years. With a majority of triathletes being relatively new to the sport, it might not be uncommon to see these types of hydration responses. People that are veterans in the sport might not make the same mistakes that the newer triathletes make since they have been competing for a longer period of time. The sample had 93.6% of triathletes who trained in the Midwest, so the results could differ if more people from the entire United States participated. Additionally, the response of "more than one" to

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the question of "what race distance do you predominately train for" generated 37.1% of the responses. This response was not specific and it was hard to interpret the responses for this group since a good chunk of the triathletes responded that they trained for more than one distance. In the future it might be helpful for the question of "How many hours do you train per week", to have smaller increments rather than 10 hour gaps because the majority of triathletes responded with the 10-20 range. Additionally, the heat-related illness question on the final page of the survey had the wording "while running" that was not caught until after the surveys were distributed. The question should be geared towards triathletes with the wording "while training", which could have altered the response if people had these symptoms while swimming or cycling.

This study made an effort to investigate triathlete's perceptions of the importance of hydration and their hydration practices while they were training and racing during a triathlon. Because triathlon is a relatively new sport, hydration guidelines are currently not in place. The main objective was to see which race distance had the best hydration practices, but the results shifted that focus slightly. It was determined that the sprint distance had the fewest incidents of dehydration, but this is most likely because of the short race distance. Triathletes tend to use thirst and listening to their bodies in order to determine when they should hydrate. While this method may work for some individuals, triathletes may want to use sweat rate or changes in body weight to determine how much they should hydrate while training and racing. Additionally for longer distance races, preplanning the amount of fluid to be consumed may be a useful method so that the triathlete is aware of when they need to be drinking fluid. If the triathlete is not aware of

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how much fluid they should be drinking or how they can calculate sweat rate/changes in body weight, they should seek the advice of a health professional or review the research regarding hydration in endurance sports. Future investigations should look at each race distance individually in order to determine how each race distance differs in their hydration practices.

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Table 1: Beverage choices and Perceptions of Differences Between Water and Sport Beverages (n=202) (%)

Item	Strongly Disagree	Disagree	Agree	Strongly Agree	Do Not Know
I intentionally increase the volumes of fluids I drink in non-exercise environments during periods of warm or hot weather	5.4	7.9	50.5	35.1	1.0
Sport Beverages are superior to water in meeting hydration needs of exercisers	6.0	37.3	42.8	11.4	2.5
I prefer the taste of water over sport beverages in exercise environments	2.5	34.2	40.6	20.8	2.0
I avoid drinking sport beverages because of their caloric content	21.3	49.0	21.3	6.9	1.5
I dilute regular sport beverages with water	21.3	24.8	32.7	13.9	7.4
I drink low- or zero-calorie sport beverages	25.4	29.9	27.9	11.4	5.5
I drink beverages marketed as "recovery" beverages that contain high percentages of carbohydrates or a carbohydrate and protein combination	11.4	27.4	40.3	13.4	7.5
Drinking a sport beverage instead of water after exercise will result in better recovery and improved performance for my next exercise session	6.0	30.0	44.0	10.0	10.0
Drinking sport beverages with carbohydrates and electrolytes before or during exercise can improve performance during runs of less than 1 hour compared to water	11.9	49.8	27.9	4.5	6.0
Drinking sport beverages with carbohydrates and electrolytes before or during exercise can improve performance for runs of greater than 1 hour compared to water	2.5	4.0	62.9	26.2	4.5

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Figure 1: Sources of Information on Hydration

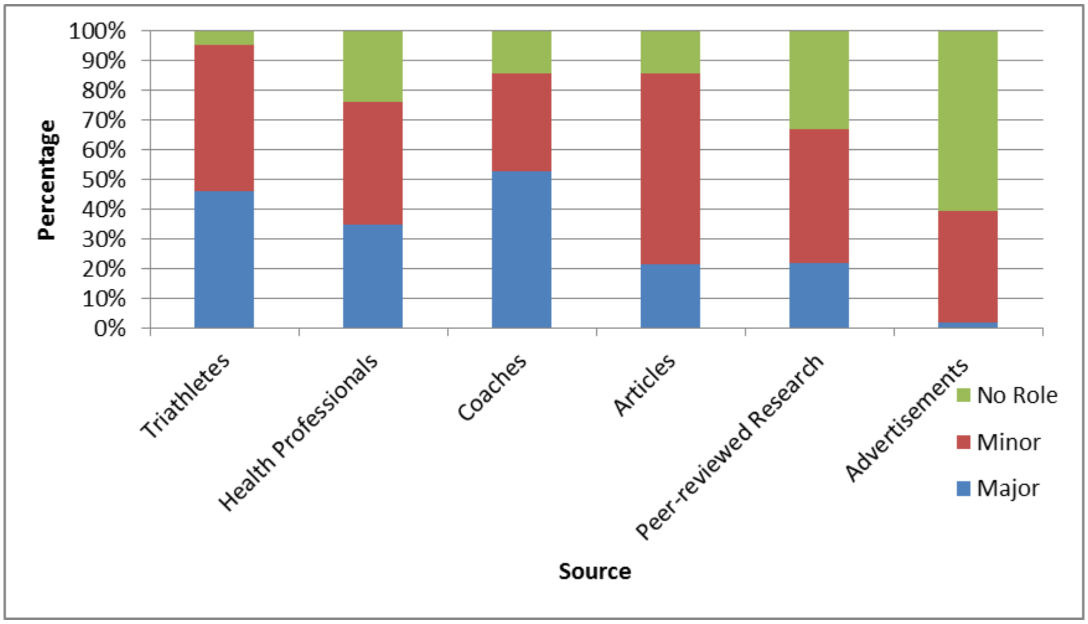

Figure 2: Performance and Hydration

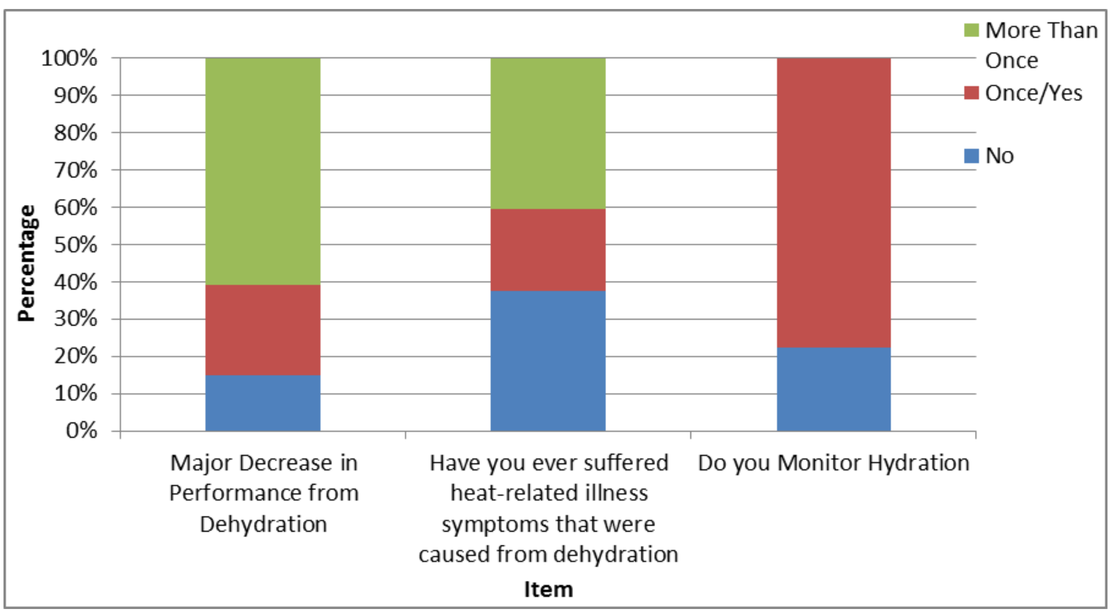

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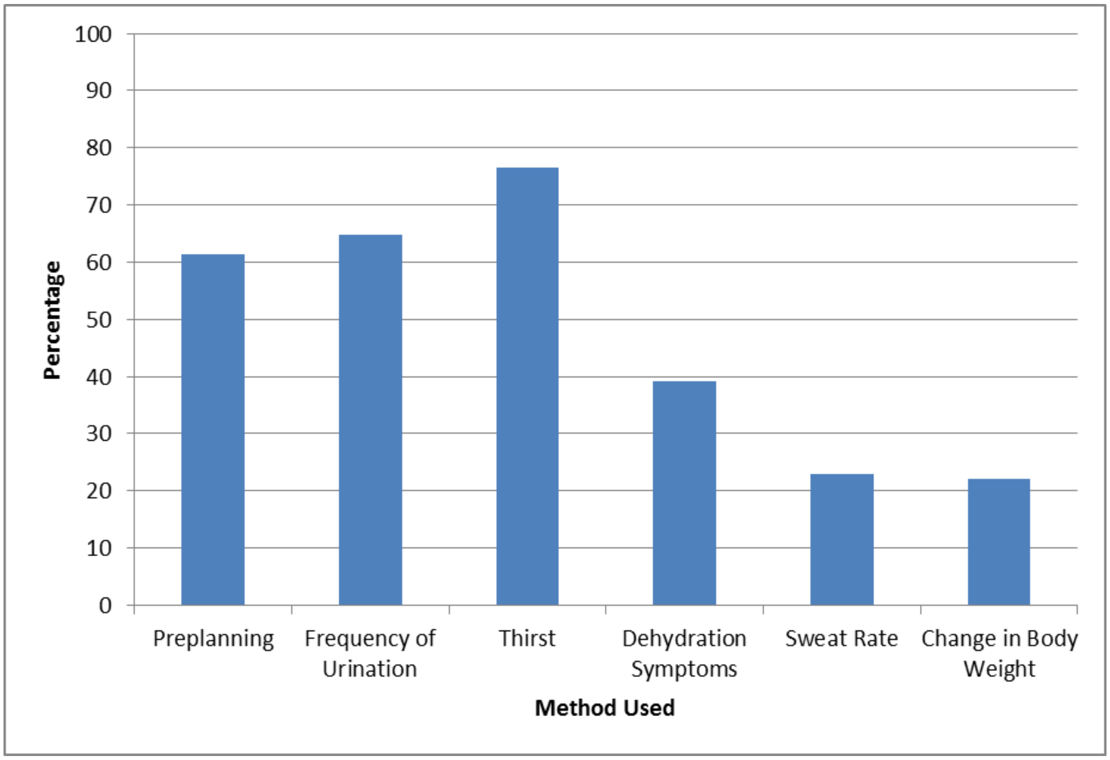
Figure 3: Methods used to Monitor Hydration Status



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CHAPTER II

REVIEW OF THE RELATED LITERATURE

Endurance events are becoming more popular as evident by the Chicago Marathon which has sold out in record times the past two years. With the marathon having nearly 40,000 participants, there are most likely a lot of new runners and inexperienced ones as well. The most recent recommendations for rehydration have been fairly conservative, emphasizing the need for sufficient fluid intake before, during, and after exercise to minimize loss of body weight between exercise bouts and recommending that consumption during exercise not exceed sweat losses but be sufficient to avoid body weight reduction greater than 2% (5). On the other hand, there is other research that is saying that drinking ad libitum is sufficient to keep hydrated (9).

With little known about the hydration practices of distance runners and the degree of influence that association guidelines have on their behaviors, the primary focus of the study was to determine which beverages the runners drink and why, whether runners have experienced decreases in performance or heat related illness symptoms believed to be caused by dehydration, and how runners monitor their hydration status (25). The researchers targeted just the average runners compared to the elite ones. The runners were surveyed during the expo prior to the Little Rock Half Marathon and Marathon. It did not matter if the participants were running the half or the full, it only mattered that

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they were at least 18 years old. The participants of the study were separated into different categories depending on running volume, expected race completion time, and racing experience. The survey was developed by the researchers with it containing 23 questions that assessed various items. There were four sections of the survey with the first being the runners demographics, the next being sources of runners' information on hydration strategies, then runners' beverage choices, and finally the section on heat related symptoms.

There were some surprising results that were gathered from the surveys of the distance runners at the Little Rock half marathon and marathon. Advice from other runners about beverage choices and hydration was the greatest source of influence (64%) by participants (25). The high group which was the more advanced runners reported greater regular consumption of sport beverages in exercise environments than did the low and moderate runners (25). 31% of the runners avoided drinking sport beverages because of their caloric content while 50% said they drink low-calorie or non-caloric sport beverages (25). Almost 70% of the participants reported they had experienced a major decrease in performance due to dehydration (25).

The study by Eric O'Neal was one of the first to look at hydration perceptions and practices in half marathon and marathon runners. According to this article, there were a lot of runners who experienced performance decrements as a result of dehydration. With the incidence increasing for the more experienced runners (25), it seems that the slower participants in the low and moderate groups are not at as much of a risk as the faster

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group. Obviously, the survey could have gone into more detail when assessing the performance decreases or heat related symptoms, but the study by O'Neal was one of the first to look at hydration practices and perceptions in half marathon and marathon runners, which has given insight as to why some runners may be experiencing dehydration.

The amount of fluid intake needed during an endurance event is often unclear, and it usually varies depending on the climate, length of the race and many other factors. The article by Fudge (2008) looked to examine the top elite runners in the world to see what their fluid intake is like during a critical training period. The article looked at elite Kenyan runners because their success at running and the importance of diet and lifestyle for optimum endurance running performance warrant examination (9). Previous research on this group of athletes showed that athletes did not consume fluids before or during training, and only infrequently consumed modest amounts of fluid immediately after training (9). Therefore, the researchers just wanted to assess the hydration levels of elite Kenyan one week prior to a competition.

The elite Kenyan runners in the study were acclimated to the heat and altitude where the study was being conducted and the research took place during a taper period prior to competition. The runners were monitored for five days while they tapered, so they usually completed two runs per day with two days of interval training during that week. Measurements that were taken every day were: Body water compartments, urine osmolality and specific gravity, body mass and body fat. While the runners were out

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training they wore heart rate monitors, GPS watches and they consumed a pill prior to exercise that measured body temperature during the training runs. Also, sweat loss and sweat rate were measured after each run depending on the body mass prior to that specific run. The main focus of the study was that the athletes consumed food and fluid ad libitum, which essentially means that nobody was telling them how much to eat or drink, they chose based on how they felt and when they thought it was necessary.

Throughout the study, the temperature outside remained fairly consistent and mild for the most part. On average there was a significant body mass loss during the short, medium, and long morning training runs as well as the afternoon and interval training runs (9). Athletes that completed a morning run and an afternoon training run did not have a significant difference in body mass, however, runners that completed a morning run and an interval training run had a significant loss in body mass when they were done (9). The average loss on body mass after the interval run was 1.5kg which was equivalent to 2.7% of the body mass (9). While the study was being conducted, mean total body water, extracellular water, intracellular water, and pre-training body mass were well maintained day to day (9). One of the interesting finds in the study was the diet of each athlete and how much of each macro nutrient they consumed. On average the runners ate 79% carbohydrates, 14.3% protein, and 6.6% fat (9). It is interesting in that the runners consumed very little fat during this training period while their carbohydrate intake was very high. While the training period was one week prior to a big competition, carbohydrate loading usually does not occur that far in advance. The fluid that was

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consumed throughout the study was mostly water but also milky tea, soft drinks and milk. The average daily fluid intake of the athletes was around 3.8L per day (9).

While the runners did not consume a lot of fluids during the day, they still were properly hydrated from day to day. The runners lost a higher percentage of body mass after the interval runs as a result of the deficit created from the morning run because there was little fluid consumed after the runs, however, it is still probably within a tolerable range because it did not affect their performance (9). Their urine tests were similar from the morning to the evening which indicates that they do stay well hydrated throughout the day even though they have body mass losses from their runs. This maintenance of hydration status, despite athletes loosing body water during training, was achieved by water gained from the diet and fluid ingested throughout the day ad libitum (9). The milky tea that was consumed during the study has similar sodium concentrations to sports drinks which could indicate why the athletes were able to stay so hydrated throughout the study (9).

According to this article, the Kenyan runners were able to stay hydrated by ad libitum fluid intake during their taper period prior to a competition. The findings in this study are critical for not just runners but endurance athletes in general. There are fluid recommendations that are consistently being modified; however, this specific study shows how athletes can consume water when they are thirsty or when they feel it is necessary and still remain well hydrated. Often time's climate will play a role in how much fluid will need to be consumed and with the climate in this study being fairly mild,

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more fluid might be necessary if the environment is hotter. Runners should pay close attention to this study with the fluid intake being ad libitum because there is a high prevalence of hyponatremia when it comes to running and marathons more specifically when people consume large amounts of water.

Hyponatremia is very common in marathon running and it needs investigation in order to determine how much fluid intake is too much. The article by Almond (2005) looked at the Boston marathon specifically in order to determine how many people developed hyponatremia and the risk factors for it. Excessive fluid intake is believed to be the primary risk factor for hyponatremia. Subjects in the study were chosen randomly at the expo which is often a day or two days prior to the race. Also, the subjects did not have to have qualified for Boston; they could be running it for a charity. The subjects that accepted to be in the study completed a survey describing baseline demographics and training information, medical history, and anticipated hydration strategies for the race (2). Some of the measurements that were taken after the race were: a blood sample, a questionnaire detailing their fluid consumption and body weight. Hyponatremia in the study was indicated by a serum sodium concentration that was less than 135mmol per liter or less, severe hyponatremia was 130mmol per liter or less and critical was 120mmol per liter or less (2).

One of the key findings of the article by Almond (2005) was that the average sodium serum concentration of the finishers was 140mmol per liter (2). Also, 13% of the finishers in the study had hyponatremia, including 22% of women, and 8% of men (2).

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Of the finishers, 3 of them had critical hyponatremia. One important thing is that all of the runners in the marathon were not part of the study so this is a small sample of 488. Therefore, these numbers would most likely be higher in the case that all of the runners in the marathon were part of the study. Hyponatremia was correlated with weight gain, longer racing time, and a body mass index of less than 20 (2). Out of everything measured in the study, weight gain had the strongest correlation for hyponatremia. Indications for weight gain typically were consumption of 3L of fluid or more, fluid consumption every mile, longer racing time, female sex, and a body mass index or less than 20 (2). Not everything measured in the study was a risk factor for hyponatremia; for example, composition of fluids and being female did not contribute to it (2).

According to this article, hyponatremia could potentially be a bigger problem than most people realize. With the sample in the study being limited to only 488 runners, 62 of them had developed hyponatremia, so that means that if all 15,000 runners were studied, the number could be closer to 1,900 for runners developing hyponatremia (2). Marathon runners should be aware of these statistics because hyponatremia can be potentially fatal in worst case scenarios. Runners can now understand that weight gain, longer racing time, and a low body mass index will put them at risk for hyponatremia during a marathon. Therefore, runners can adjust their fluid intake based on their race time and body mass index in order to finish the race healthy. Hyponatremia is something that can be considered not just for marathons but also long distance cycling, ultra marathons and Ironman events.

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Hydration is crucial to many endurance events like triathlons and marathons but it is even more critical when the events become longer or in hotter climates. Ultra-marathon events are races in which the distance exceeds the 26.2 miles that is normally a marathon. Ultra-marathons that have multiple stages can last up to a week which indicates how important hydration and nutrition is while completing the race. The thought of many long distance runners is to consume as much fluid as possible, which can cause hyponatremia or other side effects from the increase in fluid consumption. The study by Ricardo Costa occurred during the 2010 and 2011 ultimate trail run in Spain. He had 74 participants who competed in the five day event in very hot climates. The subjects were broken into two different groups with one being a walk/run group while the other was a strictly run group.

For the five days of testing, the subjects provided their own food and fluid with the race only providing plain water during the rest periods (8). Before each stage of the race, the subjects completed various physiologic measurements like body fat percentage, weight, a blood sample and a urine sample. At the end of each day, trained dietetic researchers conducted a standardized structured interview on participants to ascertain total daily food and fluid ingestion (8). The subjects had to remember how much food and fluid they drank before the stage started, during the race, and if they had any snacks once the race was over. Hydration was measured from the body mass measurement taken pre and post stage as well as from the urine sample taken before and after the stage. One of the key findings in the study was that irrespective of speed or gender, there were 8 cases of asymptomatic hyponatremia along the course of the event (8). The average total

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daily water intake was 7.7 liter per day which appears to maintain the baseline euhydration (8). The amount of water taken in through food and fluid while running was 4.5L, with fast runners and males able to taken in higher amounts than slow runners and females (8). One of the interesting finds was that there was even hyponatremia that was measured when the runners were not running which indicates that endurance athletes may over consume fluids prior to or just after a race is finished. The average body mass loss in the current study was only 2.4% which seems fairly low for a multi-stage ultra-marathon event, with the fast runners and males showing a greater loss than the slow runners and females (8). With slow runners and females losing less body mass during the event, they are at a greater risk for hyponatremia. The researchers found that using urine samples can be dangerous for some individuals who try to maintain clear urine which can promote over consumption, whereas using thirst can be more reliable and safer (8).

According to this article, hydration and food intake is critical in multi-stage ultra-marathon events because the runners are often in charge of their own food and fluid. The subjects had to remember things they ate before the race started and during it, which can be hard to do when completing such a long race, but there were some results that could not be ignored. There were 8 cases of hyponatremia out of the 74 participants in the study, but there were also more subjects who did not participate in the study that could have had hyponatremia. Therefore, it still can be seen that hyponatremia is a problem in the endurance community during the race but it also can be a problem before and after the race as evident in this study. Also in accordance to other research, the study found that women and slower runners are at a greater risk for developing it since they do not lose as

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much body mass during the race. Hyponatremia is a problem in running events and it will continue to be until runners are educated on hydration and how to properly hydrate during endurance events.

Food and fluid intake is important for all types of athletic events, but it becomes even more crucial when it is an ultra-endurance event. Ultra-endurance events are usually marathons or triathlons that have very long distances. Therefore, if an athlete is racing for many hours, the importance of obtaining calories while racing becomes very important and is critical if the athlete wants to finish the race. The study by Glace wanted to look at food intake and electrolyte status of ultra-marathoners who were racing in the heat. The purpose of this study was to document changes in blood and urine electrolytes and to relate those changes to dietary intake in runners engaged in a 160 km trail race (10). They further sought to determine whether intake had an effect upon the ability to complete the race and upon gastrointestinal function or mental status (10).

Twenty-six participants had body mass, urine, and blood samples taken prior to the start of the race. The researchers would sit at the food tables throughout the race in order to interview the participants to find out what they were eating during the race. The participants would carry any wrappers to food items they ate between the interviews in order to calculate how much food they were eating during the race. Body mass measurements were taken four different times during the race, while blood samples were taken twice during the race. Additionally, the runners were asked at every interview during the race if they were having any gastrointestinal issues and the researchers

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recorded any changes in mental status (10).

Thirteen of the twenty-six participants were able to finish the race and the mean change in weight from race start till the last time weighted during the race, or until the finish, was -0.97 +-1.8kg (10). Carbohydrates provided 81% of the 29493 J ingested by those completing the race (10). Finishers drank a mean of 19.4 +- 5.6 L, with a range of 11.9 to 28.1 L (10). Sodium intake was 16.4 +- 6.8 g, with a range of 4.9 to 27.5 grams (10). These were consumed at rates of 0.7 L/hour and 0.6 g/hour, respectively (10). Notably, 16% of the total fluid intake was contributed by the moisture contained in solid foods (10). Hyponatremia only occurred in one runner during the race, but gastrointestinal symptoms were experienced by 17 of the 26 participants (10).

The results of this study are particularly important for athletes who complete in long distance endurance events. Subjects were able to consume a lot of food and fluid throughout the race but most of the subjects complained about gastrointestinal issues. The subjects did not lose a lot of weight and the athletes who consumed a lot of fluid were more at risk for a change in mental status (10). The results can be used by ultra-endurance athletes in order to guide their food and fluid consumption while preparing for a race. When competing in an ultra-endurance event, an athlete's food and fluid intake can end up playing a big role, and it can be the deciding factor as to whether or not the athlete will finish the race.

It has been shown previously that when exercising in the heat, there should not be a body weight loss of greater than 2% (5). Most of the studies that have been looked at prior to

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this have focused on endurance athletes and their hydration levels, whereas this study focuses on children. The purpose of this study was to investigate the effect of a nutrition intervention program emphasizing water consumption on the prevention of dehydration, and in addition, study the effects of hydration improvement in the physical performance of young athletes (17).

The data was collected in 2007 over the course of two weeks during a summer camp for youth. The youth that attended the camp were trained volleyball and basketball players. For the first week of data collection, 31 children served as the control group, while the second week, 61 children served as the intervention group. All of the kids were healthy and had been trained in their respective sport for at least two years prior to the program. For the study, the children had their hydration and different body assessments taken at the beginning of the 2nd day of camp and before the 4th day. These days were selected for the measurements because they were separated by the nutrition intervention program that was given. The kids also completed various physical assessments related to their sport like sprints, vertical jumps, volleyball serving assessments, and free throw shots for basketball. The hydration measurements were assessed using urine specific gravity, urine osmolality, and a modified environmental symptoms questionnaire that was given at the end of the camp.

For the intervention, the control group received no information on hydration whereas the treatment group got several different things. They received a one hour lecture on hydration and its benefits, the urine color chart was explained to them, there

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was improved water accessibility, and they were weighed in prior to and after the workouts but were told nothing regarding what it means. The results show that 96.7% and 91.7% of the control and treatment groups were dehydrated on the second day of camp prior to the intervention (17). On the fourth day after the intervention, the dehydrated numbers were 96.7% for the control group and 66.1% for the treatment group (17). Endurance performance in the 600m running test was improved only in the intervention group with the pre-test mean being 189 while the post test was 167 (17). Also, the skills assessments for each sport improved only in the treatment group compared to the control.

According to this article, hydration interventions can be moderately successful in decreasing dehydration among children at a summer camp. The number of dehydrated children dropped significantly after the intervention; however, the majority of the children at the summer camp were still in a dehydrated state. The performance measures were not that different from the control group to the treatment group except for 600m run and the skills assessments, but that could be a result of the majority of the treatment group being in a dehydrated state at the camp. Even though performance did not necessarily change in this study, it could be different if more of the treatment group was in a euhydrated state. One thing that can be taken away from the study is that after the intervention, the number of dehydrated individuals did decrease, so it could be applied to see how an intervention works on adult exercisers or even endurance athletes.

The article by Sharwood (2004) examined Ironman races which are extreme

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endurance events which stretch from eight to seventeen hours. Ironman races consist of a 2.4 mile swim, 112 mile cycle, and a 26.2 mile run all completed in one day. It has been said that exercise can continue up to a 7% loss of body weight but the symptoms can become more severe at 4%-6%, which is why most guidelines indicate an athlete should aim to lose no more than 2% (1). However, in Ironman racing it has been shown that some of the most successful athletes complete the race with a higher percentage of body weight loss (30). Therefore, Sharwood wanted to examine these statements to see if athletes still can exercise at a 7% loss of body weight and what types of medical conditions happened at these higher percentages.

The study was completed over a two year period during the 2000 and 2001 South African Ironman triathlon. Subjects had their blood pressure and weight measured the morning of the race, and the athletes who finished the race were weighed, had their blood pressure and temperature taken, and had a blood sample for serum sodium concentration. The athletes also received a medical evaluation by sports clinicians to assess fluid status by looking at fullness of eye sockets, sweat and saliva production, and oedema of the lungs (30). The researchers grouped the athletes into three groups based on their percentage of body weight loss: the first group was higher than 5% loss, the second was a 3.5%-4.5%, and the last group was 3% loss to 3% gain. Group 1 who had the largest body weight losses also finished the race with increased serum sodium concentration (30). During the race systolic blood pressure decreased significantly in all of the groups but diastolic only fell significantly in the second group (30). There was medical diagnosis that happened in all groups with the athlete either having hypothermia,

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gastrointestinal issues, or collapsing. However, the medical evaluation to determine clinical dehydration showed no differences among groups. The performance times among groups were not significantly different although there is a weak inverse relationship between percent loss of body weight during the race and race time, so the athlete who lost the most weight completed the race in the shortest time (30).

This article by Sharwood wanted to test the belief that dehydration that results in a 2% loss of body weight impacts performance. While most of the studies that give this number have been completed in a laboratory and they do not span the entire length of an Ironman race, Sharwood wanted to see when performance was affected. The results in the study showed many important things like temperature, blood pressure, and medical diagnosis did not change between groups. On the other hand, athletes who had a higher percentage loss in body weight typically had a faster finishing time in the race. These results go against the typical thought that dehydration affects performance in endurance events. However, most of these thoughts about dehydration affecting performance are completed in short intense exercise bouts that are completed in a laboratory, so the results can obviously be different in a long slow distance race.

The next article by Speedy (2001) also examined Ironman triathlon and looked at weight changes, fluid intake, and serum sodium concentrations in order to determine what the adequate level of fluid intake is for ultra-distance events. Triathlons and more specifically Ironman races have become very popular as of late so it is important to determine how much fluid should be consumed because they may be long races, but the

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intensity is often very low. The subjects on the day of the race had blood drawn in the morning before the race started to determine sodium serum concentration, hemoglobin, and hematocrit (32). The athletes were also measured after the race was completed and the next morning as well. Also, during the study the subjects were weighed before the race started, at the swim-bike transition, at the bike-run transition, after the race and the following morning as well (32). This body weight measurement is very important because it can show at what event are athletes gaining or losing body weight. Also, the athletes were told to remember how many bottles and cups they drank throughout the race, but the researchers ran and biked next to them in order to get these measurements so the athletes did not have to remember it for the whole race. Fluid losses were also determined in the race by subtracting weight change from fluid intake.

Sixteen of the eighteen subjects in the study lost body weight during the study with the average being -2.5kg or -3.5% body weight (32). The important measurement during the study was the body weight measurement before and at each transition in order to determine where the athletes were losing the most weight. The athletes lost an average of 1kg during the swim, 2kg during the run, but had a weight gain of 0.5kg during the cycle (32). One of the other interesting finds was that athletes lost weight from the end of the race until they were weighed the following morning. The average fluid intake per hour was 716 ml/h over the course of the race; however, the intake was 889ml/h on the bike and 632ml/h during the run portion (32). Also, the serum sodium concentrations did not differ significantly from the pre-race to post-race. In the study there were five individuals who developed hyponatremia. These subjects had relatively low body

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weights to begin with and averaged a higher fluid consumption during the bike portion than the other athletes. There was a significant inverse correlation between post-race serum sodium concentration and body weight change, with subjects with higher serum sodium concentrations losing the most weight, and those with hyponatremia losing minimal weight or gaining weight (32).

There were several keys results in the study that confirm other literature in the Ironman community. Athletes took in a lot of fluid during the race but they still lost body weight throughout the race. Serum sodium concentrations were normal only for athletes who lost 3-4% of their body weight, while athletes who finished the race at the same weight had lower serum sodium concentration (32). This study did not look at performance of the athletes but the athletes who lost more body weight had more normal ranges for sodium serum concentration, like the previous research indicating that athletes who lost more body weight had better race times. While it cannot be said for sure that these athletes with the more normal ranges for serum sodium concentration would have performed better, they did not develop hyponatremia which happens when there is no loss in body weight or a body weight gain. Ultra distance races can have different results compared to laboratory tests for the fact that they occur outside and they are relatively low intensity, compared to the dehydration studies that look at short high intensity exercise.

Hydration is crucial in long distance endurance events because there are many different consequences that can arise from being dehydrated. Previous laboratory based

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research has been interpreted to suggest that, if athletes allow themselves to become dehydrated during exercise, they will experience reduced sweat rates and elevations in core body temperature, and thereby increase their risk of developing a life threatening heat disorder (29). The purpose of the study by Laursen was to measure core temperature in triathletes during a 226 km Ironman triathlon using an ingestible pill telemetry system14 and to compare these measures with various indices of hydration status after the event (20). The authors hypothesized that dehydration would lead to an increase in core body temperature.

Ten participants completed the Western Australia Ironman and had various measurements taken prior to the race and after they were finished. The participants had body mass, body composition, and concentrations of plasma sodium, potassium, and chloride measured prior to the race. They also had their core temperature measured by a pill that they swallowed prior to the race. Core temperature was able to be measured directly after the swim, twice during the cycling portion, immediately after the cycling portion, and three times during the run. The other measurements were taken immediately after the race was finished.

The important finding of this study is that, despite an average loss of body mass of 2.3kg, core body temperature in these well trained triathletes averaged only 1°C above normal resting core body temperature (20). Changes in body mass were not related to finishing core temperature, plasma, or urine specific gravity (20). Likewise, total finishing time was not significantly related to changes in body mass, finishing core

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temperature, plasma, or urine specific gravity (20). Finally, heart rate was not significantly related to core temperature during the event (20).

According to this article, a slight change in hydration level does not affect core temperature like many previous studies have thought in the past. The participants in the study lost weight during the race but their core temperature was barely above resting levels. The results in the present study refute previous findings on the subject matter, which may indicate that not every person reacts the same way to changes in hydration level. Therefore, endurance athletes should practice different hydration habits in order to see what works for them in order to avoid any heat related illnesses.

The article by Knechtle (2010) looked at a race even bigger than the Ironman triathlon in order to determine if the loss in body mass occurs because of dehydration or some other factors. The triple iron triathlon is an ultra-distance event that is triple what an ironman race is, so it is an 11.4km swim, 540km cycle, and a 126.6 km run. The course that the athletes raced on had a relatively mild climate, they swam in a heated pool, completed 67 loops of a hilly cycle course and 96 laps on a flat run course (19). Before the race started and right after the athletes had total body mass, skeletal muscle mass and percentage of body fat measured (19). Urine samples were also taken for hydration status and blood samples were taken for hematocrit, plasma urea, and plasma sodium. In the study, percent body fat was measured by skinfolds and skeletal muscle mass was calculated by an anthropometric formula.

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Throughout the race, total body mass decreased by 1.66kg, skeletal muscle mass by 1kg, and fat mass by 0.58kg (19). On the other hand, the total body water of the athletes remained pretty stable throughout the race. These changes in body mass, fat mass and skeletal muscle mass did not relate to race time but people with a lower percent body fat pre-race had a faster finishing time (19). Urinary specific gravity and plasma sodium did not differ significantly, but hematocrit decreased significantly, plasma volume increased significantly, and plasma urea increased significantly (19).

There were several key findings in this study, with the most important being the loss of total body mass, skeletal muscle mass, and fat mass but that dehydration was pretty stable throughout the race. These results can occur since it is such a long race; athletes are competing at a low intensity and therefore can adequately hydrate during the course of the event. Also, the low intensity can help explain why there is a loss of body fat throughout the race, with fat being the primary fuel in low intensity exercise. Also, the researchers believe that the loss in skeletal muscle mass is a result of loss in myofibril protein because plasma urea increased after the race and was associated with the decrease in skeletal muscle mass (19). So while there was a loss in body mass during the race, it was not due to the athletes becoming dehydrated throughout the race, while in fact the athletes remained relatively hydrated throughout it. The results of ultra-distance races indicate that dehydration does not play a major role in the body weight changes experienced by athletes, but rather it is a result of body fat and skeletal muscle changes. The results of ultra-distance studies have gone against previous research in laboratory settings, but that does not mean one is wrong while the other is right. Each specific event

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should be considered individually by the climate, intensity of the exercise, and how long the race will last in order to determine the amount of fluid needed for it.

According to Wingo (2004), during exercise in a hot environment, sweating results in dehydration and compromised thermoregulatory homeostasis unless fluids are replenished at a rate near equal to the volume of fluid lost in sweat. The challenge is trying to replace all of the fluids that are lost especially during endurance activities. Activities like running, swimming and cycling are potentially difficult to rehydrate since in swimming the only fluid intake occurs before the exercise or after it is completed. Likewise, in running and cycling it is sometimes difficult to gauge how much fluid has been lost during the activity especially if the individual has never calculated their sweat rate. For these types of endurance activities, it might be important for athletes to hydrate prior to exercising because during the event they will create a deficit. Therefore, methods designed to optimize pre-exercise hydration are important and have become the focus of a large body of current research (37). More specifically, attempting to hyper hydrate pre-exercise is being emphasized in an effort to optimize pre-exercise hydration regimens (37). While it is widely accepted that individuals should be hydrated prior to competing in endurance activities, the focus of this article is to look at hyper hydration, rather than just hydrating at normal levels. The main techniques focused on by Wingo in the study are hydrating with just water or a glycerol solution prior to exercise. The basis for using glycerol as a hyper hydrating agent is that it increases blood osmolality and, when accompanied by 1500-200ml of water, it provides an osmotic drive that augments the retention of large quantities of water otherwise eliminated by the kidneys (27). The

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effect of hyper hydrating with glycerol has shown various effects so the study created a difficult 30 mile 3 lap, mountain bike course that was completed in the Georgia heat. Wingo wanted to see if hydrating with a glycerol agent had an effect on the performance and physiologic responses during a mountain bike race.

The treatments that were applied in the study were the athletes either got no water during exercise, but they received water prior to exercise that was 2.8% of their body weight. The second treatment was a mixture of glycerol and water consumed prior to exercise that was 2.8% of their body weight and they had 2 bottles of water during exercise. The last treatment received water equal to 2.8% of their body weight prior to exercise and 2 bottles of water while they completed the race (37). After each loop of the bike course, various measurements were taken like rectal temperature, thermal sensation, rating of perceived exertion, lactate, glucose, body weight, and an environmental symptoms questionnaire. The subjects completed each trial but they were separated by a week and the solutions all had the same taste in order to ensure the subjects could not tell what was in each solution.

The important findings during the study were that the athletes who used the glycerol solution prior to exercising were less dehydrated than both of the other groups for all of the loops (37). There were no differences in sweat rate, performance, or rectal temperature in all of the groups. Also, there were no differences between the water and glycerol group in blood glucose, blood lactate, rating of perceived exertion, or heart rate. One of the interesting finds in the study was that perception of thirst, thermal sensation,

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and the environmental symptoms questionnaire was lower for the glycerol group then both of the other groups. Finally, not significantly different, the loop 1 urine volume and total urine volume was less in the glycerol group than the water group (37).

According to this article, hyper hydrating with glycerol or water prior to exercise is important when it is known that access to fluids may be limited. Therefore, events like swimming, cycling and running where water is not always readily available, it is important to hyper hydrate prior to the event. Likewise, while the physiologic responses were not very different among the groups, the thermal and thirst sensations along with the environmental symptoms questionnaire were significantly different when using a glycerol agent, which could play a role in a longer event. While the performance times did not change in this study, it could be researched how athletes perform when they feel hot and thirsty compared to when they feel hydrated and cool.

The next article by Goulet (2002) also looked at the effect of hydration with a glycerol agent on the cardiovascular and thermoregulatory responses of the body. The difference between the articles is that this one examines a highly trained triathlete cycling in a controlled environment. Like previously stated, it is particularly difficult to replace all of the sweat that is lost during an endurance activity, and performance can sometimes falter when there is not a big loss of body weight. It has been shown that a loss in body weight of just 1.8% can impair performance during a high intensity cycling time trial and decrease cycling time to exhaustion at 90% VO2 (3)(36).

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Triathletes who compete at Olympic distance racing are often racing for just under two hours, and while these activities are very intense, it can be difficult to replace all of the fluid lost during those two hours. That is why it is important for triathletes and endurance athletes to look into different hydration strategies in order to optimize performance during the activity. It has been shown that compared to starting an exercise euhydrated, hyper hydration can reduce core temperatures and heart rate when there is no fluid during exercise (14) (24). The study looks at hyper hydrating with glycerol since the kidneys are often efficient at removing excess fluid. The main goals of the study were to determine if glycerol hyper hydration increases total body water compared to a placebo hydration, if glycerol hyper hydration improves sweat rate, rectal temperature and heart rate during a two hour cycling exercise, and finally if glycerol hyper hydration increases endurance performance (12).

The study started with a preliminary test a week prior to the data collection that consisted of getting the subject's VO2 max and familiarizing them with the different tests. The subject would come back in weekly intervals in order to do the different trials. The same protocol was used throughout the study with the subject ingesting either the glycerol agent or the placebo at 0, 40, and 80 minutes after arriving to the facility. At 20 and 60 minutes, the subject was given distilled water to drink. The researchers hypothesized that by taking the glycerol every forty minutes, it would decrease the chance the subject would get nausea, headache or dizziness (12). Likewise, the distilled water was given in order to prevent the subject from getting bloated or developing cramps (12).

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There were several measurements that were taken throughout the study with one of the most important being total body water. The subject urinated in a graduated cylinder at 18, 38, 58, 78, and 110 minutes after arriving at the facility. Also, their rectal temperature was measured using a rectal probe, heart rate with an electrode, and their rating of perceived exertion was measured using the Borg scale. The cycling began after 2 hours of hyper hydration and the VO2 was monitored closely in order to make sure they were similar between the trials. The subject was given Gatorade every twenty minutes during exercise and the measurements were taken every twenty minutes as well. After two hours, the subject was weighed nude and he was given five minutes before the endurance performance test was completed. For the endurance performance test, the load was increased by 25 watts every three minutes until he was too exhausted to continue or his revolutions per minute dipped under sixty.

Both of the states of hyper hydration produced body weight measurements that were very similar. Compared to placebo hydration, the addition of glycerol increased total body water by 1, 033mL (12). One of the important findings of the study was that production of urine with the glycerol agent was 300mL less than the placebo despite having higher total body water to begin with (12). However, the glycerol had no effect on the heart rate or sweat rate of the subject during the trials. Two very important findings were the decrease in rectal temperature at the end of the cycling exercise by 0.42 degrees Celsius, and the increase in endurance performance by 24% when using the glycerol hyper hydration (12).

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According to this article, glycerol hydration increases total body water while still producing less urine than the placebo hydration. This finding is particularly important for the fact that hydrating with just water will produce more urine and the total body water is less compared to glycerol hyper hydration. Therefore, an athlete is hydrated more when using glycerol compared to water. Also, the decrease in rectal temperature and increase in performance is an important finding for endurance athletes because both trials the subject got Gatorade during the test so with the glycerol hyper-hydration they were able to show that performance increased as a result of it.

Most research in regards to hydration is performed in laboratory settings where intensity can be controlled easily in order to determine the physiologic responses during exercise. The article by Casa (2010) looked at trail running specifically and the physiologic responses that occur from being hydrated as well as dehydrated. Therefore, this study looks at physiologic responses like most when intensity is controlled except for that it is a field study compared to a laboratory setting.

In laboratory settings, when athletes perform intense aerobic exercise in the heat and become hypohydrated to a level of 2% of their body mass or greater, or when they start to exercise at this level, physiologic strain increases and performance decreases (23). This is why many laboratory studies look at hydration but control various variables in order to see the effect on performance or physiologic responses. However, when field studies are completed, it much more difficult to control the intensity of the exercise which may be why there isn't as many field based research studies. Therefore, the

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purpose of the study was to determine the role of hydration status with regard to physiologic function and performance in a field setting, using both controlled and uncontrolled exercise intensities (6).

In the study the participants completed four different trials on separate days which included a race setting and a submaximal run. For these two settings each runner completed it once when they were hydrated and then again when they were dehydrated, so essentially the runners did four trials with two being a race format and two submaximally. Water was provided on the course when the runners were participating in the hydrated trials (6). Also, the all-out race trials were performed on the first and last days of the study while the submaximal tests were in the middle. The subjects were given scales to measure their body weight every day of the study in order to track the body weight difference at the end of the study (6). Also, the subjects were instructed that the submaximal runs should have very similar times (6). The subjects followed the same procedures for every trial and there were specific measurements that were taken prior to running. Before the test started each day the participant would complete the profile of mood states questionnaire and a 56 question environmental symptoms questionnaire (6). The subjects also had body mass, body temperature, heart rate, rating of perceived exertion, urine color, urine specific gravity, urine osmolality, perceived thirst and perceived thermal sensation (6). Also, between each lap of the run several measurements were taken in order to see how they varied from the start to the finish.

Subjects in the dehydrated race and dehydrated submaximal run lost more body

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mass than the hydrated trials. Subjects in the hydrated race trial had lower body temperatures than the dehydrated race trial post run, as well as, the hydrated submaximal run had lower body temperatures after the second run loop and post run compared to the dehydrated submaximal run (6). Also, the heart rate for the dehydrated race trial was higher post run compared to the hydrated race trial, as well as, the heart rate for the dehydrated submaximal run was higher after the 2nd loop of the run and post run compared to the hydrated submaximal run (6).

There were some noticeable differences in the hydrated and dehydrated groups in the submaximal run. Physiologic responses were noticeably different when body mass loss was near 2.56% (6). Also, when dehydration increased, post run core temperature heart rate were approximately 0.5 degrees Celsius and 15 beats per min higher even though the intensity was the same. In the race format, there were some interesting findings that can be potentially important in endurance events. The runners in the race who were hydrated had lower core temperatures than the dehydrated group even though they ran a faster pace (6). Even though the dehydrated runners performed maximally and their heart rates and ratings of perceived exertion were similar to the hydrated runners, they still finished in slower times and their perceptual environmental symptoms questionnaire increased (6).

According to this article, there are some key findings from a field study that replicate the results from several laboratory tests. When intensity is controlled during the study like it was in this one with the submaximal tests close in absolute time, the

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physiologic responses will be greater in the dehydrated group compared to the hydrated one. Not only were there physiologic responses different, the performance times in the race were different which indicated a decrease in performance when dehydrated.

It is known that hydration is important during endurance activities but one point that is sometimes overlooked is the role of rehydration after exercise. Most of the research to date has focused on the effects of electrolytes on fluid retention (26). The research has shown that sodium, particularly sodium chloride, has the greatest impact on fluid retention (13). The article by Osterberg wanted to determine if there was a dose relationship between carbohydrate concentration of an oral rehydration solution and the percentage of ingested fluid that is retained to promote rehydration following exercise induced dehydration (26). Their hypothesis was that compared with water, fluid retention would be greater for fluids containing electrolytes and similar for beverages containing carbohydrate concentrations of 6% or less (26).

The subjects in the study were either runners or triathletes that were heat acclimated prior to completing the study. The research design was double-blind and the treatment order was randomized. Subjects worked out on either a bike, treadmill or elliptical and were not given fluid in order to become dehydrated. Once they were done exercising, they were put in a thermoneutral environment for four hours and were given fluids at various times in order to achieve 100% fluid replacement.

In the study, beverages containing carbohydrate and electrolytes contributed to greater fluid retention than did water alone in recreational adult male athletes (26).

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However, there were no significant differences in fluid retention between beverages containing 3% and 6% carbohydrate and the placebo with electrolytes (26). The solution that had 12% carbohydrate and electrolytes was associated with the greatest fluid retention compared with the placebo and placebo with electrolytes (26). According to this article, carbohydrate containing products with electrolytes had a greater fluid retention than water alone with is important for endurance athletes. The researchers were not able to quantify a dose relationship with the amount of carbohydrate in each drink but the 12% beverages had greater fluid retention than the 3% and 6%. The results of the study are particularly important in order to show that carbohydrate beverages can induce fluid retention just like sodium chloride products. Additionally, by showing that carbohydrate beverages have greater fluid retention than water, athletes can rehydrate with products containing a higher percentage of carbohydrate in order to induce fluid retention and thus rehydration.

When competing in an endurance event or training as an endurance athlete, it is crucial that the athlete is consuming a beverage that will allow for fluid retention as well as rehydration if the athlete is dehydrated. Although water is often suggested to many general fitness enthusiasts who may exercise for relatively short periods of time (< 75 minutes), carbohydrate-electrolyte sport drinks are highly recommended and appear to be the beverage of choice for most serious athletes–aerobic athletes in particular (35). There has been a push by the nutrition industry for “natural” beverages, so consumers have been seeking an alternative to the sports drink (16). One of the alternative methods for rehydration during exercise is with coconut water. The purpose of the study was to

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investigate the effects of two different forms of coconut water and a carbohydrate sports drink of measures of hydration status and physical performance in exercise trained men (25).

The subjects were healthy males who had been partaking in an exercise program for at least six months prior to the test. The subjects completed 4 trials where they exercised to invoke a 2%-3% reduction in body mass, which was then followed by rehydration using bottled water, coconut water or a sports drink. After the subjects rehydrated with one of the assigned drinks, they then completed a performance test on a treadmill. The researchers were not just measuring performance but hydration status as well by using: body mass, fluid retention, plasma osmolality, and urine specific gravity. Additionally, the subjects were asked questions on how thirsty, bloated, tired, and refreshed they felt after consuming the beverages.

The results of the study indicate that there was no significant difference in performance time for any of the assigned beverages (25). Additionally, it was determined that any of the four beverages are capable of promoting rehydration after one hour of dehydrating exercise (25). While coconut water had similar results for rehydration and performance, subjects felt bloated and had upset stomachs when consuming the coconut water (25). The researchers concluded that coconut water and bottled water had similar rehydrating effects compared to a carbohydrate-electrolyte sports drink (25).

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According to this article, coconut water, bottled water, or a carbohydrate-electrolyte sports drink can be used when rehydrating. Endurance athletes can use this information in order to plan what types of beverages they will consume when training or racing. With there being no difference in performance or rehydration effects among these athletes, it essentially is up to the athlete what type of beverage they want to consume. Athletes can find this information very useful because for the most part, carbohydrate-electrolyte beverages have dominated the sports nutrition market, but the results of this study have shown that bottled water or coconut water can have the same effect.

The next article by Saat looked at the same rehydration with coconut water, a carbohydrate electrolyte beverage, and plain water. Like previously stated, the carbohydrate-electrolyte beverage has been the drink that most athletes choose while working out, but there has been a push to use more natural beverages while exercising. Coconut water is one of those options, and the article by Saat wanted to look at the effectiveness of fresh young coconut water and carbohydrate-electrolyte beverage to that of water on whole body rehydration and blood volume restoration during a 2 hour period after exercise induced dehydration (28).

Eight healthy subjects completed a dehydration exercise protocol on a treadmill which was then followed by a two hour rehydration period in order to test the effectiveness of the three different beverages. Blood and urine samples were taken every thirty minutes after the exercise was completed as well as various questions related to the participant's thirst. The blood and urine were analyzed and cumulative urine outputs as

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well as net fluid balance were computed.

The participant's in the study were never able to achieve 100% rehydration when using the three fluids, but they were able to achieve similar percentages when using all three beverages (80 +-4%) (28). There were no significant differences in blood volume during the three trials, although the blood volume change was higher during the rehydration period with coconut water (28). Cumulative urine volumes at the end of the rehydration period and urine osmolality at the end of exercise were similar for all three trials (28). However, urine osmolality was significantly lower in the plain water trials compared to the carbohydrate-electrolyte and coconut water beverages at the 90 and 120 min stages of the rehydration period (28). Coconut water was significantly sweeter, caused less nausea, fullness and no stomach upset and it is also easier to consume a larger amount of coconut water when compared with plain water and a carbohydrate-electrolyte beverage (28).

According to the article by Saat, coconut water can be used for rehydration following exercise-induced dehydration (28). These results are particularly important for the fact that most athletes either consume plain water or a Gatorade type product. With the findings by Saat, coconut water can be used as an alternative drink for rehydration which could potentially be a healthier option than the carbohydrate-electrolyte beverage. The results of this study are similar to the other previous findings (25), except for the fact that the athletes in this current study did not feel bloated or nauseous after consuming the coconut water. Therefore, with the results being similar in that coconut water can be

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used for rehydration, it is up to the athlete in order to determine what beverage works best for them in order to rehydrate.

Beverage choice is very critical when it comes to hydration during exercise and rehydration after the workout is completed. Dehydration during exercise can impair the performance of the activity that a person is completing but it also could impair the next activity if rehydration does not occur. Therefore, rehydration after exercise is critical to a sport like triathlon where multiple activities are being completed during a race. Sports drinks have widely been used as the beverage during exercise and after for rehydration, but there are other drinks out there that can be used for rehydration. The article by Snell wanted to assess and compare the effects of rehydration with commercially available non-caffeinated lemon flavored sports drinks, namely, Gatorade and Rehydrate Electrolyte Replacement Drink (AdvoCare International), using lemon flavored Crystal Light as the control rehydration fluid (31).

Eight healthy subjects were used in a double blind placebo randomized within study design where they tested the rehydration effects of three different drinks. The subjects performed 60 minutes of dehydration exercise, followed by 60 minutes of recovery, prior to performing an individualized treadmill test to induce exhaustion in 7-10 minutes, the subjects were then allowed to rehydrate for 60 minutes which was then followed by the same maximal exercise test again (31). The subjects had four different visits to the lab, the first being an initial VO2 max test and the other three to test the rehydration effects of the different sports drinks.

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There were no differences in heart rate or minute ventilation following rehydration with the three different sports drinks (31). Rehydration with Crystal Light failed to restore VO2max to baseline values (31). Rehydration with Gatorade returned VO2max to slightly below baseline values, while rehydration with Rehydrate resulted in a VO2max (mL. min-1) that was 2.9% above the rehydrated state, and above baseline (31). The treadmill performance times were statistically significant when comparing the difference between Rehydrate to Crystal Light and Gatorade (31).

The article by Snell compared the effects of various commercially available sports drinks against each other in order to determine their effects on rehydration and subsequent performance after rehydrating with them. Their findings can be used by the general public as well as endurance athletes when it comes to choice of beverage during exercise and after exercise is completed. The main finding in the study was that a rehydration medium comprising transportable monosaccharides, fructose and dextrose, glucose polymer (maltodextrin), the electrolytes sodium and potassium, conditionally essential amino acids and a host of other nutrients results in enhanced performance, which has implications for success in a competitive setting (31). Beverage choice is very important when it comes to exercise, so by knowing which ones are better with rehydration, it can subsequently improve one's performance in an athletic event.

The article by Miller also tackles the topic of beverage choice but it looks at specifically, exercise associated muscle cramps and if a person develops them from loss of fluid. Athletes commonly develop exercise-associated muscle cramps (EAMCs), and

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researchers think that fluid and electrolyte disturbances often are the cause (4). The article by Miller looks at electrolyte and plasma changes after drinking water, a carbohydrate-electrolyte solution, and pickle juice. Therefore, the purpose of the study was to determine if ingesting small volumes of pickle juice, CHO-e drink, or water would cause increases in plasma sodium concentration, plasma potassium concentration, plasma magnesium concentration, plasma calcium concentration, plasma osmolality, or plasma volume and would elicit these changes in less than 1 minute (22).

The study had nine male participants and the interesting thing about this article is that they did not perform any exercise during it. The subjects had blood drawn from them and then they would rest and then consume 1 ml/kg of body mass of 1 of the 3 fluids in 30 seconds time. After the fluid was consumed, they had blood taken 9 different times with the last being 60 minutes after they consumed the fluid.

Plasma volume and plasma osmolality did not differ among the fluids over time (22). Plasma sodium concentration was higher after pickle juice ingestion than after water ingestion at 15 and 25 minutes post ingestion and was also higher than after CHO-e drink ingestion at 25 and 30 minutes (22). However, compared to the baseline measurements, the drinks did not alter the plasma sodium concentration for the entire 60 minute period (22). Urine volume, osmolality, specific gravity, and osmolar clearance were not different over time among fluids (22).

The main observation from this study was that was that pickle juice and CHO-e drink ingestion (1 mL/kg body mass) produced no changes in plasma electrolytes or

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plasma volume in rested, euhydrated men (22). These findings are very important however because it can put an end to the myth that pickle juice can eliminate muscle cramps one minute after consumption. Muscle cramps are something that all athletes may encounter, and the way that they are treated can have an impact on the performance of the athlete. It seems like the idea that pickle juice can eliminate the cramps instantaneously is false, so the athletes should look at other means in order to rectify the problem.

Beverage choice is not the only thing that can affect how hydrated a person is while they are exercising. The environment in which a person is exercising can play a major role in the hydration status of the individual. Continuous exercise in the heat challenges the body's thermoregulatory systems (21). The extent to which thermoregulation is adversely affected dictates the physiological responses, from decrements in physical performance to thermal injury and, in severe cases, even death (15). The purpose of the study by Maresh was to examine the effect of hydration status on perceived thirst, drinking, plasma volume, and hormonal responses during low intensity exercise in the heat (21).

Ten subjects completed four different trials of low intensity exercise by walking on a treadmill while being dehydrated or euhydrated, as well as two trials where water was either restricted or allowed. After the tests were over, body mass, blood samples, and thirst questionnaires were completed within a minute of the test being terminated.

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Body mass changed significantly for three of the trials, (euhydrated and no water, euhydrated and water, hypohydrated and no water) with the euhydrated and water trial increasing in body mass (21). Subjects who were hypohydrated had higher responses on the perceived thirst questionnaires (21). Additionally, subjects drank more during the hypohydrated and water trial than any of the other trials (21). A primary finding of this study was that the extended period of hypohydration before low-intensity exercise magnified the drive to drink such that the hormonal and circulatory measures of exercise-heat stress were indistinguishable from results obtained when exercise was initiated in a euhydrated state (21). This investigation suggests that dehydration preceding low-intensity exercise in the heat magnifies thirst driven drinking, effectively attenuating the negative influences of preexercise hypohydration on plasma volume and fluid-regulatory hormonal measures (21).

The findings of this study are particularly important especially for some endurance activities because they are very low intensity. For example, Ironman training is usually completed at a very low intensity, so by knowing the results to this study, athletes can understand the importance of hydration even when the activity is at a low intensity.

The next article by Cheuvront (2005), examined the effects of hypo-hydration in a cold environment as well as a temperate one. It has been well documented that exercising in the heat puts a great strain on various physiological responses of the body, but there has not been as much research in endurance sports about the effect in temperate

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and cold environments. Recent literature though has indicated that exercise in cooler environments reduces the core temperature elevations associated with hypo-hydration, as well as, tachycardia is attenuated and stroke volume and cardiac output better preserved during progressive dehydration up to 4% body mass loss (11)(18). Cheuvront hypothesized that exercising in the cold air would mitigate the decrement in performance attributable to hypo-hydration in a temperate environment (7).

The subjects completed the tests on a cycle ergometer and they performed three different practice sessions in order to become more familiar with the tests. The tests were separated by forty-eight hours with the same protocol happening each day that they arrived at the facility. After breakfast, the subjects sat for one hour before being moved to a hot room that was forty-five degrees Celsius. The subjects either got water if they were in the euhydrated test or they received no water in the hypo-hydrated test. After the hot room, the subjects had two hours before they were moved to the cold environment. The subjects sat in the cold room which was two degrees Celsius for one hour before they completed the thirty minute submaximal test followed by the thirty minute performance time trial. Various measurements were taken throughout the test like rectal temperature, skin temperature, heart rate, rating of perceived exertion, and gas exchange measurements.

When viewed individually, all eight of the subjects performed worse when hypo-hydrated in temperate air compared to only five of the eight performing worse in the cold air (7). The difference in performance from euhydrated to hypo-hydrated was also

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significantly different from the temperate to cold climates. Subjects in the temperate climate had a decrease in performance from the euhydrated state to hypo-hydrated state of -7.6% (7). The decrease in performance from the euhydrated state to the hypo-hydrated state in the cold environment was only -2.7% (7). There were also several physiological responses that were measured throughout the performance of the tests. Heart rate in the temperate climate where the subjects was hypo-hydrated was higher than the temperate climate euhydrated state as well as the cold hypo-hydrated state (7). The heart rate differed by 5 beats per minute from the hypo-hydrated to euhydrated state in the temperate climate and by 11 beats per minute in the cold environment (7). Finally, the temperature that was taken during the tests was lower in the cold euhydrated and temperate euhydrated state compared to the temperate hypo-hydrated state (7).

According to this article, there is a decrease in performance when an athlete is hypo-hydrated in a temperate environment but not a cold one. These findings are particularly important for endurance athletes who are exercising in temperate or cold environments. Environment can play a key role in endurance sports with many athletes not knowing how to properly hydrate during the event. Cheuvront was able to show how hydration is important even in temperate climates and how an athlete's performance can decrease as a result of being hypo-hydrated.

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