THE BASICS OF CANINE HYDRATION:

WHAT HEALTHY DOGS NEED AND WHY

ABSTRACT

Although it is well-understood that life cannot exist without water, the effect of water intake on health remains an area of active scientific research. This article is intended to provide an overview of how water regulation differs in humans and dogs, with a focus on the physiology of canine dehydration and overheating—conditions that can quickly become life-threatening. We will discuss current knowledge of canine hydration needs, summarize recent research on novel strategies for improving canine hydration, review special considerations for hydration across the canine lifespan, and highlight canine health conditions for which special attention is merited.

INTRODUCTION: WHY WATER MATTERS

Water is essential for life. The health and physiology of every living creature on earth depends on molecular processes uniquely enabled by water (Armstrong and Johnson, 2018; Jequier and Constant, 2010). The regular intake of food, water, and nutrients enables the complex biochemistry that keep animals alive. Water is a building material, solvent for metabolism, a carrier of nutrients and waste, an essential component of thermoregulation in multiple species, and a lubricant for joints and general shock absorber for the mechanical forces experienced by bodies in motion (**Figure 1**)(Jequier and Constant, 2010).

FIGURE 1. WHY WATER MATTERS: IMPORTANT ROLES FOR HYDRATION IN HEALTH

BUILDING MATERIAL

Water is the primary material in every cell of the body. The need for water is higher during periods of growth and development.

SOLVENT FOR METABOLISM

Water acts as a medium and reactant for biochemistry involved in hydrolysis of dietary macronutrients for energy (carbohydrates, fat, and lipids). It is also produced from oxidative metabolism.

CARRIER FOR NUTRIENTS AND WASTE REMOVAL

Cellular homeostasis relies on water to transport nutrients to and wastes away from cells. It is also the means by which substances are exchanged among the cellular compartment, the interstitial space, and the vasculature. All organ systems depend circulation of blood in the vascular compartment; adequate hydration to function properly.

THERMOREGULATION

The high heat capacity of water within the body limits rapid changes in temperature when the environment becomes cold or hot. The high heat of vaporization of water allows for evaporative cooling in hot environments.

LUBRICANT AND SHOCK ABSORBER

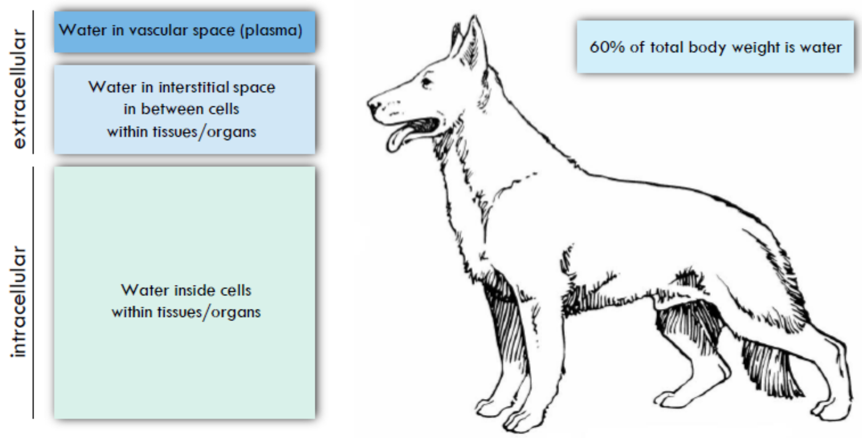
Water within the body acts as a lubricant in joints and shock absorber when running or walking. Water and other substances form mucus which provides an immune barrier on the epithelium lining the digestive, respiratory, and genitourinary tracts.

This article outlines the basics of how water is regulated in healthy dogs to support the cells, tissues, and organ systems that coordinate the functions that support life. A generic overview of electrolytes and other nutrient categories will be briefly discussed. Critical differences between how water is regulated in dogs vs. humans will be highlighted, especially with respect to dissipation of metabolic heat; then, dehydration and its consequences will be described. Water requirements to prevent dehydration will be reviewed. The hydration and nutrient needs across the canine lifespan will discussed with attention to recent scientific evidence that flavored oral solutions supplemented with electrolytes and nutrients can improve hydration, health, and performance. Lastly, we will briefly discuss health conditions in dogs that can affect water and electrolyte balance. These animals may benefit from individualized strategies for hydration support in consultation with a veterinarian.

NORMAL WATER REGULATION IN DOGS: HOW ELECTROLYTES AND NUTRIENTS SUPPORT HEALTH

Water makes up ~60% of the weight of healthy, non-obese animals and is divided into different compartments or spaces (Jequier and Constant, 2010)(**Figure 2**). Water will either be found inside cells (the intracellular compartment/space) or outside cells (the extracellular compartment/space). Water outside cells can be further divided into the intravascular fluid compartment (the contents of blood vessels) and the interstitial fluid compartment (the space in between cells within tissues or fluid free in body cavities). These compartments differ with respect to contents and function (James and Lunn, 2007). The intracellular compartment is the largest, with 2/3 of the total body water. The remaining 1/3 of body water is found in the extracellular compartment, which includes both the interstitial and vascular compartments.

FIGURE 2. BODY FLUIDS ARE DISTRIBUTED ACROSS DIFFERENT COMPARTMENTS IN THE DOG



Electrolyte levels differ in different water compartments. Extracellular fluid has high sodium and chloride and low potassium. The intracellular compartment is high in potassium but not sodium or chloride. Dog drawing (Evans and Miller, 1993)

The intravascular compartment contains blood, the delivery system for every cell in the body's essential needs. Blood contains red blood cells which carry oxygen, white blood cells which help the body respond to pathogens and damage, and the liquid portion is plasma, which contains water and solutes (e.g. electrolytes, minerals, sugars, proteins, amino acids, enzymes, immune system antibodies, clotting factors, and other organic and inorganic substances) that support normal cell function. The vasculature is the delivery system to all the cells within the tissues and organs that make up the rest of the body.

Electrolytes and other substances in the serum (plasma without the blood clotting factors) are often measured as an indicator of whole-organism health (Duncan and Prasse, 2011; Stockham and Scott, 2008):

- *Sodium*. Maintains extracellular fluid osmolality and essential for kidney water retention, a key function in maintaining hydration status. The movement of sodium between extracellular compartments is frequently associated with movement of water due to changes in osmotic forces. In health, the extracellular fluid has high levels, and the intracellular fluid has low levels.

- *Potassium*. Maintained within narrow limits for normal cardiac and neuromuscular functions. In health, the intracellular fluid has high levels the extracellular fluid has low levels.

- *Chloride*. The major anion in the extracellular fluid balancing the positive charge of sodium. Many secretions have chloride as a component, including gastric fluid, sweat, and saliva. In health, the extracellular fluid has high levels the intracellular fluid has low levels.

- *Magnesium*. Acts as a cofactor for the function of many enzymes.

- *Calcium*. Important in bone formation, neuromuscular function, clotting of blood, and biochemical functions of cells.

The regular intake of food, water, and nutrients in combination with the oxygen-dependent cellular respiration enables the complex biochemistry that keep animals alive. The distribution of solutes across the fluid compartments relies on osmotic forces, Starling's forces, and active transport (James and Lunn, 2007). Cells spend a lot of energy actively pumping electrolytes against their concentration gradients across membranes separating the different fluid compartments to maintain homeostasis and normal function. The chemical reactions that support cellular function are tightly restricted to an optimal temperature and pH. The chemistry underlying water, electrolytes, and acid-base interactions and their role on health is complex (Duncan and Prasse, 2011; James and Lunn, 2007; Nelson and Couto, 2020; Stockham and Scott, 2008).

Normal daily water intake for healthy dogs at maintenance (no excessive physiological demands, no illness, and/or no environmental/exercise-induced heat stress) can be found in **Table 1** (see next page). In such conditions, water is lost in urine and feces, and to a much lesser extent, via evaporation from the respiratory tract and footpads. Water loss via the respiratory tract will increase when there is a demand on a dog's body to dissipate heat—this is recognizable to dog owners as panting.

TABLE 1. NORMAL DAILY MAINTENANCE WATER REQUIREMENTS OF THE DOG. BASED ON A METABOLISM FORMULA OF 132 KCAL*KG0.75. ADAPTED FROM NUTRITIONAL REQUIREMENTS OF THE DOG, NATIONAL RESEARCH COUNCIL, BETHESDA, MD, 1995

Body weight		Daily maintenance requirement		Hourly maintenance requirement	
kg	lbs	kcal/day or water in ml/day	water in 8-ounce cups/day	ml/hour	ounces/hour
1	2.2	132	0.6	6	0.2
2	4.4	222	0.9	9	0.3
3	6.6	301	1.3	13	0.4
4	8.8	373	1.6	16	0.5
5	11.0	441	1.9	18	0.6
6	13.2	506	2.1	21	0.7
7	15.4	568	2.4	24	0.8
8	17.6	628	2.7	26	0.9
9	19.8	686	2.9	29	1.0
10	22.0	742	3.1	31	1.0
11	24.2	797	3.4	33	1.1
12	26.4	851	3.6	35	1.2
13	28.6	904	3.8	38	1.3
14	30.8	955	4.0	40	1.3
15	33.0	1006	4.3	42	1.4
16	35.2	1056	4.5	44	1.5
17	37.4	1105	4.7	46	1.6
18	39.6	1154	4.9	48	1.6
19	41.8	1203	5.1	50	1.7
20	44.0	1248	5.3	52	1.8
21	46.2	1295	5.5	54	1.8
22	48.4	1341	5.7	56	1.9
23	50.6	1386	5.9	58	2.0
24	52.8	1431	6.0	60	2.0
25	55.0	1476	6.2	62	2.1
26	57.2	1520	6.4	63	2.1
27	59.4	1563	6.6	65	2.2
28	61.6	1607	6.8	67	2.3
29	63.8	1650	7.0	69	2.3
30	66.0	1692	7.2	71	2.4
35	77.0	1900	8.0	79	2.7
40	88.0	2100	8.9	88	3.0
45	99.0	2293	9.7	96	3.2
50	110.0	2482	10.5	103	3.5
55	121.0	2666	11.3	111	3.8
60	132.0	2846	12.0	119	4.0
70	154.0	3194	13.5	133	4.5
80	176.0	3531	14.9	147	5.0
90	198.0	3857	16.3	161	5.4
100	220.0	4174	17.6	174	5.9

DIFFERENCES BETWEEN DOGS AND HUMANS: HEAT DISSIPATION AND ELECTROLYTE LOSS

Panting is a strategy for heat dissipation that dogs share with other mammals, but not humans. Sweating is uniquely human. The profound difference in the physiology of heat dissipation between dogs and humans has critical implications regarding different hydration and electrolyte replacement needs between the species. Panting is a type of rapid breathing that enables heat dissipation through evaporation (Baker, 1984b). Air is warmed and humidified upon intake. Heat is dissipated and water is lost through evaporation when the dog breathes out. The limitation on heat loss is the amount of air that the dog moves through the respiratory tract. This is what creates and drives the rapid breathing that we humans observe as panting. More vigorous exercise generates more metabolic heat. In dogs, this results in panting harder to dissipate more heat, and dogs are exceptional at this.

In humans, heat dissipation involves profuse sweating with subsequent evaporative cooling, salt loss, and flushing of the skin as the cutaneous vasculature dilates to dissipate heat more efficiently. Dog skin not only lacks sweat glands and a robust network of cutaneous blood vessels (with the exception of footpads for maintenance of pliability and traction (Ninomiya et al., 2011)), but also is covered by a layer of hair that provides insulation from the environment (Pavletic, 1991).

DEHYDRATION AND ITS CONSEQUENCES

In health, fluid loss is typically restricted to urine, feces, and some losses from respiratory tract and footpad evaporation. Mild changes in hydration status of working dogs after a 15-minute exercise period are clinically detectable by assessing skin turgor (Goucher et al., 2019). Mild dehydration (5%) may also be characterized by dry mucous membranes, while moderate dehydration (6%-8%) increases heart rate (Tello and Perez-Freytes, 2017). More intense dehydration reduces performance in exercising dogs (Baker, 1984a; Baker, 1984b). Severe dehydration (8%-10%) will impact pulse quality and capillary refill time (Tello and Perez-Freytes, 2017). Electrolyte loss and dehydration from any cause can become *life threatening,* with serious clinical signs including hypotension, hypothermia, weak to absent pulses, cold extremities, and/or altered mentation (Tello and Perez-Freytes, 2017).

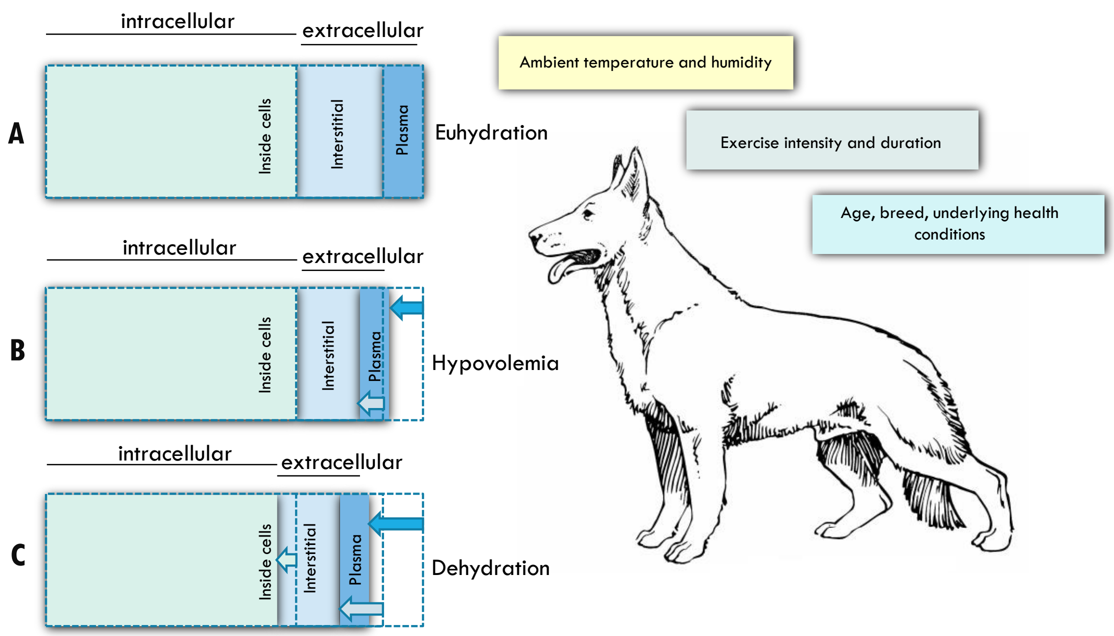
Veterinarians are trained to think about fluid status on the basis of the different compartments (**Figure 3A**) because appropriate fluid therapy—both with respect to the electrolyte composition of the fluid needed and the rate at which it is administered—differs with different causes of fluid loss (Duncan and

NEED-TO-KNOW

- Humans sweat. Dogs pant.
- Sweating humans lose both water and electrolytes (volume depletion).
- Panting dogs lose primarily water (dehydration).

Prasse, 2011; James and Lunn, 2007; Langston, 2017; Lee and Cohn, 2017; Stockham and Scott, 2008; Tello and Perez-Freytes, 2017). The term *dehydration* can create confusion because it is sometimes used to describe a loss of extracellular fluid volume, a condition more accurately called *volume depletion* or *hypovolemia* (**Figure 3B**). It occurs when there is a loss of total body sodium (recall that almost all of the body's sodium is in the extracellular fluid), which can happen with conditions including (but not limited to) vomiting, diarrhea, bleeding, excessive sweating (in people), or kidney failure. Technically, *dehydration* occurs if there it is a loss of total body water, which also produces hypertonicity (an increased concentration of electrolytes). This leads to a homeostatic contraction of the intracellular fluid compartment as osmotic forces move water out of the intracellular space to reduce hypertonicity in the extracellular space (**Figure 3C**).

FIGURE 3. SCHEMATIC OF VARIABLES AFFECTING NORMAL WATER BALANCE



Normal hydration (A), volume depletion (B), and dehydration (C) . Arrows show losses of water from different compartments. Dog drawing (Evans and Miller, 1993).

HYDRATION ACROSS THE CANINE LIFESPAN: NEW STRATEGIES AND UNMET NEEDS

Strategies to define and fulfill hydration needs across the canine lifespan and in different health and environmental conditions represents an area of active research (Baker, 1984a; Baker, 1984b; Goucher et al., 2019; Niedermeyer et al., 2020; Otto et al., 2017; Sollanek et al., 2019; Stephens-Brown and Davis, 2018; Zanghi and Gardner, 2018; Zanghi et al., 2018). In part, this is to better prepare animal professionals to mitigate health risks when undertaking routine or extreme activities. Interestingly, there is no universal scientific consensus on what the daily water needs are in either dogs or humans (Armstrong and Johnson, 2018), because so many variables can affect heat tolerance and increase water need beyond the maintenance levels listed in **Table 1**, including but not limited to breed, age (Larsen and Farcas, 2014; Lee and Cohn, 2017), ambient temperature, humidity, activity level, body composition, diet, conditioning, and acclimatization (**Figure 3**)(Otto et al., 2017).

A promising approach to address hydration needs involves oral electrolyte solutions. Oral rehydration solutions are specifically formulated with an osmolality to optimize fluid absorption (Sollanek et al., 2019). Co-administration of fluid and sodium with a monosaccharide or amino acid improves hydration in non-vomiting animals with otherwise healthy gastrointestinal tracts (Nelson and Couto, 2020; Tello and Perez-Freytes, 2017). Importantly, human electrolyte replacers are usually *too high in sodium* for dogs because dogs are not losing salt to sweat. Dogs are losing total body water when they exercise, which increases water requirements and daily water turnover (Stephens-Brown and Davis, 2018).

Several studies have evaluated dog-appropriate oral electrolyte formulations and found promising results:

- Dogs acclimated to work and the environment were more likely to increase fluid consumption and hydration when provided a flavored oral electrolyte solution (Otto et al., 2017).

- Dogs increase water intake when offered nutrient-enriched water (Zanghi and Gardner, 2018).

- Oral pre-exercise hydration strategies for working dogs in hot environments (water, chicken-flavored water, and chicken-flavored electrolyte solution) suggested that electrolyte enrichment may reduce muscle injury and help dogs maintain lower peak temperatures (Niedermeyer et al., 2020).

- Access to nutrient-enriched water reduced exercise-induced hyperthermia and improved pulse rate recovery in a population of working dogs (Zanghi et al., 2018).

- There is some evidence that oral electrolyte rehydration may be safe and improve mild to moderate dehydration associated with hemorrhagic diarrhea in dogs, with the added benefit of reducing owner-related veterinary costs and decreasing staff time associated with treatment (Reineke et al., 2013).

Young animals need more fluid compared with adults and can be more prone to rapid development of serious dehydration, low blood sugar, and electrolyte disturbances (Lee and Cohn, 2017). Improved oral hydration strategies for this age group could improve outcomes because their small size can make vascular access technically challenging and increase the risk of overhydration.

Old dogs are also more likely to be afflicted with certain disease conditions that may be amenable to nutritional intervention; however, for safety and best outcomes it is recommend to obtain an individualized nutritional assessment and monitoring plan under veterinary supervision (Larsen and Farcas, 2014).

There are some conflicting viewpoints within the field of veterinary medicine regarding the utility of oral electrolyte solutions under different conditions. For example, an older widely-cited of review of nutrition for working and service dogs did not recommend electrolyte supplementation based on 1) electrolyte deficiencies are not typically reported for dogs fed AAFCO-approved diets and 2) a citation of two studies that indicated either no benefit or increased rates of post-activity diarrhea (Mazin et al., 2001; Wakshlag and Shmalberg, 2014; Young et al., 1960).

The study concluding no benefit involved urban search and rescue dogs performing a behavioral task. The authors acknowledged they only looked at one electrolyte formula and that results should not be overinterpreted to include all possible electrolyte solutions. Dogs offered the chicken-flavored electrolyte solutions did, in fact drink more; however, the study endpoint was a behavioral parameter that showed no benefit. Therefore, the authors concluded that oral electrolyte solutions would not justify additional expense and distribution burdens (Mazin et al., 2001).

The electrolyte solution given in the 1960 study was intended to mimic the electrolyte balance of milk, which can cause diarrhea when given to dogs in volumes more than a few tablespoons. Other limitations of the study that make it difficult to compare with more current studies include limited sample size (two dogs per treatment group) and different test conditions. In the 1960 study, adult male beagles were pushed beyond maximal performance by hours of exhaustive treadmill running, a very intense physical stressor. The results of the study support conclusions of more contemporary work:

> *The results described…agree with our earlier data in demonstrating an important relationship between nutrition and performance. In terms of physiological priority, water appears to be the most essential of all ingested nutrients. Within the range of 0-1.6 L [liters] of water, work performance is a positive function of the fluid intake. Water requirements during work may be modified by several nutritional parameters, including the effect of excessive body weight or adiposity. In overweight dogs the water loss during work is significantly increased (Young et al., 1960).*

This study supports the importance of proper hydration for the modern dog population given its high prevalence of obesity (30-50% depending on source).

Recent studies show that oral electrolyte solutions are safe and effective in improving hydration because dogs drink more when offered them. An effective oral hydration strategy is the best defense again heat stress. Additionally, oral electrolyte solutions improve performance, minimize muscle injury, and enhance post-exertional recovery.

HEALTH CONDITIONS AFFECTING WATER BALANCE: SPECIAL CONSIDERATIONS

As mentioned previously, there are a significant number of health conditions that can impact fluid and electrolyte balance. It is recommended that pet owners and animal handlers get annual health checks and clearance from a veterinarian to ensure dogs are healthy before engaging in demanding activity. It is best to discuss an individualized hydration and nutrition strategy for any canine athlete or working dog expected to experience extreme activity and heat stress. Any dog with an underlying health issues should be evaluated by a veterinarian to ensure activity levels are unlikely to exceed the animal's health resources.

Examples of factors and health conditions that can affect water and electrolyte balance:

- Dehydration in working dogs can be affected by diet effects on metabolism
- Brachycephalic syndrome (breed-specific heat stress due to inefficient respiration)
- Vomiting/Diarrhea
- Trauma/blood loss
- Kidney disease
- Endocrine disease

For these and other conditions, special consideration is merited, and a veterinarian should be consulted before using products that could affect fluid and electrolyte status.

SUMMARY

This review has provided an overview of the importance of water to canine health. The rationale for studying oral electrolyte solutions in dogs is based on clear evidence that water absorption is *enhanced* with the addition of sugar, amino acids, and electrolytes. While plain water can address hydration needs, evidence suggests that dogs drink more total water when offered an oral electrolyte solution *in addition to* plain water. Additional data are needed to better understand what health circumstances are best met by oral electrolyte solutions as a hydration approach. Formulations may need to be individualized to address specific health needs, which include but are not limited to hydration for heat stress during exercise, and common clinical situations such as vomiting and diarrhea, where more aggressive measures (such as IV or subcutaneous fluids) are either not available or economically feasible.

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