Abstract

The purpose of this research paper is to examine current research in the field of ultra-marathoning to determine the most safe and effective methods for hydration and electrolyte (sodium) balance. Hyponatremia and Hypernatremia are both blood conditions that result from poor fluid and electrolyte balances. The current literature looks at common misconceptions in relation to the effects of various race rituals on race-day performance. The ultimate goal, after examining the current research field studies, is to determine a set of rough guidelines that ultra-athletes can follow to help them perform at maximum capability along with avoiding medical injury.

Ultra running is an up and coming endurance sport that has been on the rise in the last two decades. Ultra running involves running any distance over the standard 26.2 mile marathon, however, is usually 50 kilometers or greater in distance. People decide to do ultra-marahtons for numerous reasons, which means that research needs to be conducted for safety and performance reasons in terms of nutrition and hydration (reasons why people get into ultra-endurance activities is shown quite well in this video: http://www.youtube.com/watch?v=qwIE0cSaniA). Ultra marathons are conducted in a variety of environments, conditions, and terrains. A person would have quite a challenge finding an ultra-endurance event that was not mountainous or, at the very least, extremely hilly. Given the aforementioned conditions and the nature of ultra-running, the demands for fluids and electrolytes, most notably, sodium, are very high for athletes in this field. Fluids can be anything from water to the ever-marketed, high electrolyte containing sports drinks, notably Powerade™ and many others.
Fluids are absolutely necessary to the ultra-endurance athlete, as 60 percent of the average person’s body weight is water. Next, electrolytes can include, but are not limited to, sodium, magnesium, and potassium. The electrolyte focused on will be sodium, as it is one of the most depleted electrolytes experienced by ultra-distance runners (the basics behind the science of ultra-running is illustrated quite well in this video: http://www.youtube.com/watch?v=SYuDH90mTfQ)

Sodium depletion, as well as depletion of other nutrients, can result in a condition referred to as hyponatremia. Hyponatremia is a blood condition that is the result of reduced levels of sodium in the blood (refer figure 1). Hyponatremia can manifest in many ways, which include nausea, light-headedness, confusion, muscle cramping, and, in very severe cases, coma or death. Hyponatremia can be the result of many lifestyle factors.

*Hyponatremia: low blood sodium as a result of high fluid intake.

*Hypernatremia: high blood sodium as a result of dehydration.

*Common Electrolytes
- Sodium
- Magnesium
- Chloride
- Potassium

*Hyponatremic Symptoms
- Light-headedness
- Nausea
- Confusion
- Cramps
- COMA
- DEATH

*Ultra-marathoning involves running any distance over the typical 26.2 mile marathon. The ultra-endurance sport took off in the early 2000’s, but was not unheard of in the 80’s and 90’s.

*Figure 1: illustrates the causes and results of hyponatremia.
In the racing field, the main cause of hyponatremia is over-hydration. Over-hydration occurs when too many fluids are consumed, which results in the body not being able to function at peak performance, due to the dilution of electrolytes in the blood. A condition known as hypernatremia can also occur, although is less common in the field of ultra-running. Hypernatremia occurs when inadequate amounts of water are consumed during an ultra-endurance event. This results in less fluid volume in the blood (reduced plasma volume). Less plasma volume means that the sodium and other electrolytes in the blood become too concentrated (over-saturation occurs), which then results in hypernatremia. (for greater detail on hypernatremia, visit [http://www.youtube.com/watch?v=VU0nLSG2Ms](http://www.youtube.com/watch?v=VU0nLSG2Ms)).

The conditions of hyponatremia and hypernatremia in ultra-endurance athletes happen more often than is ideal for safety and performance. There are several studied causes for inadequate intake of sodium and fluids, which include NSAID (non-steroidal anti-inflammatory drug) usage, over versus under consumption of fluids, temperature and relative humidity, and psychological aspects, such as prior convictions and knowledge which then, in turn, affects race day behaviors that may have otherwise been unaffected. This last potential cause has and will most likely always be a problem in the running world. Many runners take anecdotal advice over the research and science (although, as any distance runner knows, trial and error are the norm for race day behaviors). Research in this field is still fairly limited, due to the fact that this sport is still working its way up in popularity.

Ultra-running has been progressively gaining national interest as well as research opportunities over the two decades; as its popularity increases, so do the amounts of cases of hyponatremia, hypernatremia, and dehydration. Ultimately, nutritional status (electrolyte balance) and hydration are key components of successful completion of an ultra-endurance event. Recommendations are made based on current research in the ultra-endurance field (can be found in the last section of this research paper).
Variables Tracked by Race Officials

Methodology in hypernatremic and hyponatremic testing varies between several techniques. Weight is a common factor that is looked at by race officials and medical professionals. As an athlete exercises, they lose weight in the form of sweat and salts. For the general populous performing normal exercise for less than 90 minutes, this is not a major issue of concern or relevance. Be that as it may, ultra-athletes can easily lose two to seven percent of their body weight in water before the halfway point in an ultra-endurance race. This has an appreciable effect on performance and overall health. Customarily, it has been noted that a decrease in body weight is the result of hypernatremia, and an increase in body weight as hyponatremia. The decrease in body weight is due to dehydration (water weight loss through sweat, lack of intake of necessary fluids for optimal health and performance). The increase in body weight is due to consuming too much water, which, as mentioned before, causes the body to be in a hyponatremic condition. Most ultra-endurance races actually have aid stations and weigh stations, where it is mandatory to be within a certain percentage of the runner’s starting body weight.

Another method that is used is blood analysis. Blood is drawn pre and post- race by phlebotomists, and is analyzed based on plasma volume (hematocrit can be analyzed, but is not the norm), which consists of electrolytes, water volume, plasma proteins, and respiratory gases. An important plasma protein to note is albumin, which helps osmotic (oncotic) blood pressure, which will be discussed in further detail later in this research paper. All in all, when variables such as electrolytes, hydration, and weight changes are evaluated, it can help determine the root causes of hyponatremia (or hypernatremia, although less often the case) on ultra-endurance exercise.

Nutrition & Hydration Status Significance

Nutritional status of Ultra runners is a new and developing area of research. Nutritional status is also of critical concern to the athletes involved in the sport as well, because serious medical issues can be the denouement of poor planning and nutrient intake during an ultra-endurance event. Not only is nutrition important for injury prevention, but it also allows for peak performances to take place. A proper hydration status and sodium balance can be the difference between performing at one’s best and crawling across the finish line in agony. Nutritionally, the experts in the field of performance nutrition agree that water intake and sodium levels need to be kept in check. This is especially true for an ultra-endurance event, due to the length and external factors, such as weather (notably humidity), and internal factors, such as blood concentration and proper plasma volume maintenance.

Research & Data Collection for Nutrition Status

There are numerous ways that poor nutrition can be measured in an ultra-endurance event. One way is to measure weight loss. Weight loss is closely associated with inadequate sodium levels (Hoffman, M D et. al., 2013). Weight loss is a repercussion of low plasma volume due to a lack of fluid intake. In a field of competitors, weight loss is the most practical approach to determine sodium and hydration balance, and is actually mandatory at certain stages in many ultra-marathons. Weight loss during an ultra-marathon can be quite severe,
Weight variability can occur due to multiple causes. A decrease in weight can be the result of dehydration, but can just as easily be the result of depleted glycogen stores and loss in fat due to mobilization of free fatty acids (FFA’s).

Weight Variability Patterns in Ultra-Endurance Events

There are some results that conflict with weight loss being correlated with sodium balance maintenance issues. There does seem to be a trend, however, when it comes to ultra-endurance races and noticeable weight loss. A good question is the what is causing the weight loss. Weight loss can be caused by several factors. One is, of course, dehydration, but there are other sources. One such example is depleted glycogen stores, and at a point, fat burning during periods of glucose sparing. An example of studies that conflict on the sources of weight loss can be demonstrated in the following two studies: first, a simulated, 67 hour run was conducted on treadmills in a lab setting. Seven out of the original ten athletes actually completed the run. However, there was a noticeable trend among the finishers of the simulation. All seven of the athletes that did finish the run all had a noticeable reduction in weight. The caloric intake was almost ten thousand (kilocalories) less than the total caloric expenditure for that 67 hour bout of exercise (Zimberg, et. al. 2008). Nevertheless, a second study that took place in 1997 by Rogers, Goodman, and Rosen is referred to as saying that the weight loss can be attributed to other sources than fluid loss, such as glycogen depletion and fat loss (Zimberg, et. al. 2008).
This shows a relative difficulty in determining whether weight loss is due to hypernatremia and if weight loss is really an accurate way to gauge performance hindrance and medical safety. Glycogen depletion and fat utilization are normal responses to prolonged exercise and would most definitely result in weight reduction, to an extent. A different study, however, was done on eleven female ultra-athletes. The study was conducted for a 100 kilometer race. Overall, the competitors (including finishers) had a decline in body weight, and the fluid intake did not seem to affect sodium levels, and no EAH (exercise-associated hypernatremia) occurred. Each of the females was given ad libitum, which seemed to help conserve the sodium balance (Knechtle, B. (2010).

There does not appear to be a consistent opinion on whether or not weight loss can truly be attributed to hypernatremia or hydration status. Hypernatremia is mainly caused by dehydration, which results in weight loss, but weight loss is the eventuality of other metabolic processes as well. This means that studies conducted using blood analysis will be a better indicator of sodium and hydration status amongst ultra-endurance athletes (although less practical). A great indicator of hypernatremia, a more common phenomenon amongst distance athletes, is weight gain, and as a result would be advisable to be on the lookout for during these ultra-endurance events, as weight gain really has one common issue tied to it, and that is hypernatremia.

**Blood Composition Modulation During Ultra-Exercise**

Blood tests can be used to determine an athlete's sodium and hydration status. This is more of an experimental approach, and will reflect most of the studies done in research, due to inconsistent, and slightly vague, issues and opinions with weight change being a result of poor hydration and sodium balance versus alternative factors. Some research and field studies have actually shown that EAH (exercise associated hyponatremia) might not be as prevalent in competitive ultra-athletes. In an observational field study of ultra-runners in a 24 hour run, the end result yielded that none of the runners developed EAH (Knechtle, B. 2010). This study is contradictory to many other field studies and is therefore being considered unique yet extraneous. Most other studies yield opposing results that show ultra-athletes battling issues with hyponatremia. Root causes, or possibly alternative causes of hypernatremia, however, are debated heavily.

In a 60 kilometer race, 131 ultra-runners were evaluated on sodium and hydration status. Pre-race weights and sodium balances were taken via blood sampling. The same blood tests were also conducted post-race. The results actually determined that a gain in weight, not a loss in weight, is the better indicator of poor fluid and electrolyte balance. This is because the weight gained is actually water weight, which then, in turn, dilutes the blood’s supply of sodium (Page, AJ. 2007). This is yet another contradiction to the two other theories proposed; that weight loss is the best indicator of poor hydration and electrolyte balance, and that weight change is not an indicator of hyponatremic conditions at all.

**Psychological Component of Hydration-Electrolyte Balance**

Another proposed idea is that mental factors can come into play into who does and does not develop fluid and sodium imbalances after an ultra-endurance type event. One study evaluated 207 runners in a 161 kilometer, ultra-endurance race.

*Psychological aspects also affect blood homeostasis during ultra-endurance exercise. The most notable incidents of this aspect are learned race day behaviors via anecdotal advice.

*Over-thinking hydration habits for race day can sometimes be the downfall to your own performance. You may accidentally drink too much water for fear of becoming dehydrated, but this could lead to over-hydration and hyponatremia.*
Only twelve of these runners developed EAH (exercise associated hyponatremia). This result and the fact that other runners who had no hydration routine did not develop exercise associated hyponatremia, illustrated the possibility that prior beliefs did not affect race behavior in ultra-endurance athletes (Winger, J et al. 2013). This means that there must be another source of the causes in reduced performance in relation to sodium and hydration balance. An additional factor that comes into play could be age, along with speed and level of training.

In a study done on the Western States 161 kilometer race, five cases of hyponatremia and rhabdomyolysis (see figure 3, glossary) were present after the race (Bruso, Jessica et. al. 2010). There were several characteristics that these runners had in common. First off, they were all men with a mean relatively young age (young for the sport of ultra-running) of 39 years. Another common factor among the five cases of hyponatremia observed at this event was that

*Figure 3: shows a urine sample representing renal failure as a result of rhabdomyolysis.

*Figure 4: diagrams the pathophysiology of Rhabdomyolysis.

*NSAID usage has shown mixed results in several studies as far as whether benefits outweigh negative consequences.
they tended to be faster runners who experienced an injury at some point in their training routine that resulted in a modification to their overall training plan. The injuries then encouraged these injured athletes to use a commercial NSAID (non-steroidal anti-inflammatory drug). Three of the five cases of injury and NSAID usage almost emerged into acute renal failure. A commonality among these three athletes was that their BUN (blood urea nitrogen) content was elevated above normal, along with an increase in blood Creatinine (Bruso, Jessica et. al. 2010). An increase in BUN is the result of the kidneys’ reduced ability to remove urea from the blood for excretion, and in this particular context, the increase in the BUN:creatinine ratio in ultra-athletes; in several cases, NSAID (for types of commercial NSAIDs, see figure 4) use led to acute renal failure among competitors (Bruso, Jessica et. al. 2010). Be that as it may, a field study conducted at the 2009 Western States 161 kilometer run and the Vermont 100, a study of n=500 (n is population size), yielded that the primary reason for dropping out of the race was nausea and vomiting, common symptoms of hyponatremia. Interestingly though, the nausea and vomiting in the Western States and Vermont 100, experienced by 23 percent of the drop outs, was not correlated to NSAID use, the course with warmer weather, or training volume of the athletes analyzed. In fact, NSAID use was actually higher among those who did not get sick and finished the race (Hoffman, M D et. al. 2011). However, it is concluded from this study and many other cases that NSAID use is abused and is unnecessarily high amongst ultra-marathon competitors (Hoffman, M D et. al. 2011).

**Non-Steroidal Anti-inflammatory Drug (NSAID) Praxis**

Jessica Bruso’s (2010) study has introduced another theorized factor that may cause hyponatremia in a number of ultra-marathon competitors. This factor is the use, both regular and pre-race customary use of an NSAID (non-steroidal anti-inflammatory drug). It has shown to result in increased BUN levels (blood urea nitrogen content) and creatinine levels (an increase in the BUN:creatinine ratio) in ultra-athletes; in several cases, NSAID (for types of commercial NSAIDs, see figure 4) use led to acute renal failure among competitors (Bruso, Jessica et. al. 2010). Be that as it may, a field study conducted at the 2009 Western States 161 kilometer run and the Vermont 100, a study of n=500 (n is population size), yielded that the primary reason for dropping out of the race was nausea and vomiting, common symptoms of hyponatremia. Interestingly though, the nausea and vomiting in the Western States and Vermont 100, experienced by 23 percent of the drop outs, was not correlated to NSAID use, the course with warmer weather, or training volume of the athletes analyzed. In fact, NSAID use was actually higher among those who did not get sick and finished the race (Hoffman, M D et. al. 2011). However, it is concluded from this study and many other cases that NSAID use is abused and is unnecessarily high amongst ultra-marathon competitors (Hoffman, M D et. al. 2011).

Temperature & Fluid-Electrolyte Balance Correlation

According to current research, temperature may be the major element of EAH (exercise associated hyponatremia). One study conducted evaluated 86 ultra-runners in a five stage event on their hydration condition and sodium intake. The temperature was between 32 and 40 degrees Centigrade (between 89.6 and 104 degrees Fahrenheit).
The results deduce that water intake during hot weather was adequate for the 86 ultra-runners in this particular race scenario. Despite the results of Costa’s study (2013), sodium intake could have been higher, signifying that there was possibly not enough sodium as a result of blood dilution (which actually is the resultant of over-hydration). One noticeable trend amongst the ultra-runners was overconsumption of fluids throughout the race (Costa, R.J.S. et. al. 2013). However, even with the overconsumption of fluids and under consumption of sodium, normonatremia and euhydration were still the overall terminal result.

Temperature might not be the forthright cause of hyponatremia, but it may factor in hydration and sodium consumption patterns that may correlate to an increased risk of developing hyponatremia during an event or succeeding the event for an ultra-runner. This suggestion explicates the previous idea that race patterns can be altered for worse based on learned race day behaviors or on race day environment and relative humidity and heat.

Race day patterns along with scientifically incorrect, anecdotal advice may be the base causes of electrolyte and fluid imbalances in the ultra-endurance athlete.

Osmolarity & the Fluid-Electrolyte Quandary

Finally, a contributing factor in fluid and sodium balance in ultra-athletes is fluid exchange rates and osmolarity of various performance drinks and supplements. In ultra-endurance endeavors, fluid loss and sweat rates can vary from extremely low to low, and to upwards of 3 L/H, depending on relative temperature and humidity (Cheuvront 2003). This is important in the manufacturing of fluid replacement beverages. One essential concept that is not always discussed is the absorption
efficiencies and rates of fluid and electrolytes. Simply considering that a person consumes a set amount of fluid or electrolyte does not signify that the body retains all of the fluid or utilizes the electrolytes in consistent, uniform ways. During ultra-endurance events, carbohydrate taken with a fluid can increase its absorption rate; it is recommended that three to five percent of a fluid should be glucose as well as contain adequate carbohydrate (Gisolfi 1998). This results in better overall absorption of fluids and electrolytes, which can aid in offsetting hyponatremia, hypernatremia, as well as enhance athletic performance and reduce medical injury.

**Conspectus on Fluid-Electrolyte Balance**

In conclusion, hyponatremia and hypernatremia are conditions that affect ultra-runners, and those conditions inhibit performance and may even result in need of critical medical attention, up to and including issues involving kidney failure. Although hyponatremia is the more common of the two, hypernatremia is still an issue that affects many ultra-runners. There are varying opinions as to the direct and indirect causes of sodium and fluid imbalances. Despite this, there are several generalized possibilities, which include temperature, NSAID use, prior beliefs in conjunction with race day behavior (anecdotal advice ties adds its own implications), and hydration behaviors (under vs. over-consumption of fluids/sodium). One connecting idea between all of these research studies and field observations is that race day behavior, either learned or adapted (based on race day feelings and conditions) is the cause of hyponatremia and performance hindrances. The debate is on which behaviors cause the greatest deviations from homeostatic norms.

*Figure 7: shows the colored flag system used to determine and alert runners on race day conditions.

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*Sodium (and other electrolytes) and fluid imbalances are multicausal in nature, and a variety of factors need to be managed during training and on race day in order to perform at peak and to prevent medical issues in novice and/or amateur ultra-distance runners.*
Ultra-running is a rather new sport on the up and rise in popularity. The research is becoming more prevalent, but the research data and conclusions have yet to appear in most contemporary race strategies by the athletes in the field of ultra-running. Anecdotal advice currently dominates the ultra-running field in terms of race day strategies and racing tactics. When running with endurance athletes for prolonged periods of time, one is talking and discussing strategies constantly, most of which are anecdotal in nature. This leads to many misconceptions about fluid and electrolyte balance being cycled over and over again until it is claimed as fact without scientific support. The objective of this (and future) academic papers is to rid the sport of ultra-running of these misnomers through developing scientifically sound hydration and electrolyte recommendations. This not only will help the athletes’ performance, but will also the benefit the amateur ultra-endurance runner medically through safe and generalized recommendations for fueling during an ultra-marathon event.

**Recommendations**

I. Carry fluids so you do not drink too much at aid stations, and you can keep track of how much you are drinking (this is also a safety issue, never drink from unsponsored aid stations!).

II. Fluid intake should be roughly 16-24 ounces per hour, with three to five percent of the fluid in the form of infused carbohydrate depending on heat and trail conditions (temperature conditions will be dictated by a flag system by the racing staff; these flags should be taken very seriously).

III. 1-2 salt pills an hour on four plus hour runs, depending on heat and fluid intake, as well as the relative amount of salt per unit volume of sweat that a specific ultra-runner may have. Runners know whether or not they are “salty sweaters” and should ingest sodium pills based on that knowledge.

IV. Disregard anecdotal advice, and learn your body’s sweat and fluid intake patterns for various temperate conditions. Anecdotal advice is anecdotal for a reason and may work well for some, but horribly for you. Develop your own methods in conjunction with the current scientific literature that will be coming forth in the next few years.
GLOSSARY

*BUN: blood urea nitrogen content

*EAH: exercise associated hyponatremia.

*Hypernatremia: elevated blood sodium content, often the result of dehydration.

*Hyponatremia: depressed blood sodium content, often the result of over-consumption of non-electrolyte containing beverages (i.e. water).

*Nnormonatremia: normal blood sodium content.

*NSAID: non-steroidal anti-inflammatory drug (i.e. ibuprofen, aspirin).

*Osmolarity: the measure of solute concentration in solution.

*Rhabdomyolysis: the breakdown of muscle fibers that results in the release of myoglobin into the blood stream, which is very damaging to the kidneys.

*Ultra-marathon: a race that is over the traditional 26.2 mile marathon distance, but in reality, is usually at least 50 kilometers in distance.

*Weigh Station: method used to determine likelihood of hyponatremic or hypernatremic conditions; often used in ultra-endurance events to determine whether or not a competitor is fit to continue the race after an aid station. Competitors are weighed and cannot deviate from a certain percent gain or loss in initial body weight.

**Example of weigh station below:

References


