Effect of Plasma Volume on Myofibril Hydration, Nutrient Delivery, and Athletic Performance

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Abstract

Hydration is vital for maximal performance and thermoregulatory balance. Cardiac output, blood flow, LA clearance, and sweat, among other physiological occurrences, are dependent on blood plasma. Moreover, proper levels of osmolarity must be taken into account. Imbalances will inhibit gastric emptying, intestinal fluid absorption, blood pumps, and induce side effects such as fever, and cramping. This and practical applications will be reviewed.

Recommended Readings:

The Window of Opportunity

Sodium - A comprehensive Analysis

Active Recovery - A Threefold Breakdown

Dextrose, Maltodextrin, and Sodium an In Depth Analysis

Sea Water

Water, water everywhere

Nor any Drop to Drink

This famous line is from the great poet Samuel Taylor Coleridge. He wrote it during his epic poem, “The Rime of the Ancient Mariner,” which depicts the life of a sailor. So what is Samuel’s point? Allow me to elaborate.

As you well know, sailors are surrounded by water all day. However, they can not depend on the ocean for sources of fluid. Hence, the line, “Water, water everywhere Nor any Drop to Drink.” The reason being drinking salt water would severely dehydrate them, resulting in certain death. This danger results from the concentration of solutes dissolved within the ocean. The osmolarity of sea water ranges from 2000-2,400 mOsm, primarily contributed by sodium chloride. This is 8 times the osmolarity of your plasma--300 mOsm. The most concentrated urine our kidneys can produce ranks at 1400 mOsm, far below the level of ocean water.

Let’s say during a hardcore training session you excreted approximately 1 liter of water from sweat alone. Afterwards, you replace this water with a liter of sea water. This would initially return your plasma volume back to normal levels. However, because the sodium concentration of ocean water is so high, your plasma osmolarity would skyrocket. This would stimulate the release of the Antidiuretic Hormone (ADH, explained in the aforementioned sodium article), causing your body to secrete a minimal volume of concentrated urine, assisting in water conservation, lowering osmolarity. Ideally, your body would secrete all the solute, with only small amounts of water. But this is not possible, because as mentioned earlier, the highest urine concentration is 1400 mOsm. To excrete 2400 milliosmoles of salt water, your kidneys would have to release at least 1.7 liters of water (the amount of water which accompanies the solute is known as the obligatory water loss). The amount of fluid lost is almost twice as much as you originally ingested!

Therefore, drinking seawater would cause more water to be lost in your urine than orally consumed, resulting in a net loss of bodily fluids. As such, the athlete who drank salt water post-workout would actually promote dehydration, which brings us to our topic of discussion.

Thermoregulation- Introduced

Thermoregulation refers to the control of body temperature within a narrow range. This is done by adding or subtracting body heat. Core temperature rises if heat gain exceeds heat loss. This readily occurs during intense exercise in humid environments. In contrast, in the cold, when heat loss exceeds heat production, core temperature falls. A drop in core body temperature of 10 degrees and an increase of 5 is tolerable; beyond this, however, can be fatal. Multitudes of heat related deaths in the past 20 years certainly attest to this [39]. Since the metabolism of an elite athlete often rises 20 to 25 times above resting level, your body would, in theory, increase temperature by 1 degree every 6 minutes. However, thermoregulatory adjustments help prevent this from occurring [30, 40].

Several mechanisms are involved in thermoregulation. Indeed, this is a complex subject, and several journals must be dedicated to adequately serve it justice. This issue will focus primarily on hydration.

To begin, we discuss the sweat mechanism.

Sweat

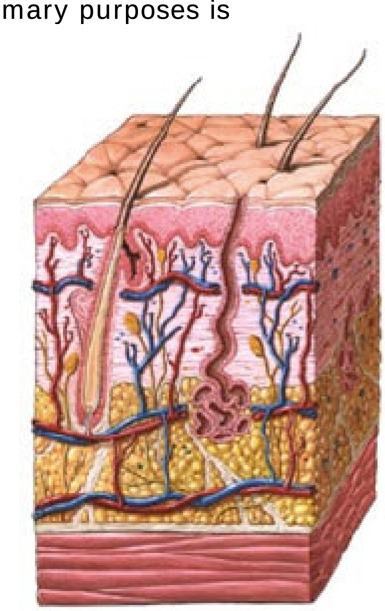
There are more than 2.5 million sudoriferous (sweat) glands distributed over the surface of the human body. These consist of apocrine and eccrine glands. The former plays little role in thermoregulation, thus, we will focus on eccrine glands exclusively.

Eccrine glands

These sweat glands are abundantly found on the palms, soles, and the forehead. They are small, tubular, coiled glands of the merocrine variety (refers to a common mode of secreting substances to the exterior portion of the body). The secretory portion is coiled within the dermis (connective tissue underlying the epithelium of the skin), while its duct extends up to open a funnel-type pore at the skin's surface.

This secretion is what we normally refer to as sweat. Sweat is derived from blood plasma filtration. Its composition is 99% water, with the rest coming primarily from sodium, along with antibodies, lactic acid, vitamin C, and metabolic wastes. The exact composition can vary according to genetics and diet. It is an acidic substance with a pH between 4 and 6 (remember, the lower the pH, the more acidic the solution).

Sweat is monitored by the sympathetic division of the autonomic nervous system. We have little control over this system. One of its primary purposes is



thermoregulation, in the prevention of over-heating.

Heat-induced sweat starts on the forehead and spirals downward over the body. Emotional conditions, also known as the, "cold sweat," are brought on by nervousness, fright (i.e. seeing a gym moron approaching you to give advice!), embarrassment, etc. Secretion begins on the palms, soles, and armpits, and then spreads to other parts of the body.

Evaporation

In relation to training, when body temperature rises, sweat is released, acting as a refrigeration mechanism to cool the body. Sweat is not actually what cools your body, but rather, evaporation. Each liter of water that vaporizes by sweat exerts 580 kcal from the body and transfers it to the environment. The cooled skin in turn cools the blood diverted from interior tissues to the surface. Blood flow is vital to the sweat mechanism. This will be discussed further on.

Humidity heavily affects the efficiency of the sweat mechanism. Air becomes saturated with water vapor at 100% relative humidity. This blocks any evaporation of fluid. In such conditions, sweat would eventually roll off your body without providing any cooling. On a dry day, the air can hold considerable moisture, and fluid evaporates quickly from the skin. High temperatures are handled relatively well by the body. It is more comfortable to train in dry desert climates than cooler, but more humid environments.

Note: Condensation is an energy releasing process. In a humid environment, more water is condensing on your skin, and thus releasing energy to the skin in the form of heat. Such a concept is easy to test. When you turn off the shower, it is still warm as water condenses on the skin. However, when you walk out of the shower you are immediately hit with the cold. This is due to the fact that more water is evaporating (an energy-absorbing process) than is condensing. Next time you take a shower, try dying off while in there; you will stay warmer. These concepts are due to the amazing chemistry of water!

For more on sweat, I turn to Sodium - A comprehensive Analysis. Here is a quote:

> **Sweat loss**
>
> “As mentioned previously, sodium is water soluble. This relates to a large amount of sodium loss through sweat during intense training sessions. Sweat is produced by specialized sweat glands beneath the skin. Evaporation of sweat’s water components results in a refrigeration mechanism to cool the body down.
>
> Typically, a well-assimilated athlete will loose .5L - 3L of sweat during each hour of exercise. On average, an athlete looses 1-1.5 liters per hour. Higher intensity results in increased sweat loss. Humidity, heat, and other weather-related factors will result in increased sweat secretion as well. Every liter of sweat contains a whopping .6 g of sodium. This is a vital factor in optimal post-workout nutrition.

It is also important to note that increasing heat and sweat loss before and during training sessions is extremely beneficial to the athlete. For more on this, refer to: Mobility Training and the Application of Proper Warm-Up for Bodybuilders."

As you see, sweat promotes the loss of bodily fluids. Next we analyze how to counter these effects and work to promote thermoregulation through the most abundant component of the body--water.

Hydration

Hydration is the maintenance of plasma volume in the body. This is done by consuming adequate supplies of water throughout the day.

Hydration is the most effective defense of heat stress. Furthermore, a well-hydrated athlete will predominantly perform at a higher proficiency than a dehydrated one.

Proper hydration during exercise is of the utmost importance. Fluid ingestion must be strictly monitored in order to achieve maximum results. Most athletes, however, do not adequately replace water loss. They instead rely on the thirst mechanism. While this is helpful, it does not precisely monitor water needs. When unlimited amounts of water are supplied, and athletes do not consume enough water voluntarily, dehydration occurs. This is known as voluntary dehydration. For example, if you were to entirely rely on the thirst mechanism for rehydration after being severely dehydrated, it would take several days to regain fluid balance [35]. As such, athletes must know the exact science behind rehydration, and follow it to a T [34]. Subsequently, we will analyze this, and the anabolism behind hydration.

Water

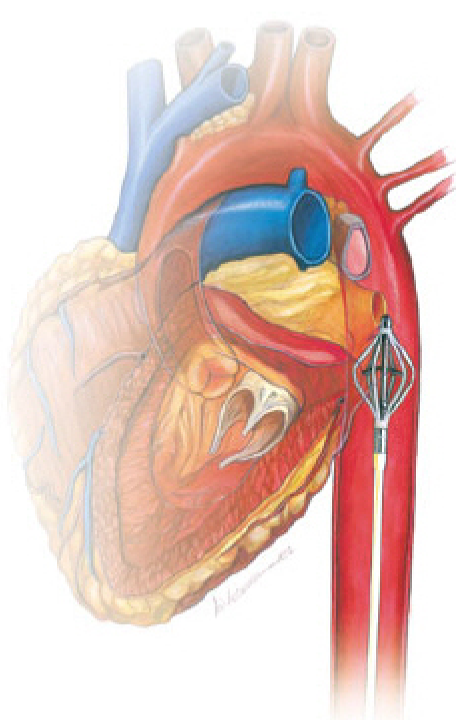
Water makes up 40-70% of body mass, and 75% of muscular weight. It is a vital nutrient. Without water, death would occur within a few days. Waste products leave the body through water in the urine and feces. Water lubricates the joints, and organs such as the heart, and intestines. It also provides structure for bodily tissues. Moreover, water has great thermoregulatory qualities because it absorbs high amounts of heat with minuscule changes in temperature, and has a high heat of vaporization. These traits are imperative for internal heat generated amidst exercise, and external heat stress. Dehydration will decrease athletic performance [2, 3, 10, 12, 38].

Staying hydrated during exercise greatly benefits the athlete. These anabolic traits will be discussed as follows:

- Cardiac Output
- Lactic clearance
- Blood flow and Sweat

Cardiac Output

Hydration has been shown to be an effective means of increasing cardiac output. The reason is threefold. First, the more blood plasma you have, the more blood your heart can pump throughout your body. Secondly, your heart is a very elastic organ, and optimal filament overlap is not reached until it is notably stretched. Increasing plasma volume (via water) effectively accomplishes this, inducing more forceful contractions from the heart and with it an increase in blood flow. Moreover, if stroke volume goes down (how much blood is pumped out of the heart), heart rate goes up in order to maintain cardiac output. The higher the heart rate, the quicker the heart contracts, which would decrease filament overlap due to less filling time, causing weaker contractions and minimized blood flow. In summery, staying hydrated provides your body with more blood to use, and maximizes filament overlap/elasticity, effectively increasing stroke volume, and decreasing heart rate.



In light of this subject, an experiment was performed by Hamilton et al. to test the effects that 2 hours of moderate to heavy exercise with and without fluid replacement had on cardiovascular conditioning [35]. When athletes consumed enough water to replace the water lost through sweat, stroke volume did not drift down, and actually increased, and heart rate raised only a few beats throughout the session. This resulted in a cardiac output remaining nearly constant in the first hour of training, with a slight increase in the latter half. When dehydrated, heart rate increased by 10%, and stroke volume decreased by 15%, leading to a reduction in cardiac output.

To clarify the importance of this, here is an editor's note from President Wilson in, Active Recovery - A Threefold Breakdown:

> "As Venom has so eloquently displayed, active recovery exerts many of its effects by enhancing oxygen delivery to the musculature. One of the most vital keys in your understanding of this concept is once again centered around what Seyle in the 1950's labeled as the "counter shock" phase of a stress reaction. To review, any activity which requires above resting levels of work knocks the body out of balance. It responds with a counter, by utilizing such mechanisms as increased epinephrine levels, or dilating certain blood vessels. You must realize that this study (of homeostatic reaction) is an intricate one. That is, differing activities stimulate differing reactions in the body, and therefore varying "counter shocks." Dynamic resistance training (lifting weights) for various reasons has been shown in several studies to actually lower stroke volume.
>
> Cardiac Output = Heart Rate x Stroke Volume (blood ejected per beat - out of the heart)
>
> While training intensely with weights, heart rate actually increases markedly, as you no doubt have noted. However, with a stagnant or lowered stroke volume, CO will only increase moderately, a predicament which will not optimally facilitate recovery. Venom, however, has the solution to this obvious problem. Active recovery between sets utilizes a very aerobic (with Oxygen) protocol. During such activities, stroke volume notably increases, and with it, Cardiac Output. Boom! You're in and 02 levels to the working musculature is instantly - optimized!"

So drinking adequate amounts of water during intense training session has the same benefits of AR in between sets, which has been shown to effectively enhance athletic performance [5,6,7,11,14,16, 17, 41,42,43,44]. For more, study the aforementioned article.

Lactic Acid

For various reasons, dehydration leads to a decrease in the lactate threshold. For example, Moquin and Mazzeo performed an experiment on collegiate female rowers [29]. Two groups participated in intense exercise. One was supplied adequate amounts of fluid, while the other group was denied fluid, and trained in a sweat suit to increase dehydration. Both groups then trained the following morning. In the dehydrated group, there was a statistically significant ($p<.05$) decrease in lactate threshold relative to the percent of VO2max, and a marked decrease in performance both of exhaustion and power output compared to the hydrated group.

Two factors increase blood lactate. First, reduced lactate uptake by the liver because of reduced blood flow, and second, decreased cardiac output (CO).

Now, considering the previous discussion on CO, this makes perfect sense. Lactate accumulation occurs when the appearance of lactate exceeds its clearance rate. Consequently, the number one process for lactate removal is oxidation. So when you are dehydrated, cardiac output, and inevitably, oxygen consumption, is diminished. Hence, a decrease in lactate threshold, and performance.

For much more on the benefits of lactate removal, I again refer to Active Recovery - A Threefold Breakdown.

Blood flow and Sweat

Fluid deficits can quickly reduce the body's ability to dissipate heat. This is largely due to a decline in sweat rate and blood flow. This leads to diminished cardiac function and performance during intense exercise. Furthermore, your chance of heat illness greatly increases in a dehydrated state [28, 36]. Dehydration of up to 5% of body mass significantly increases heart rate and temperature, while decreasing sweating rate, VO2 max, and exercise performance compared to a hydrated state [31, 37]. This inevitably leads to an increase in core temperature, which has been shown to further reduce sweat and blood flow [31].

Sudoriferous and blood are vital to thermoregulation. We have previously discussed the benefits of sweat. As you know, sweat depends on blood plasma for operation; dehydration decreases blood plasma, limiting the sweat mechanism.

The circulatory system is essential in thermal balance. When training, cardiac output increases, and blood vessels dilate (increase in diameter) to transfer warm blood to the body surface. This results in a reddened face on a hot day, and increased vascularity. Enhanced blood flow can greatly assist thermoregulation. Reduced blood flow occurs when the body is trying to maintain cardiac output because of diminished plasma volume, caused by sweating and inadequate liquid replenishment [13]. To clarify on the circulatory system, here is a quote from President Wilson in his masterpiece, The Anatomy of A Muscle.

> Another cool fact - Do you know why you get that flushed look while training? Or why your skin turns red?

Your muscles produce heat. When they are contracting extra hard, this heat is intensified and needs to be gotten rid of. The capillaries, aside from their above job, also dispose of heat. I have an excellent illustration for you! What happens when you stick your hand in hot water? Your hand turns red almost immediately right?! The same principle applies here. When your body is producing excess heat, it is passed to the capillaries, and they rapidly release them into the surrounding tissue, making your skin appear reddish.

Veins are very elastic to accommodate for blood flow and actually have muscle in the middle of their structure. When forced to accommodate for greater blood flows veins become stronger and can handle more blood volume. They also become more elastic. Moreover, the muscle which is in the middle of the veins can be hypertrophied (1) by an intensified blood flow! In other words, the muscle within will grow and enhance the size of your veins! Anyone who emphasizes extreme blood pumps will increase the size and strength of their veins.

Capillaries connect a muscle to our cardiovascular system. They do contribute to the size of a muscle as well. Increased blood demand will actually cause muscle capillarization, which means that the density or number of capillaries will increase in your muscle cells. Another proven method to enhance capillarization is direct cardiovascular work. In fact the same style of cardiovascular work that I prescribe in "The Anatomy of a Muscle Fiber" for enhanced mitochondrial density will stimulate this much sought after adaptation!

Therefore, exercises such as supersets, flexing between sets and anything that increases the blood pump will increase vascularity, muscle size, and your ability to recover faster between sets! I say it will improve recovery for obvious reasons. You will have a greater ability to deliver precious nutrients and carry waste products outside of your muscles!

So as you see, hydration not only enhances thermoregulation, but blood pumps as well! Not only is a blood pump vital for vascular hypertrophy, but also contains many anabolic nutrients. Here is another excerpt from Active Recovery - A Threefold Breakdown:

Leviticus 17:11

11 For the life of the flesh is in the blood... [12]

Blood carries innumerable vital nutrients throughout your body. A pump can assist several essential mechanisms such as protein synthesis and cellular hydration [33]. Now, if blood carries so many anabolic nutrients, than is there a way to channel it for the benefit of muscular hypertrophy? Indeed there is. In this next section of the article, we will analyze how to use blood flow to enhance recovery between workouts. First we need to elaborate on the aspect of blood flow and its physiological effects.

Haussinger D et al. [18] displayed evidence that cellular hydration is an important factor in controlling cellular protein turnover, while protein synthesis and degradation are affected in opposite directions by cell shrinking, and that an increase in cellular hydration (swelling) acts as an anabolic agent, whereas cell shrinkage is catabolic.

Waldegger S et al. [34] concluded from his experiment that, “Cell swelling inhibits proteolysis (protein breakdown), and stimulates protein synthesis, whereas cell shrinkage stimulates proteolysis and inhibits protein synthesis”

Brad Schoenfeld [7] displayed that a hydrated cell stimulates protein synthesis and inhibits proteolysis, in effect, providing muscles with the raw material to lay down new contractile proteins (myosin and actin).

Additionally, Millar ID examined the effect of cell volume on protein synthesis [21]. The results strongly suggest that cell volume is an important cellular signal for the control of protein synthesis in general.

So as is clearly displayed, blood flow is a highly anabolic agent.

In conclusion, dehydration will halt your athletic performance, and negatively effect thermoregulation [39, 30, 40, 36, 37, 28]. Practical applications will be discussed further on.

Sodium

Exercise causes large losses of sodium--every liter of sweat contains .6 grams of NA +. As such, it is prudent to consume sodium post-exercise, and during exercise (if performed long enough).

Drinks absent or containing little amounts of sodium post-exercise dilutes blood plasma, increase urine production (decreased fluid retention), and lower osmolarity. This further inhibits the thirst mechanism, and delays rehydration [8, 26, 32, 21, 22]

For example, an experiment was performed on six men following strenuous exercise in the heat [23]. Within 30 minutes after, they ingested one of four drinks (all with 2045 ml of water) with sodium concentrations of 2, 26, 52, and 100mmol per L of water, respectively. Those who had 2mmol of sodium excreted almost 800 ml of water 1.5 hours later and almost 1400 ml 5.5 hours later. The best results came with 100 mmol of sodium. Only 300 ml of water was excreted in the first 1.5 hours, and 500 in 5.5 hours--which is less than what those who had little sodium excreted in 1.5 hours!

Furthermore, the presence of glucose and sodium post-exercise greatly enhances intestinal fluid absorption over plain water, due to the Glucose/Sodium co transport system [23, 24, 25]. For much more on this and the benefits of sodium, study Dextrose, Maltodextrin, and Sodium an In Depth Analysis and Sodium - A comprehensive Analysis.

Practical applications are discussed further on.

Exercise Fever

A fever refers to abnormally high body temperatures. This usually occurs in response to invading microorganisms. Normal body temperature is 98.6 degrees F, however, this increases in response to chemicals called pyrogens, secreted by macrophages, and white blood cells exposed to bacteria and such like foreign substances. This response is due to the fact that bacteria requires large amounts of iron and zinc production to survive, but during a fever, the liver and spleen minimize production of these nutrients, making them less accessible. Additionally, fever speeds metabolic rate, increasing defensive actions and repair processes. Commonly during a fever, heat loss from the body surface declines, the skin becomes cool and shivering starts in order to generate heat. This is known as the "chills," a common sign of body temperature elevation. When temperature rises to its new setting, it is then maintained there until body defenses such as antibodies reverse the process back to a normal state. Once the thermostat is set to normal, the sweat mechanism begins, and skin becomes warm, a sign of decreased body temperature. Nervous system injuries, cancer, and allergic reactions can cause a fever as well.

Now, during exercise your body uses several thermoregulatory mechanisms such as sweat, and blood flow. When this becomes ineffective, temperature increases, causing a heightened metabolic rate, which further increases heat. Moreover, the skin becomes dry and hot. As temperature continues to rise, this may lead to heat stroke, a fatal condition in which brain damage can occur. This further supports the reason behind adequate hydration.

Injury of the nervous system can occur by water intoxification, a serious osmotic unbalance caused by excessive water intake, with little electrolytes or other foods. If you were to consume adequate amounts of water post-exercise but no electrolytes, your plasma and ICF would become hypo osmotic (low osmolarity). More water would move into your cells by osmoses to balance the ICF and ECF osmolarity. This is primarily a problem for the central nervous system inside your skull. The pressure buildup crowds the nervous system, causing dysfunctions such as headaches, and even more life-threatening conditions. This may be why the thirst mechanism does not promote complete liquid restoration, to limit severe osmotic imbalances. This again supports the benefits of sodium post-exercise, and in some scenarios, during.

Cramping

Cramping refers to sustained spasms or large, painful contractions of muscles, lasting a few seconds, minutes, or hours. Cramping causes the muscle to become hard, and is quite agonizing. This may reflect low blood sugar levels, dehydration, and/or electrolyte depletion. This again supports why workout nutrition is vital to your health, and fitness goals. If you happen to cramp, I would look at these three facets, and increase them immediately. Cramps may also be caused by spinal cord neuron aggravations.

Practical Applications

The following recommendations are centered on water and sodium in pre, during, and post-workout nutrition. For the complete package of exercise nutrition, you will need to read The Window of Opportunity and Dextrose, Maltodextrin, and Sodium an In Depth Analysis.

Pre-Workout Nutrition

About 500 ml of water should be taken within 30 minutes of your workout [4, 20, 33]. This is to help maintain a high gastric emptying rate, optimal pre-workout hydration, and elevated plasma levels, ready to assist thermoregulation via sweating, and blood flow.

During Workout Nutrition

The ability for the body to use ingested water depends on the rate of gastric emptying (the process of digesting and emptying food out of the stomach). Gastric emptying is influenced by fluid volume, caloric intake, and temperature. Only the first and last issues need to be covered during this section.

Gastric emptying is greatly influenced by its volume. Emptying rate decreases exponentially as fluid volume is depleted. Therefore, an effective way to speed up gastric emptying is by maintaining high fluid volumes in the stomach [8, 19, 27]. This will also optimize nutrient passage into the intestines (discussed more next). When you consume fluids, the rate of gastric emptying is speedy in the first few minutes, and then steadily slows down. To prevent this, you should consume small amounts of fluids frequently throughout your workout. Large amounts of water ingested quickly (such as 600 ml) during exercise, often causes gastrial intestinal distress. Around 400 ml of water can be cleared in 15 minutes for use, so with this information, it is recommended to have 200-400 ml of water every 15 minutes for ample hydration. [18, 34, 8].

Concerning fluid temperature, it was thought previously that gastric rate was speeded by cold beverages. Conversely, recent studies show the rate of digestion for cold and hot beverages is primarily the same [19]. Cold drinks are often preferred because they taste better, but a cold fluid does not add heat to the body, while a hot liquid does. As such, it has been suggested to keep your fluids at 59-72 degrees F [8].

During exercise lasting longer than 90 minutes, adding 500 mg of sodium per liter of water has been recommended [8, 19, 33].

Post-Workout Nutrition

Post-exercise supplementation is vital. Several nutrients must be consumed in this short period of time such as glucose, maltodextrin, and whey protein. The problem is, the more calories consumed, the slower gastric emptying is. However, having between a 2.5-10% carbohydrate solution has been shown to be almost equivalent in gastric emptying rate to just plain water [27, 9, 19]. Moreover, the glucose sodium co transport system greatly increases fluid absorption compared to plain water, as discussed previously. An additional 500 mg of sodium per liter of water should be ingested [8, 33, 18], and a 92% water solution (including carbohydrates and proteins). So, following the window of opportunity journal entry, a man with 200 pounds of LBM cutting would have 50 grams of protein, 50 grams of carbohydrates, 550 mg of sodium, and 1,250 milliliters of water post-workout.

Conclusion

As you see, staying properly hydrated takes hard work and extreme dedication. But what if I told you that you would never have to thirst again? And what if I told you this was for free? Only a fool would refuse such an offer! Thankfully, this gift is available--and all you have to do is accept it [1].

John 4:13-14

13 Jesus answered and said unto her, Whosoever drinketh of this water shall thirst again: 14 But whosoever drinketh of the water that I shall give him shall never thirst; but the water that I shall give him shall be in him a well of water springing up into everlasting life.

John 6:35

35 And Jesus said unto them, I am the bread of life: he that cometh to me shall never hunger; and he that believeth on me shall never thirst.

Revelation 22:17

17 And the Spirit and the bride say, Come. And let him that heareth say, Come.

And let him that is athirst come. And whosoever will, let him take the water of life freely.

Keep it Hardcore,

Venom

Executive of Bioenergetic Research

Venom@abcbodybuilding.com

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