Hydration Strategies for Exercising Dogs

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Introduction

The late Dr. Rolland Lombard is often credited with being the first competitive musher to realize the importance of watering his dogs during the racing season. During his day, most mushers believed that their dogs got all the water they needed by just eating snow. The dependence of performance upon good hydration is just one of the legacies left behind by the innovative and dominant force that was Rolland Lombard. Over the past 25 years, racing and research have demonstrated the benefits of providing working dogs with sufficient amounts of protein, fat, vitamins, and minerals. Still, a working dog may tolerate a dietary deficiency in one of these nutrients for several days or even weeks before any adverse effects on its performance or health are observed. In contrast, dehydration may lead to diminished performance and, in severe cases, even to death within hours of onset.

To understand why dehydration leads to such rapid and severe performance problems, one must first understand the many vital roles this important nutrient plays in the maintenance of nearly all body functions. A typical healthy dog has a total body water content of about 70% of its body weight. This water is divided into four compartments as shown in Table 1. Most (65%) of the total body water (TBW) resides within the individual cells of the dog's body.1 This water is the solvent in which all reactions of the cell take place. It thus facilitates the generation of energy, the synthesis of new cell materials, the storage of products, and the detoxification of wastes. Intracellular water is also the medium of transport for all materials within the cells.

Table 1. Division of total body water (TBW) content of a typical healthy dog.

Compartment	% Body Weight	% Total Body Water
Total Body Water	70	100
Intracellular	45	65
Extracellular	25	35
Interstitial	14	20
Plasma	7	10
Transcellular	4	5

The extracellular water is divided up between three spaces.[1] The interstitial space (20% TBW) is the second largest compartment; it represents the water which lies immediately outside of the cells and bathes them. The main role of the interstitial water is as a transport medium for nutrients and other materials into, and wastes and other products out of, the cells.

The plasma space (10% TBW) is the water found in the liquid or non-cellular part of blood. This water transports materials between all locations of the body. The transcellular compartment (5% TBW) is a conglomerate of all other extracellular spaces and is made up of the water found in the aqueous humor, the synovial fluid, the cerebral-spinal fluid (CSF), and the secretions of the gastrointestinal tract. This water acts as a medium for the passage of light and as a source of lubrication and shock absorption in the joints and CSF. In the GI tract it is a solvent for digestion and a transport medium to facilitate absorption of digested nutrients.

Under normal circumstances, water is free to shift between these compartments. The direction of that shift will depend on the conditions to which the body is exposed. During exercise for example, the metabolic changes occurring within the muscle cell increases the concentration of solutes or dissolvable particles within these cells. This increase in solute concentration causes water to move into the cell from the interstitial fluid.[2] This loss of interstitial fluid volume is then replaced by the movement of water from the plasma compartment into the interstitial space.[2] The result of exercise is thus an expansion of the intracellular compartment and a contraction of the plasma compartment. This fluid shift is in part responsible for the increased size of a weight lifter's muscles after a work out.[2]

The small loss of plasma volume that normally occurs during short bouts of exercise does not usually adversely affect performance. If exercise is prolonged, or if a dog is losing significant amounts of water through other means, the loss of water from the plasma may lead to a potentially dangerous contraction of plasma volume. As plasma volume diminishes, the heart has to work harder to circulate the blood because there is less fluid travelling through the vessels, and that fluid is more viscous.[3] The result of these changes is a decreased delivery of oxygen and nutrients to, and a slower rate of waste removal from, muscle cells. In this situation working muscle cells have less fuel available and accumulate wastes more rapidly, a combination which restricts the sustainable intensity and duration of exercise. In severe cases plasma volume contraction can lead to major organ failure and even death.[3]

Dehydration is almost always easier to prevent than it is to treat. Still, early recognition of the problem gives the dog the greatest chance for a rapid and complete recovery. As dehydration progresses from the mild to the moderate and severe states, the animal's ability to correct the problem on its own diminishes. Dogs suffering from advanced dehydration usually refuse to eat or drink. Such animals need veterinary attention immediately since loss of only 15% of TBW may result in death.[4] Correction of moderate and severe dehydration usually requires intravenous administration of fluids. Mildly dehydrated animals may be able to restore their water deficit by drinking but will often recover more rapidly if at least some of the fluid is replaced parenterally.

To prevent dehydration, one must try to balance the dog's daily water loss with its daily water intake and production. To achieve this goal one must first understand how water is added to and lost from a dog's body, and how each of these components of water balance change with changes in the dog's workload, environment, and health status. A dog may add to its total body water through its diet, by-drinking water, and by burning fuels for energy in its muscles. When a dog is fed a meat diet or a dry dog food soaked in water, 70—80% of what that animal eats is actually water. Water that is taken in as part of food is called "preformed water." Many sled dogs get half or more of their daily water intake from preformed water. Most of the rest of their daily water intake comes from drinking water and eating snow. A small amount of water is also generated when fats, carbohydrates, and proteins are converted to energy in the muscle.

For each 100 kcal of energy burned about 13 ml of water is generated and for each gram of muscle glycogen used, 3-4 ml of water are produced.5 Water produced in the body by these processes is referred to as "metabolic water." Metabolic water may contribute as much as 10% of the total water gained by a dog each day.

Usually, the amount of water gained each day by a dog is exactly balanced by the amount lost. Each day a dog loses water through its urine, feces, saliva, breath, and sweat. Unlike humans and horses, dogs do not lose much water due to sweating. In fact, the only place a dog sweats is through its foot pads. The dog's inability to sweat from the rest of its skin probably stems from its large surface area to volume ratio. Water loss from such a large surface area would put the animal at constant risk of dehydration if it perspired from its entire skin surface. In larger animals like humans and horses, a relatively small surface area and large volume inhibits heat dissipation. Dehydration due to sweating is less of a risk than heat accumulation in these larger animals.

Most of the water a dog loses each day leaves its body through urine, feces, respiratory vapor, and saliva. The contributions of each of these factors depend greatly upon the dog's health, environment, workload, and diet. For example, consider the same 20 kg (44 lb) sled dog as a sedentary house dog, a sprint racing dog, and a distance racing dog. Each day the house dog, living in a climate controlled environment, loses about 1000 ml of water through urine, about 100 ml of water through its feces, and about 300 ml of water through evaporation of respiratory water and saliva. If that dog is moved outside and he becomes an open class sprint racing dog, he will lose about 1500 ml of water through his urine and 150 ml of water through his feces. Assuming an ambient temperature of at least 0° F, this dog will also lose about 300 ml of water from evaporation during a one hour run and about 800 ml of water from evaporation during the remaining 23 hours of the day. If this dog now becomes a distance racing dog his water

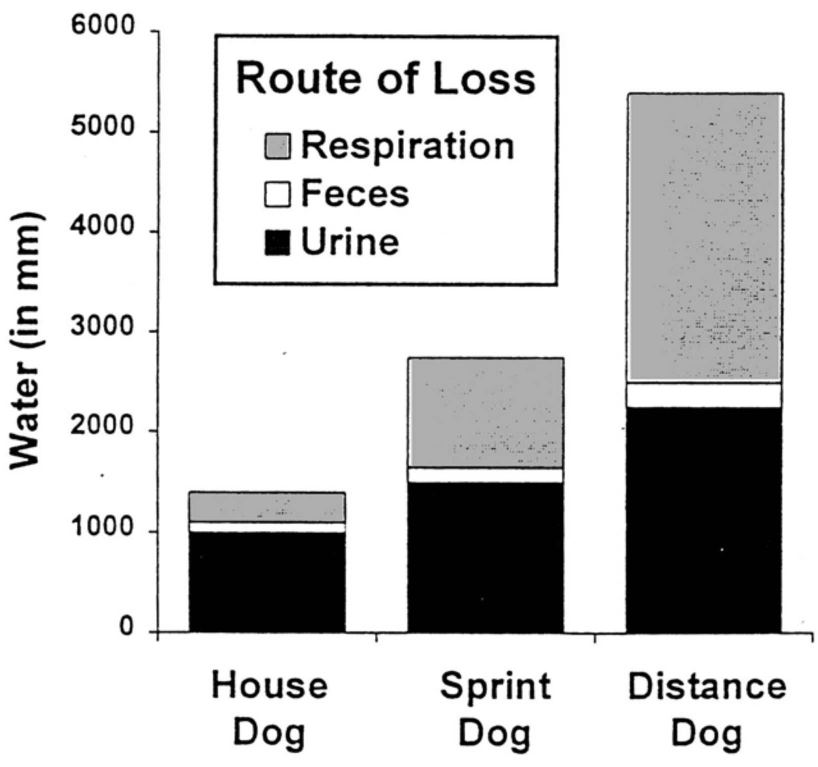

Figure 1. Amount and sources of daily water loss associated with exercise and environment.

loss to urine and feces will increase to about 2250 ml/day and 250 ml/day, respectively. Assuming he works 12 hours at about a 40% of VO2 maximum workload and rests 12 hours in an ambient temperature of-20° C or below, he will lose between 2000 and 2500 ml of water during exercise and about 400 ml of water during rest to evaporation from his mouth and respiratory tract. A summary of the water balance for these three dogs is shown in Figure 1.

The combination of exercise and living in a cold environment dramatically increases the dog's daily water requirement. The increase in this requirement is about 2-fold for the sprint dog and about 4-fold for the distance dog as compared to the house dog. The greater losses of urine and fecal water seen in working dogs are mostly due to their increased food intake. A greater food intake leads to an increased production of feces which are usually 80-90% water. More food also means the generation of more metabolic wastes which must be filtered by and excreted from the kidneys. The excretion of these additional wastes results in an increased urine volume and consequently a greater urinary water loss.

The most remarkable increase in water loss observed in working dogs is due to the increase in evaporation from the mouth and respiratory tract. Depending on the dog's exercise intensity, and the environmental temperature and humidity, evaporative water losses may increase 10- to 20-fold during exercise.6 At cold temperatures, the air a dog breathes in has very little moisture in it. When this cold air reaches the lungs it is saturated with water so that about 6% of every exhaled breath is water. In warm climates the inhaled air is more nearly saturated with water and so the dog loses less water from its lungs with each breath. However, since dogs pant to cool themselves off, water loss through the evaporation of saliva often leads to evaporative losses in warm conditions equal to or in excess of those seen in cold environments.[7]

The numbers given above are estimates for specific cases, but they give an idea of the influence that exercise and environment have on a dog's daily water requirement. Health problems may also greatly influence daily water loss. Urinary water losses increase dramatically in renal disease, systemic infections, diabetes, and other hormonal abnormalities. Most of these dogs are sick enough that they would not be able to perform as sled dogs and would require veterinary attention. Increased water loss from the gastrointestinal tract is more common and often less serious. Nearly all kennels experience stress diarrhea and the "flu" during the course of a season. Often, dogs will continue to perform well with these conditions as long as their hydration can be maintained. However, the rate of dehydration resulting from severe diarrhea, as in the case of parvovirus infection, can be a life threatening situation. The severity of the situation can usually be assessed by the frequency and volume of fluid eliminated. In any case the fluid lost through the feces must be replaced or the dog's health will deteriorate rapidly.

The factors which contribute to water loss in the dog are complex and constantly changing. If one had to exactly calculate a dog's daily water requirement in order to hydrate it properly, it would be nearly an impossible task. Fortunately nature has designed a complex system to regulate water intake and output, thus allowing the dog to maintain hydration across a wide range of environmental conditions. As a dog's plasma begins to lose water, the increase in concentration of salts is detected centrally, triggering thirst.[8] Since it takes some time for water to be absorbed into the plasma, the quenching of thirst does not immediately rely on the return of salt concentrations to normal. Instead, stretching in the stomach and a drop in throat temperature are the signals that lead to thirst satiation.[3] This system is so well tuned that a healthy dog will adapt to changes in water loss just as quickly as these changes occur. Theoretically, the dog will drink as much as it needs as long as water is available when it is thirsty.

Therein lies the problem of keeping sled dogs well hydrated. They are not always thirsty when water is available, and water is not always available when they are thirsty. For this reason strategies were explored that would promote hydration in these specialized athletes. For years mushers have tried to encourage relatively large amounts of water consumption during the relatively short periods of time that water could be made available by flavoring the water with palatable additives. This technique, known as “baiting the water”, has proven to be successful under all but the most severe environmental and racing conditions.

Recently there has been much attention focused on the use of glycerol containing solutions to hyperhydrate human endurance athletes performing in hot, humid environs.9’10’” Glycerol acts as a hydrating agent because it is osmotically active, rapidly absorbed, and freely crosses all cell membranes.12 Compared to subjects ingesting an equal volume of water alone, cyclists consuming dilute glycerol solutions prior to exercise in hot and humid conditions have exhibited an increased sweat rate, decreased rectal temperature, and decreased urine output. Time to exhaustion was also significantly greater in the glycerol treated cyclists.

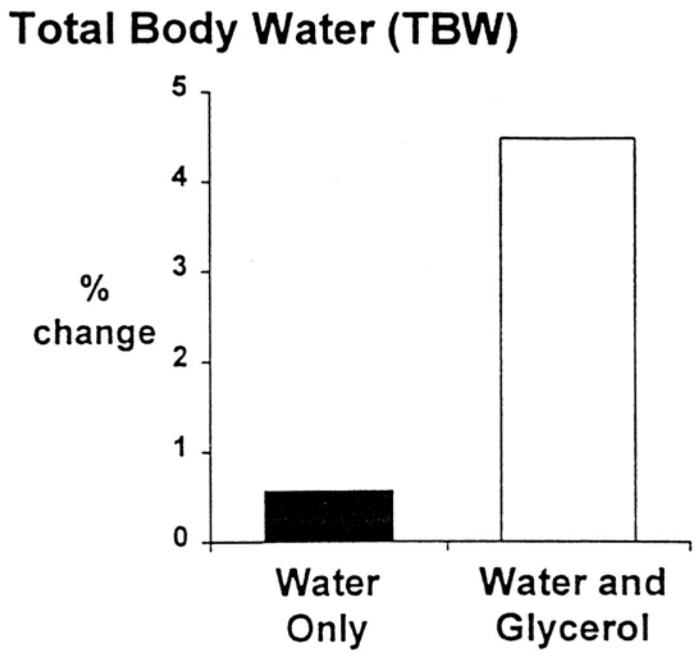

Figure 2. Percentage change in total body water (TBW) in sedentary dogs three hours after ingestion of 1 L of water or 1 g/kg body weight glycerol in 1 L water.

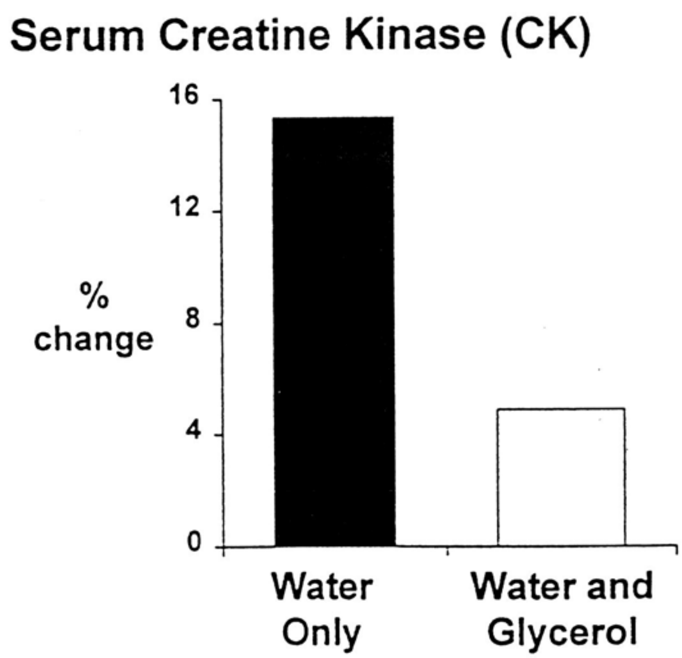

Figure 3. Percentage change (pre to post fluid ingestion) in serum creatine kinase (CK) values measured in sedentary dogs three hours after ingesting 1 L of water or 1 L of water with 1 g glycerol/kg body weight.

The ingestion of glycerol containing solutions has been shown to result in a state of hyperhydration.[13-14] “Water loading”, as this practice is often referred to as, has been achieved in both human and rat models. The effect of a single loading dose may increase total body water up to 5% for as long as 48 hours.[14]

The mechanism by which this hyperhydrated state is achieved has yet to be determined. One recent study has found that glycerol containing solutions increase anti-diuretic hormone secretion and increase renal medullary concentration gradient.[15] The hyperhydrated state may thus be mediated through a decrease in urinary water loss.

Critics of glycerol induced hyperhydration note the risk of gastrointestinal upset and the potentially serious risk of excessive cellular swelling that may result from the practice.[16] Indeed, fatal rhabdomyolysis and acute renal failure have been induced in rats given massive oral doses of glycerol.[16] The solutions used in the studies noted above were moderate doses and ranged from 1 to 5%; they were not associated with any significant side effects.

Recently three studies were undertaken to evaluate the effect of glycerol supplementation on the hydration status of working sled dogs. In the first study, the effects of a single loading dose of a glycerol solution (l liter of 1% glycerol) versus an equal volume of water on total body water (TBW) in 8 sedentary dogs was examined. Using a deuterium oxide dilution technique, it was found that glycerol ingestion significantly increased TBW (Figure 2) without increasing creatine kinase concentration (Figure 3) or altering any measured parameter on a serum biochemistry panel or a complete blood cell count analysis. Once it was established that glycerol solutions could induce a hyperhydrated state, the safety and efficacy of such a treatment for dogs exercising in cold and dry or warm and humid environs was investigated. In the cold weather study two age, ability, and sex matched groups of 12 dogs each were given either 1 L of a 1% glycerol solution or 1 L of water two hours prior to a 30 mile run. This procedure was repeated for three days. Immediately after and six hours after each run all dogs were given access to 1 L of baited water. Blood samples for TBW, hematocrit, and serum chemistry analysis were drawn immediately before the first administration of fluid on day 1 and after the last bout of exercise on day 3. The ambient temperature during the experiment averaged -35° C. The dogs receiving the glycerol solution maintained their hydration at pre-exercise levels while those receiving just water became approximately 3% dehydrated (Figure 4). There was no difference in creatine kinase concentrations between the two treatment groups at any time in the study.

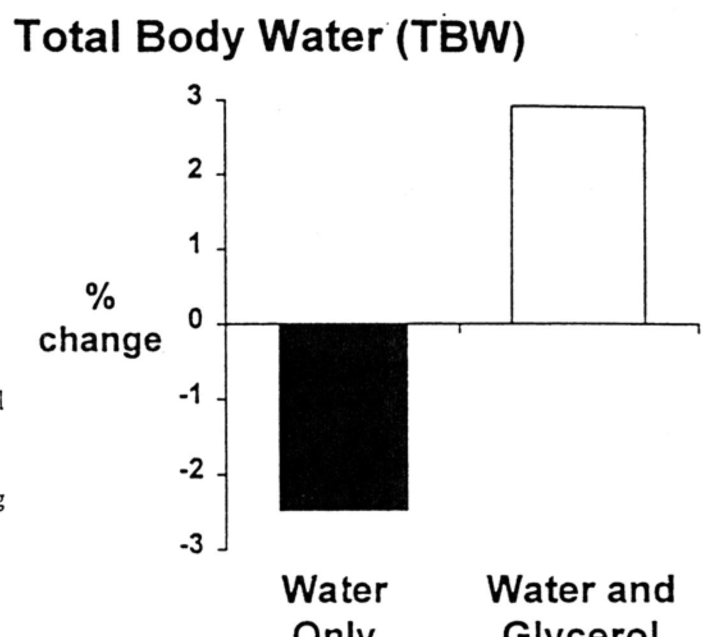

Figure 4. Percentage change in total body water (TBW) after a three day exercise period in which dogs were given water only or water with 1 g/kg body weight glycerol.

In the warm weather study, 2 groups of 8 dogs each were treated and measured as described above for the cold weather study, except that they were exercised on a hot walking wheel in a warm (25° C), humid (85% relative humid-icy) environment until their rectal temperature reached 41° C. Data from the warm weather study is still being collected and analyzed at this writing. The results of this study will be available at the time of the 1998 lams Nutrition Symposium.

The results of the first two studies have indicated that ingestion of a dilute glycerol solution is a safe and effective way to induce a mild state of hyperhydration in the dog. The degree of hyperhydration achieved did not have any observable adverse effect on gastrointestinal, renal or muscle function and may instead help these animals maintain hydration while exercising under extreme environmental conditions. These findings may also have clinical applications in the formulation of oral rehydrating solutions. Due to the long lasting effect of glycerol on hydration, glycerol solutions may promote a greater and longer lasting state of rehydration than is presently achievable from standard glucose electrolyte solutions. Further research will undoubtedly clarify the role of glycerol supplementation in the clinically dehydrated patient.

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