Hydration Efficacy of Oxywater; a Hyperoxygenated Nutritionally Enhanced Water

THESIS

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Abstract

Exercising in hot and humid environmental conditions produces high sweat rates and may lead to significant dehydration and decline in athletic performance. Hyperoxygenated beverages have been on the market for several years claiming hydration and health benefits and even enhanced athletic performance. The addition of vitamins and minerals increases osmolality, which may result in physiological responses that could enhance hydration status. To date, no research has provided evidence to support the claims, nor demonstrated any negative side effects, from drinking a hyperoxygenated beverage enhanced with vitamins and trace minerals. **Purpose:** When compared with water, our objective was to determine if a commercially available hyperoxygenated beverage (O$_2$water), would limit dehydration when consumed during a sub-maximal running bout in hot and humid conditions. **Methods:** Experienced male runners (N = 12, Mean age = 24.2 years, VO$_2$ = 61.9 VO$_2$ ml/kg/min, height = 1.8 m, body mass = 75.1 kg, and percent body fat = 12.4%) completed two 45-minute runs at 70% of their pre-determined VO$_{2\max}$ in a temperature and humidity controlled environmental chamber. Conditions were set to 30° C and 50% humidity. Subjects were randomly provided either O$_2$water or water during their first run, and were permitted to consume *ad libitum*. For the second run, subjects were prescribed the same volume they consumed in the first run of the alternate beverage. Hydration status was determined via plasma osmolality pre-run and 30, 60, and 90 minutes post-run. Pre- and post-run nude body weight was used to measure sweat rate
and fluid retention. **Results:** Average sweat rate and fluid consumption for subjects was 1,377 mL and 508 mL, respectively. Post urination body weight indicated greater fluid retention (52g), when consuming Oxywater water versus plain tap water. Pre-run osmolality averaged 288.3 mOsm/kg. When subjects consumed water, 90 minute post-run plasma osmolality increased 2.97 mOsm/kg. Conversely, when subjects consumed O₂water, plasma osmolality increased 1.89 mOsm/kg. **Conclusion:** Compared with water, O₂water does not limit dehydration for experienced male runners in hot humid conditions.
Dedicated to Erin Wallace and my parents. Without their continued support, I would not be the person that I am.
Acknowledgments

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Publications


DeAngelo, B., F. de la Chesnaye, R. Beach, A. Sommer and B. Murray. 2006 “Methane and Nitrous Oxide Mitigation in Agriculture.” The Energy Journal Multi-Greenhouse Gas Mitigation and Climate Policy Special Issue.

Pattanayak, S. K., R.C. Abt, A. Sommer, B. Murray, F. Cubbage, D. Wear, J.-C. Yang, S.Ahn. 2004 “Accounting for landowner heterogeneity in forest sector model forecasts.”


Fields of Study

Major Field: Education
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Chapter 1: Introduction

Oxywater is a commercially available hyperoxygenated beverage that contains added vitamins, minerals and electrolytes. Hyperoxygenated water has been on the market for several years, claiming health benefits and enhanced athletic performance. Past research has assessed the claims of enhanced performance by investigating the effects of ingesting oxygenated water on cycling performance (Leibetseder et al. 2006, Wing-Gaia et al. 2005, and Hampson 2003). Results showed that consuming hyperoxygenated water has no significant effect on any variables measured (VO₂, HR, CO₂ production, RER, minute ventilation, lactate, RPE and hydration).

Although it is unlikely that the added oxygen in Oxywater has any performance benefits, the other ingredients may aid in hydration capabilities. Past research has shown that it is essential to consume a beverage that contains electrolytes, specifically sodium, in order to rehydrate after exercise induced dehydration (Shirreffs, S. et al 2007, Shirreffs, S. and R. Maughan. 1998, Shirreffs, S. et al 1996). The primary aim of this study was to investigate the hydration efficacy of OXYwater in recreational runners, exercising at sub-maximal efforts, in a hot and humid environment.

As individuals exercise, they begin to lose water faster than it can be replaced, resulting in dehydration. Sweat rates for individuals exercising in hot and humid conditions can be as high as two liters per hour (Sawka, Montain, & Latzka, 2001).
Fluids lost as sweat originate from both the intracellular and extracellular space (Nose et al 1988). As a result, plasma and blood volumes are reduced. Reduced plasma volume results in increased cardiovascular strain, decreased cardiac output, impaired thermoregulation abilities, and impairments to several other physiologic processes that negatively impact performance (Sawka et al 2007).

In addition to fluid loss, electrolytes are lost in sweat. Electrolytes, most importantly sodium, are essential for many physiological processes in the body including muscle contractions and neurological signaling. Research has shown that after exercise induced dehydration, both fluid and electrolyte replacement greater than or equal to the amount lost through sweat is necessary for proper rehydration (Sawka et al 2007, Shirreffs et al 2007, Shirreffs and Maughan. 1998, Shirreffs et al 1996, Montain, Maughan, and Sawka 1996). The addition of electrolytes to a beverage helps to restore those lost through sweat, in addition to stimulating a thirst response in individuals (Nose et al 1988). An increased drive to consume liquids after bouts of dehydrating exercise is key to ensuring that fluid volumes are properly replenished. The stimulation of the thirst response through electrolytes, or increasing the palatability of the drink through flavoring, have been shown to increase the amount of fluids consumed when individuals are permitted to drink *ad libitum* (Shirreffs et al 2007).

The ingredients in Oxywater, specifically the electrolytes, minerals and flavoring, may enhance its hydration capabilities compared to plain water. To test this hypothesis, experienced runners were recruited to participate in multiple dehydrating bouts of sub-maximal exercise. During these tests subjects consumed either Oxywater or tap water *ad libitum*. To compare hydration abilities of each beverage, pre and post plasma osmolality
measures were measured and compared. In addition to plasma osmolality, we also collected data on sweat rates, timing and volume of fluid consumption, heart rate and ratings of perceived exertion.

The remaining chapters of this thesis provide a literature review of past hydration research, a detailed analysis of this research methodology and findings, and finally a summary and discussion of the overall research findings and applications.
Chapter 2: Literature Review

While performing physical activity, humans regulate body temperature through sweat loss and resulting evaporative cooling. There are many factors that influence an individual's sweat rate. These factors range from physiologic conditions that are unique to the individual, to environmental conditions that are beyond human control. The loss of fluid from the body in sweat triggers several physiologic responses as the body attempts to maintain homeostasis. These responses, given a severe enough level of dehydration, can negatively impact athletic performance. In addition to the fluid loss, there is also a loss of electrolytes from the human system. This loss of electrolytes, primarily sodium, results in increased plasma sodium concentrations and increase osmolality. This deviation from a baseline level will also trigger physiologic responses that attempt to maintain homeostasis. These responses, in addition to those stemming from the loss in body fluids, compound to produce conditions that reduce athletic performance, and in severe cases lead to serious medical conditions. Much research has focused on the role of replacing the fluids and electrolytes lost during athletic performance in order to establish the optimal replacement strategies for each. The research has covered replacement during exercise, in order to optimize athletic performance replacement, to post exercise in order to return to a hydrated state before the next bout of exercise. The focus of this
literature review is to summarize this body of research and highlight areas that are directly applicable to this research study.

The human body maintains total body water within a very tight range. This range is referred to as a euhydrated state or condition, and is characterized by a plasma osmolality measure of 285-295 mOsm/kg (Sollanek et al 2011). As an individual exercises, sweat production increases as the body attempts to maintain core temperature. The loss of fluids results in a decreased plasma volume and increased sodium concentration, manifesting as an increased plasma osmolality. Dehydration is characterized as plasma osmolality of 300±5 mOsm/kg, or a 5 mOsm increase from a baseline measurement (Sollanek et al 2011). As mentioned earlier, both individual characteristics and environmental factors play a role in sweat rate. In hot and humid conditions sweat rates can reach 2 L/hr (Sawka, Montain, and Latzka, 2001). If environmental conditions are more temperate, or exercise intensity declines, the sweat rate will also decline. The rates of fluid loss, in combination with the sodium concentration of the sweat will have implications on the magnitude of change in plasma osmolality, and thus physiologic responses to correct the deviation from baseline conditions. These changes from baseline, in concert with the body’s reaction to correct the change, are the factors that will have impacts on athletic performance.

Exercise in hot and humid environments elicits increased sweat rates. As body temperatures rise, increased blood flow to the skin and increased sweat production commence. It is the increased production of sweat that provides the primary evaporative cooling mechanism, and thus temperature reductions (Sawka et al 2007). The fluid for this sweat is derived from both intracellular and extracellular space (Saat et al 2002,
Maughn et al 1994). Mentioned earlier, depending on the characteristics of the individual, such as body weight, heat acclimation and metabolic efficiency, sweat rates will vary. The more an individual sweats, the greater reduction in plasma volume. Even a small reduction in percent body weight, as a result of fluid loss through sweat, can have physiologic implications. For example, it has been shown that a 1% reduction in body weight due to sweat loss, can result in a 5-8 beats per minute in heart rate, a decrease in cardiac output and an increase in core temperature (Coyle 2004). Current literature suggests that loss in total body weight of ≥ 2% is an indicator of dehydration (Noakes 2012, Sawka et al 2007, Coyle 2004). Fluid replacement is essential during and after dehydrating bouts of exercise to restore total body water.

Water lost during exercise contains various concentrations of electrolytes, particularly sodium and potassium. As with sweat rates, the electrolyte concentration varies among individuals. Sodium and potassium concentrations in sweat range from 10-70 mmol/L and 3-15 mmol/L respectively depending on sweat rate, heat acclimation, diet and other factors (Sawka et al 2007, Shirreffs and Maughn 1998). Of primary importance here is sweat rate. Electrolyte concentration increases with sweat rate resulting in an accelerated loss in electrolytes in a hot and humid environment. Electrolytes play a major role in many biological processes including neurological signaling and muscular function. As noted by the ranges in concentration for the primary electrolytes, sodium is the primary cation lost through sweat. If excessive amounts of sodium are lost, essential physiologic functions can be affected, leading to a decline in athletic performance. Additionally, a reduced sodium concentration in the plasma can result in decreased plasma osmolality. This change in osmolality can result in increased urine production,
via changes in vasopressin and aldosterone levels, further decreasing total body water (Shirreffs and Maughan 1998). In addition to fluid replacement, it is also necessary to replace electrolytes after exercised induced dehydration.

It is clear based on past research that both sweat rates and electrolyte concentration vary amongst individuals and across environmental conditions. Depending on the amount of each lost during exercise, the degree of dehydration and implications on athletic performance will vary. Dehydration results in physiologic strain on several major systems including the cardiovascular system, skeletal muscle contraction and function, the central nervous system, metabolic efficiency and thermoregulation processes (Sawka et al 2007, Coyle 2004, Montain and Coyle 1992). The loss in plasma volume will result in an increased heart rate and a reduced cardiac output. It has been shown that dehydration can reduce cardiac output by as much as 8% (Gonzalez-Alonso 1998). If dehydration and increased core temperature develop together, the combined effects can reduce cardiac output by more than 20%. Cardiac output is essential for maintaining blood flow, in order to provide ample oxygen to the working skeletal muscle, and to the skin surface for thermoregulation processes. As cardiac output declines, muscular efficiency and thermoregulation processes decline, resulting in decreased athletic performance (Walsh, Noakes, and Hawley, 1994, Montain and Coyle 1992, Armstrong et al 1985). Past research has show that the negative impacts on the physiologic systems responsible for athletic performance are directly related hydration levels. It is recommended that in order to maintain optimal athletic performance, dehydration should be limited to <2% of total body weight (Sawka et al 2007, Coyle 2004).
In order to maintain peak athletic performance both fluid and electrolyte replacement are necessary to limit and recover from dehydration. Given that individuals have varying sweat rates and electrolyte concentrations, the volume and composition of the beverage chosen for rehydration are of major concern. A large volume of research has been published that has investigated these key rehydration characteristics of concern. Looking first at volume, it has been suggested post exercise rehydration should provide a volume of fluid greater than that was lost during exercise. Fluid consumption during exercise should be at a rate that matches fluid losses as closely as possible, though never exceed them (Sawka et al 2007, Coyle 2004, Shirreffs et al 1995, Montain and Coyle 1993, 1992). These recommendations are based on the fact that increased fluid consumption will result in increased urine production due to increased plasma volume. To account for the fluids lost in urine, excess fluids need to be consumed post exercise. Additionally, consuming fluids low in electrolyte concentrations in excess of fluid loss can lower plasma osmolality to dangerously low levels, leading to hyponatremia. The importance of electrolyte concentrations in fluids selected for rehydration is highlighted in the case of plain water. Consuming large volumes of plain water post dehydrating bout of exercise will reduce plasma osmolality, stimulating urine production (Nose et al 1988). The increased urine output will restrict the subject from attaining a positive fluid balance through fluid consumption. Shirreffs and Maughan 1998 showed that in order to attain a positive fluid balance from rehydrating after exercise, electrolytes needed to match or exceed what was lost in sweat. The inclusion of electrolytes keeps the plasma osmolality from dropping, as seen after ingesting plain water, and prevents the increased urine production. Finally, reduced plasma osmolality resulting from rehydrating with a
beverage with little to no electrolytes, reduces an individual’s drive to drink (Nose et al 1988). The lowering of plasma osmolality and reduction in drive to drink highlights the importance of rehydrating with fluids that contain electrolytes.

It is clear from past research that proper hydration is essential for both overall health, and maintaining athletic performance in hot and humid conditions. While exercising in hot conditions it is recommended to replace fluids at a rate as close to loss as possible. However, when athletes consume fluids during activity ad libitum, they generally only consume ~500 ml/hr, replacing only one-half to two-thirds of fluid loss (Coyle 2004, Noakes 1993). This reduced consumption will not have any negative impacts on performance as long as individuals do no lose more than 2% of total body weight. Additionally the timing, before the onset of exercise, or during exercise, does not have different outcomes in terms of dehydration (Montain and Coyle 1993). Post exercise consumption must happen at a rate to exceed total water lost through sweat. This is due to the physiologic responses from increased fluid consumption that leads to increased urine production. In addition to the volume of fluids needed for hydration, the electrolyte content is essential. If the concentration is too low, or absent, the individual will not be able to attain a positive fluid balance via rehydration post exercise. Given the highly variable sweat rates and electrolyte concentrations of sweat amongst individuals, finding the optimal balance is difficult. However, a rehydration beverage that encourages consumption and has added electrolytes will potentially have a better hydration efficacy than a beverage lacking these qualities.
Chapter 3: Research Paper

3.1 Introduction

As individuals exercise, they begin to lose water faster than it can be replaced, resulting in dehydration. Sweat rates for individuals exercising in hot and humid conditions can be as high as two liters per hour (Sawka, Montain, and Latzka, 2001). This fluid lost as sweat originates from both the intracellular and extracellular space (Nose et al 1988). As a result plasma and blood volumes are reduced. Reduced plasma volume results in cardiovascular strain, decreased cardiac output, thermoregulation abilities, and impairments to several other physiologic processes that negatively impact performance (Sawka et al 2007).

In addition to the loss of fluids, electrolytes are also lost in sweat. Electrolytes, most importantly sodium, are essential for many physiological processes in the body including muscle contraction and neurological signaling. Research has shown that both fluid and electrolyte replacement greater than or equal to the amount lost through sweat is necessary for proper rehydration (Sawka et al 2007, Shirreffs et al 2007, Shirreffs and Maughan. 1998, Shirreffs et al 1996, Montain, Maughan, and Sawka 1996).

Oxywater is a commercially available hyperoxygenated beverage that contains added vitamins, minerals and electrolytes. Hyperoxygenated water has been on the market for several years, claiming health benefits and enhanced athletic performance. Past research
has assessed the enhanced performance claims by investigating the effects of ingesting oxygenated water on cycling performance (Leibetseder et al. 2006, Wing-Gaia et al. 2005, and Hampson 2003). Results showed that consuming hyperoxygenated water has no significant effect on any variables measured (VO2, HR, CO2 production, RER, minute ventilation, lactate, RPE and hydration). Given these past findings regarding hyperoxygenation, the primary objective of this research was to evaluate the hydration capabilities of Oxywater.

3.2 Methods
3.2.1 Subjects

Twelve experienced male runners participated in this study. The Ohio State University Institutional Review Board approved all aspects of the research prior to subject recruitment and obtainment of informed consent. The subjects anthropomorphic data were (Mean ± S.D) age 24.2 ± 5.1 years, VO2max 61.9 ± 7.2 ml/kg/min, height 180.6 ± 5.5 cm, body mass = 75.1 ± 8.1 kg, and percent body fat 12.4 ± 4.7%.

3.2.2 Data Collection Protocol

The research protocol utilized a randomized crossover design to compare the hydration efficacy of Oxywater and plain water. Key outcome measures of interest were, plasma osmolality (pOsm), percent loss in total body weight (% TBW), sweat rates, the volume of fluid consumed and retained, heart rate (HR), and rating of perceived exertion (RPE). Subjects were required to complete three sessions at the Ohio State Exercise Science Lab. Session one was a subject screening and fitness assessment. Sessions two
and three were submaximal exercise bouts on the treadmill to induce dehydration. Each session was separated by one week. Subjects were required to refrain from heavy exercise two days prior to all testing sessions to control for delayed onset muscle soreness. Additionally, for the dehydration sessions, subjects were prescribed fluid consumption (5 mL/kg) to ensure they arrived to the laboratory in a euhydrated state.

Both plasma osmolality and percent change in total body weight were used to assess subject’s hydration status. Blood samples (5 mL) were collected via venipuncture pre- and post-run to measure changes in osmolality. Post run samples were collected at 30, 60, and 90 minutes to allow for renal compensatory mechanisms (Sollanek 2011). Prior to all blood draws required for plasma osmolality measures, subjects assumed a supine position to allow for even compartmentalization of blood volume. Samples were transferred to Na-Heparin tubes and centrifuged separate plasma. Plasma osmolality was measured using freezing point depression. For each time point assessed (pre- and post-run), five osmolality readings were collected. The highest and lowest values were discarded, and the remaining three were averaged. Nude body weight measures were used to assess total body weight loss during exercise. For initial measures of nude body weight, subjects were required to urinate prior to measures. Post run NBW measures required subject to towel dry before measures were recorded to remove all sweat. Because subjects were allowed to consume fluid during exercise bouts, the volume of fluids consumed was accounted for in NBW measures. When measuring post-run NBW, subjects were not allowed to urinate. To assess the total fluid retained, subjects were weighed prior to leaving the research labs. These measures were taken 90 minutes after the last volume of fluid was consumed. After taking this weight, subjects were allowed to
urinate, and a second weight was recorded. The pre and post urine weights were used to assess volume of fluids retained.

3.2.3 Testing Sessions and Protocol

During session one, subjects first completed a body composition assessment using the BodPod. This was followed a VO\(_{2\text{max}}\) test on a treadmill. The treadmill protocol required subjects to run at continuously increasing speed and then grade to exhaustion. Treadmill speed started at 6 mph, increased 0.5 mph every minute until they reached 12 mph. After reaching 12 mph, the treadmill speed was held constant and the grade was increased by 1% every minute.

For session two, subjects completed a 45-minute run at 70% of their VO\(_{2\text{max}}\) in a temperature and humidity controlled environmental chamber. Conditions were set to 30° C and 50% humidity. Prior to completing the run, blood samples and NBW were collected for hydration assessment. Subjects were randomly provided either Oxywater or plain water during the run and were permitted to consume the fluid \textit{ad libitum}. The timing and volume of fluid consumption were recorded. For the duration of the run, heart rate (HR) and rating of perceived exertion (RPE) were recorded every five minutes. Immediately upon completion of the run, subject’s towel dried and nude body weight was collected. After the weight had been recorded, subjects assumed a supine position and blood samples for osmolality measures were collected 30, 60 and 90 minutes post-run. Finally the subject was weighed, allowed to urinate, and then re-weighed in order to assess fluid retention.
For session three, subjects were required to complete the sub-maximal run under identical environmental conditions. However, for session three subjects were prescribed the alternate beverage to that which was provided during session two. Pre-measured volumes were provided to the subject at specific time intervals during the run in order to match the exact timing and volume of fluid consumed during session two. Again, HR, RPE, pre- and post-run plasma osmolality, nude body weight, and fluid retention data were collected.

3.2.4 Statistical Analysis

Changes in all variables of interest from pre- to post-exercise were tested using a one-way ANOVA using subjects as a blocking factor. This allowed for the control of variance in the data that is directly associated with individual subjects. Data are reported as mean ± SEM. The data collected throughout trials (heart rate and rating of perceived exertion) were analyzed using repeated-measures MANCOVA. Statistical analysis was performed using SPSS (version 20, IBM). Statistical significance was defined a priori as the critical α-level of \( P < 0.05 \).

3.3 Results

The pre and post-exercise values collected from subjects are presented in Table 1, with the exception of plasma osmolality. The mean and standard deviation for the results obtained during the Oxywater and plain tap water trials are presented separately and pooled. In addition, the ANOVA p-values for comparing each of the variables between the Oxywater and plain tap water trials are provided.
Table 1. Pre- and Post-exercise Values

<table>
<thead>
<tr>
<th></th>
<th>Oxy</th>
<th>Plain</th>
<th>Pooled</th>
<th>p-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre NBW Mean</td>
<td>75.20</td>
<td>75.22</td>
<td>75.21</td>
<td>0.932</td>
</tr>
<tr>
<td>Pre NBW SD</td>
<td>7.94</td>
<td>7.99</td>
<td>7.79</td>
<td></td>
</tr>
<tr>
<td>Post NBW Mean</td>
<td>74.69</td>
<td>74.74</td>
<td>74.72</td>
<td>0.844</td>
</tr>
<tr>
<td>Post NBW SD</td>
<td>7.89</td>
<td>8.11</td>
<td>7.82</td>
<td></td>
</tr>
<tr>
<td>Sweat Rate Mean</td>
<td>1,014.4</td>
<td>989.7</td>
<td>1,002.0</td>
<td>0.799</td>
</tr>
<tr>
<td>Sweat Rate SD</td>
<td>483.97</td>
<td>0.35</td>
<td>414.83</td>
<td></td>
</tr>
<tr>
<td>Fluid Consumed Mean</td>
<td>508.17</td>
<td>508.17</td>
<td>508.17</td>
<td>-</td>
</tr>
<tr>
<td>Fluid Consumed SD</td>
<td>243.70</td>
<td>243.70</td>
<td>243.70</td>
<td></td>
</tr>
<tr>
<td>Change TBW Mean</td>
<td>1.3%</td>
<td>1.3%</td>
<td>1.3%</td>
<td>0.988</td>
</tr>
<tr>
<td>Change TBW SD</td>
<td>0.6%</td>
<td>0.5%</td>
<td>0.5%</td>
<td></td>
</tr>
<tr>
<td>Fluid Retained Mean</td>
<td>320.44</td>
<td>268.33</td>
<td>294.39</td>
<td>0.051</td>
</tr>
<tr>
<td>Fluid Retained SD</td>
<td>274.92</td>
<td>275.38</td>
<td>270.42</td>
<td></td>
</tr>
</tbody>
</table>

Results show that there were no differences between the Oxywater and plain water trials for any of the measures. Subject’s pre- and post-exercise nude body weights were the same for both trials. The average sweat rate for individuals was 1002 ± 414.8 ml (Table 1), within the range expected for exercise in hot and humid conditions (Sawka, Montain, and Latzka, 2001). The percent change in bodyweight after exercise (1.3%), indicated that individuals were slightly dehydrated after exercise, though there was no difference between the Oxywater and plain water trials, p = .988 (Table 1). It should be noted here that in order to calculate the percentage change in total body weight using the values presented, the amount of fluid consumed must be accounted for. The difference in the volume of fluid retained between the trials was nearly significant (p = .051).

The percentage change in total body weight suggests that subjects were slightly dehydrated post exercise. However, this measure is only one indicator of hydration status. Table 4 below provides pre- and post-exercise plasma osmolality measures in
addition to the absolute change pre- to post-exercise. Consistent with the measures on total body weight, plasma osmolality measures increased in both trials indicating dehydration. Again, the difference in the level of dehydration was not significantly different between Oxywater and plain water (p = .255).

Table 2. Pre- and Post-exercise Osmolality Measures

<table>
<thead>
<tr>
<th></th>
<th>PreRun Mean (mOsm/kg)</th>
<th>90m Mean (mOsm/kg)</th>
<th>Abs. change (mOsm/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxywater</td>
<td>288.83</td>
<td>290.72</td>
<td>1.89</td>
</tr>
<tr>
<td></td>
<td>6.13</td>
<td>7.54</td>
<td>3.58</td>
</tr>
<tr>
<td>Tapwater</td>
<td>287.67</td>
<td>290.64</td>
<td>2.97</td>
</tr>
<tr>
<td></td>
<td>4.98</td>
<td>5.28</td>
<td>1.78</td>
</tr>
<tr>
<td>p-values</td>
<td>0.557</td>
<td>0.962</td>
<td>0.255</td>
</tr>
</tbody>
</table>

Given the flavoring, electrolytes, antioxidants, and minerals of Oxywater, it was hypothesized that subjects may consume a larger volume than plain water. Recall that subjects were required to drink the same volume of fluid, at the same time during the second trial as was consumed during the first trial. If, a larger volume of fluid were consumed during the first exercise trial, this would have implications when comparing pre and post-exercise hydration status. Table 3 provides data on the volume of fluid consumed by individuals when they were provided either Oxywater or plain tap water on their first trial. Although subjects drank a larger volume of fluid when Oxywater was provided during trial one, the difference was not significant (p = .096). On average,
individuals replaced 50% of the fluids lost during exercise. Again, these findings are typical of past research (Coyle 2004, Noakes 1993)

Table 3. Volume of Fluid Consumed Under Given Initial Condition

<table>
<thead>
<tr>
<th>Condition</th>
<th>Fluid Consumed (ml)</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxywater First</td>
<td>Mean</td>
<td>641.2</td>
<td>276.2</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>276.2</td>
<td></td>
</tr>
<tr>
<td>Plain Water First</td>
<td>Mean</td>
<td>375.2</td>
<td>109.3</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>109.3</td>
<td></td>
</tr>
<tr>
<td>p-value</td>
<td></td>
<td>0.096</td>
<td></td>
</tr>
</tbody>
</table>

Heart rate and rating of perceived exertion were recorded every five minutes throughout each exercise bout (Figure 1 and Figure 2). As anticipated, both measures increased throughout the trials. These findings are also consistent with past research where dehydration was induced through exercise (Sawka et al 2007, Coyle 2004, Montain and Coyle 1992, Gonzalez-Alonso 1998). Although recorded values for HR and RPE were higher in the Oxywater trials, the differences were not significant $p = .105$ and $p = .056$ respectively.
Figure 1. Heart Rate Response

Figure 2. Rating of Perceived Exertion
3.4 Conclusions

It was hypothesized that given the ingredients in Oxywater, it would provide an enhanced hydration capability compared to plain water. Past research has shown that hydration beverages with an electrolyte profile will result in improved rehydration. This hydration enhancing benefit comes from maintaining an elevated plasma osmolality, and maintaining or stimulating thirst response (Shirreffs et al 2007, Nose et al 1988). These key physiologic conditions increase the chance that individuals will attain a positive fluid balance, regaining all or more of the sweat lost, through rehydration efforts.

The hydration variables of primary importance, changes in plasma osmolality and change in total body weight, were not significantly different between the Oxywater and plain tap water trials. After 90-minutes of sub-maximal exercise in hot and humid conditions, plasma osmolality increased 2.97 mOsm/kg when plain water was consumed and 1.89 mOsm/kg when Oxywater was consumed. Although plasma osmolality increased to higher levels when drinking plain tap water, the difference was not significant. Pre- and post-exercise changes in total body weight also revealed no difference between plain water and Oxywater. On average individuals lost 1.3% of bodyweight over the 90-minute effort.

Over the duration of the exercise bout, heart rate and rating of perceived exertion increased steadily. These are typical symptoms associated with dehydrating bouts of exercise. The changes in plasma volume increase cardiac strain, which lead to increased heart rates and ratings of perceived exertion (Montain and Coyle 1993). Although the values for both heart HR and RPE were higher during the Oxywater trials, the results of the MANCOVA analysis showed not statistical significance.
Finally, the ingredients in Oxywater did not cause the individuals to drink a larger volume than plain water. The added ingredients, specifically the electrolytes and flavorings, did not result in the individuals consuming more fluid during trial one when Oxywater was provided. Though on average they did consume a larger volume of Oxywater, the difference was not significant.

Regardless of condition, plain water or Oxywater consumption, individuals became dehydrated, though not to a level that would impair physical performance, >3% change in total body weight or >5 mOsm/kg change in plasma osmolality (Cheuvront et al 2013, Sawka et al 2007, Coyle 2004). The beverage consumed during exercise did not have a significant difference on any of the variables measured. It can be concluded that Oxywater is no more effective at limiting dehydration than plain tap water.

There are several limitations that need to considered when evaluating the findings. First is the sample size, a priori sample size calculations indicated that 30 subjects would be needed to have 80% power. The total sample size was less than half of this, N = 12. There were several variables, fluid retained, volume consumed, heart rate and RPE, that were close to significant a the p = .05 level. It is possible that these variables would become significant given a larger sample size. These variables are closely related in the sense that if more fluids were consumed, more would likely be retained. An increased volume consumed would require longer gastric emptying times and thus higher retention. An elevated RPE and HR in the Oxywater trials, if significant, could be the result of the high level of B vitamins in Oxywater. Finally, the duration, intensity and environmental conditions of the experiment may not have been rigorous enough to elicit levels of dehydration.
Chapter 4: Summary

The primary objective of this research was to evaluate the hydration capabilities of Oxywater. Oxywater is a commercially available hyperoxygenated beverage that contains added vitamins, minerals and electrolytes. As individuals exercise, they begin to sweat, losing water faster than it can be replaced. In addition to the loss of fluids, electrolytes are also lost in sweat. The loss of these components, which are both essential for many physiologic processes, results in dehydration. Past research has shown that hydration beverages with an electrolyte profile will result in improved rehydration. This hydration enhancing benefit comes from maintaining an elevated plasma osmolality, and maintaining or stimulating thirst response (Shirreffs et al 2007, Nose et al 1988). These key physiologic conditions increase the chance that individuals will attain a positive fluid balance, regaining all or more of the sweat lost, through rehydration efforts.

Given ingredients of Oxywater, it was hypothesized that it may be more effective at limiting dehydration than plain water. To test the hydration capabilities of Oxywater, twelve experienced male runners participated in two dehydrating bouts of exercise. Subjects were provided either Oxywater or plain tap water and permitted to consume ad libitum. Markers of hydration status were recorded before, during and after each trial.

Results showed that there were no differences between the Oxywater and plain water trials for any measures. Subject’s pre- and post-exercise nude body weights were
the same for both trials. The average sweat rate for individuals were, within the range expected for exercise in hot and humid conditions (Sawka, Montain, and Latzka, 2001). The percent change in bodyweight after exercise indicated that individuals were slightly dehydrated after exercise, though there was no difference between the Oxywater and plain water trials. There was no difference in the volume of fluid retained between the trials. Consistent with the measures on total body weight, plasma osmolality measures increased in both trials indicating dehydration. However, the difference in the level of dehydration was not significant between Oxywater and plain water.

Reduced plasma volume resulting from dehydration leads to increased cardiovascular strain, decreased cardiac output, thermoregulation abilities, and impairments to several other physiologic processes that negatively impact performance (Sawka et al. 2007). Although heart rate and rating of perceived exertion increased throughout both trials, the difference between the two was not significant.

Although the added ingredients in Oxywater had the potential to enhance hydration capabilities compared to plain tap water, the results revealed otherwise. The electrolyte profile and flavoring did not result in subject drinking a larger volume of fluid compared to plain tap water. On average, individuals replaced 50% of the fluids lost during exercise. Regardless of condition, plain water or Oxywater consumption, individuals became dehydrated, though not to a level that would impair physical performance, >3% change in total body weight or >5 mOsm/kg change in plasma osmolality (Cheuvront et al 2013, Sawka et al 2007, Coyle 2004). The beverage consumed during exercise did not have a significant difference on any of the variables
measured. It was concluded by this research that Oxywater was equally as effective at limiting dehydration in experienced male runners as plain tap water.
References


