

THE EFFECTS OF HYPERTONIC, ISOTONIC, AND HYPOTONIC  
BEVERAGES ON REHYDRATION AFTER EXERCISE: A REVIEW

By

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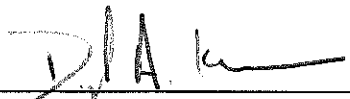
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# The Effects of Hypertonic, Isotonic, and Hypotonic Beverages on Rehydration after Exercise: A

## Review

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### **Abstract**

Rehydration depends on the rate of gastric emptying, intestinal absorption and fluid retention after fluid consumption. The increased rate of gastric emptying and intestinal absorption that occurs with hypotonic beverage consumption provides an advantage in rapid rehydration, but results in increased urine production, which can cause a return to negative fluid balances over time. Isotonic beverages provide an advantage over hypotonic and hypertonic beverages, as they are rapidly absorbed, but do not cause diuresis due to their increased electrolyte and/or carbohydrate concentration. Hypertonic beverages can hinder rehydration due to their decreased rate of gastric emptying and intestinal absorption. However, they prevent urine production and thus aid in long-term rehydration compared to hypotonic and isotonic beverages. Athletes should select beverages based on their hydration needs and the type of activity performed.

## Introduction

Both professional and recreational athletes work toward improving their performance and efficiency during exercise; one aspect that can help achieve high performance and efficiency is proper hydration. Athletes have experimented with many different types of beverages from plain water to expensive sports drinks to pickle juice to enhance hydration and electrolyte balance.<sup>1</sup> Exercise typically causes decreases in sodium concentration in the blood and plasma volume from sweat loss leading to dehydration.<sup>2</sup> As fatigue during exercise generally results from a depletion of glycogen stores and dehydration, determining the best type of beverage for rehydration is vital for peak performance.<sup>3</sup>

The efficiency of rehydration after exercise may be affected by the beverage osmolality. Beverages can be categorized by this osmolality as hypotonic, isotonic or hypertonic. Their tonicity is based on their relation to blood osmolality with hypotonic solutions having lower concentrations, isotonic solutions, equal concentrations and hypertonic solutions, greater concentrations.<sup>4</sup> Determining the concentration that most efficiently replaces fluid lost through sweat can aid athletes in selecting the most suitable drink for rehydration.

The three interrelated processes that affect rehydration are gastric emptying, intestinal absorption, and fluid retention.<sup>5</sup> The rate of gastric emptying refers to the speed that a solution passes through the stomach to the intestines.<sup>5</sup> It is dependent upon the volume, energy density, and osmolality of the fluid.<sup>7</sup> Gastric emptying affects the rate of intestinal absorption, which is the speed that water is absorbed into the blood from the intestines.<sup>5</sup> The osmolality of the fluid in the intestines determines the osmotic gradient across the intestinal wall, providing the driving force for water movement.<sup>6</sup> As fluid osmolality affects both of these factors and

thus the speed of absorption, it plays a vital role in rehydration.<sup>3</sup> The amount of fluid loss impacts long-term rehydration, as increased urine output can delay or prevent rehydration.<sup>8</sup> Beverage composition can either promote or prevent diuresis, based on its osmolality and rate of absorption.<sup>7</sup> Increased blood osmolality stimulates the release of arginine vasopressin from the pituitary. This hormone causes the kidneys to reabsorb more fluid, preventing increased urine production and increasing blood volume.<sup>4</sup> By applying beverage osmolality and composition to these three factors, this review will provide a better understanding of fluid tonicity's effect on rehydration.

### **Hypotonic beverages**

Although hypotonic beverages have an advantage in that they are absorbed the most rapidly into the blood after consumption, they cause the greatest increase in fluid loss. Gastric emptying occurs most rapidly after consumption of beverages with a low osmolality and energy density.<sup>7</sup> Because fluid moves very quickly through the stomach and intestines, hypotonic beverage ingestion results in a less bloated feeling compared to more concentrated beverages.<sup>7</sup> The addition of glucose to a solution may result in a more bloated feeling as it slows gastric emptying.<sup>9</sup> However, compared to water, the addition of up to 20 g/ L of glucose did not affect gastric emptying.<sup>9</sup> This addition may be advantageous during exercise when rapid rehydration and a small energy intake is desired.

The absorption speed from the intestines is also highest in hypotonic beverages due to the concentration gradient.<sup>10</sup> As the osmolality of fluid in the intestine is less than the blood, water flows from the low concentration to the high concentration.<sup>4</sup> The difference in concentration determines the rate of this passive process. Using a dilute solution with

carbohydrate or sodium may enhance fluid uptake as the absorption of these molecules can create a larger osmotic gradient and increase the rate of water absorption.<sup>11</sup> Although this rapid absorption aids in fast rehydration, it can also cause negative effects with long-term rehydration.

The rapid absorption of water into the blood results in a prompt reduction in the sodium concentration and plasma osmolality, causing diuresis.<sup>7</sup> The decreased blood osmolality inhibits the release of AVP, preventing the kidneys from reabsorbing as much water, leading to an increased urine production, which decreases plasma volume.<sup>5</sup> In order to remain hydrated, individuals must intake more fluid than was lost through sweat during exercise. In one study, drinking twice the amount of fluid that was lost still lead to a negative fluid balance for hypotonic beverages after 2 hours.<sup>8</sup> The decrease in sodium concentration and plasma osmolality associated with intake of hypotonic beverages can also have more serious complications, as this reduces the drive to drink and can potentially lead to hyponatraemia.<sup>12</sup> Although rare, hyponatraemia can cause nausea, vomiting, lethargy, confusion, and in extreme cases, seizures, due to the sharp drop in blood osmolality.<sup>4</sup> Overall, use of hypotonic beverages in post exercise rehydration may not be effective in maintaining fluid balance over time, but is advantageous when rapid fluid rehydration is desired.<sup>7</sup>

### **Isotonic Beverages**

Compared with hypotonic beverages, isotonic beverages contain more electrolytes and/or glucose. This can place them at a disadvantage in terms of gastric emptying, as both increased osmolality and energy content of fluids tends to decrease the rate of gastric emptying.<sup>7</sup> However, some studies have found that isotonic beverages have similar gastric

emptying rates to hypotonic beverages, depending on the amount of carbohydrate and electrolytes in solution.<sup>6</sup>

The addition of both sodium and glucose to beverages can be more advantageous on the rate of intestinal absorption compared to adding just one in order to increase fluid osmolality.<sup>12</sup> Sodium stimulates glucose absorption along the small intestine, increasing the rate of absorption while also establishing an osmotic gradient.<sup>12</sup> Solutions containing different types of carbohydrates also aid in building this gradient, as they have increased movement across the lumen due to the activation of multiple different transporters.<sup>6, 10</sup> Without this gradient, the rate of intestinal absorption would decrease, as isotonic beverages have the same concentration as the blood.<sup>3</sup>

Isotonic beverages are more effective at maintaining hydration than hypotonic beverages. The addition of electrolytes and glucose aids in both rapidly increasing plasma volume, but with less extreme changes in sodium concentration and osmolality.<sup>12</sup> Isotonic solutions tend to increase plasma volume greater than normal, which increases blood pressure.<sup>13</sup> This increased blood pressure can aid in extended exercise in the heat.<sup>13</sup> Isotonic solution can also aid in replacing electrolytes lost through sweat to maintain electrolyte balance and prevent issues with hyponatremia.<sup>13, 12</sup> Overall, isotonic beverage consumption appears to provide a more balanced rehydration, with fairly quick gastric emptying and absorption rates in addition to increased fluid retention.

### **Hypertonic Beverages**

Hypertonic beverages contain the highest amount of solute and have the greatest advantage in maintenance of a hydrated state.<sup>7</sup> However, they are not appropriate for rapid

rehydration due to their decreased rate of gastric emptying and intestinal absorption.<sup>1,7</sup>

Because hypertonic fluids contain higher amounts of electrolytes and glucose than isotonic or hypotonic fluids, their gastric emptying rate is decreased comparatively.<sup>7</sup> With large amounts of concentrated fluid remaining in the stomach, issues arise with gastrointestinal comfort and consumption.<sup>7</sup> Hypertonic fluid intake results in an increased bloated feeling and feeling of fullness, due to the large portion of the drink that remains in the intestinal tract.<sup>5</sup> This discomfort becomes problematic when it causes a cessation of drinking before enough fluid has been consumed to reach a euhydrated state.<sup>7</sup>

Unlike hypotonic and isotonic solution absorption from the intestines, hypertonic solutions cause the formation of an unfavorable gradient across the intestinal wall. Because the concentration of fluid in the intestine is higher than that of the blood, an initial efflux of water occurs in order to establish an osmotic gradient that is suitable for fluid uptake into the blood.<sup>5</sup> This initial secretion results in an increased plasma osmolality and temporarily delays plasma restoration and rehydration.<sup>5</sup> However, this also results in increased levels of arginine vasopressin, which decreases urine production, allowing the individual to remain hydrated for a longer period after absorption.<sup>7</sup>

When rapid rehydration is unnecessary, hypertonic solution intake provides a gradual return of blood osmolality to pre-hydration levels.<sup>7</sup> The decreased speed of gastric emptying and intestinal absorption prevents large, rapid increases in blood volume and tends to limit decreases in sodium concentrations, preventing diuresis and fluid loss through urine.<sup>7</sup> The decreased amount of fluid lost through urine attenuates the decline in serum osmolality, providing an advantage over hypotonic or isotonic beverages in terms of long-term

rehydration.<sup>5,7</sup> In addition to long-term rehydration, hypertonic drinks are beneficial in both restoring electrolytes and resynthesizing muscle glycogen after exercise, due to the increased amounts of minerals and carbohydrates present compared to hypotonic and isotonic solutions.<sup>5</sup> These drinks may also be beneficial in long duration exercise as they contain more carbohydrates that provide energy.<sup>10</sup>

## **Conclusion**

Hypotonic, isotonic, and hypertonic solutions provide both advantages and disadvantages in rehydration. Hypotonic beverages provide the fastest rehydration, but cause increased fluid loss through urine. Isotonic solutions provide a more balanced rehydration, as they are absorbed more quickly than hypertonic solutions, while also preventing increased urine production. Hypertonic beverages work best for long-term rehydration, but are not appropriate when rapid rehydration is required due to their slow gastric emptying and intestinal absorption. Athletes should select the appropriate drink based on the type of rehydration desired. However, an isotonic drink appears to provide the most rehydration benefits with the least amount of negative consequences.

This review not only provided information on rehydration, but also allowed me to better understand the experiments that I performed in the lab, where I assisted Dr. Douglas Keen, Dr. John Konhilas, and Eleni Constantopoulos with the study "The impact of Post-exercise Hydration on Rehydration and Exercise Performance." I helped in both conducting experiments and running saliva samples over the past year. Using the osmolality of saliva, we were able to determine the most effective beverage for rehydration and performance through experiments in which participants lost 3% of their body mass in sweat followed by rehydration with one of



three beverages (spring water, sports drink, or Kona deep-ocean mineral water). Compared to spring water and sports drinks, Kona water provided the most effective rehydration and increased muscle performance. Although the mechanism is unclear, based on the information in this review, the greater amount of electrolytes present in the Kona water compared to spring water and the decreased energy content compared to the sports drink could aid in intestinal absorption and increase the speed of hydration.

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