Water Homeostasis and Diabetes Insipidus in Horses

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KEYWORDS

- Polyuria • Polydipsia • Primary polydipsia
- Water-deprivation test • Desmopressin
- Pituitary pars intermedia dysfunction

Diabetes insipidus (DI) is a rare disorder of horses characterized by moderate to severe polyuria and polydipsia (PU/PD). Before the problems that may result in DI are discussed, a review of body water balance and factors affecting water intake and renal water loss is warranted.

BODY WATER BALANCE

Water accounts for 60 to 65% of total adult body mass, equivalent to 300 to 325 L in a 500-kg horse.[1–3] About 200 to 220 L of total body water is intracellular fluid, and the remaining 100 to 110 L is extracellular fluid (ECF). ECF is divided between plasma (5–6% of body weight, ∼25 L), interstitial fluid and lymph (8–10% of body weight, ∼45 L), and transcellular fluid (6–8% of body weight, ∼35 L, the majority in the lumen of the gastrointestinal tract). Despite marked differences in ionic composition, ECF and intracellular fluid compartments exchange water freely to maintain osmotic equilibrium.[1–4]

Appropriate water balance maintains plasma osmolality (P_{osm}) in a narrow range (270–300 mOsm/kg) and is achieved by matching daily water intake with water loss.[1,4–6] Water is provided from 3 sources: (1) free water intake (drinking); (2) water in feed; and (3) metabolic water. For horses on a dry forage (hay) diet, most water is consumed by drinking (about 85%), but feed and metabolic water provide about 5% and 10% of daily water, respectively. Water can be lost by 3 routes: (1) in urine; (2) in feces; and (3) as insensible losses (evaporation) across the skin and respiratory tract. Studies of water balance in horses have revealed a daily maintenance water requirement of 55 to 65 mL/kg/d, of which 45 to 55 mL/kg is provided by drinking, equal to 22.5 to 27.5 L/d for a 500-kg horse.[5,6] These values are consistent with the recommendation that stalled horses under temperate environmental conditions should be provided with 5 to 10 gallons of fresh water daily.[7] Urinary and fecal water

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losses range from 20 to 55% and 30 to 55%, respectively, of the total daily water loss.[5,6] The remaining (insensible) loss accounted for up to 15 to 40% of daily water loss, despite mild ambient conditions and the lack of sweating in these studies of water balance. In contrast to horses consuming hay diets, horses grazing pasture acquire most water from feed and may drink only once a day (or less frequently). Further, the maintenance water requirement of horses that are off feed because of a variety of medical problems is considerably lower; horses receiving intravenous fluid support at a rate of 0.75 to 1.0 mL/kg per hour (9–12 L/d for a 500-kg horse) consistently produce moderately dilute urine (specific gravity 1.010–1.020).

Although balance of daily water intake and output is critical for maintenance of homeostasis, it warrants mention that equidae tolerate water deprivation.[8–11] For example, after horses were deprived of water for 72 hours (which resulted in body mass loss in excess of 10%), most of the weight lost (90% of which was assumed to be water) was recovered within the first hour of being provided with access to water.[11] Similarly, even greater body mass losses (approaching 20%) induced by water deprivation and desert walking in donkeys and burros were largely replaced within the first few minutes after water was provided.[9,10] Thus, in terms of water balance, equidae (especially donkeys and burros) can truly be considered desert-adapted animals.[9,10,12,13] An important reason for their ability to tolerate water deprivation seems to be a substantial intestinal reserve of water and electrolytes (transcellular fluid) that can be called on during periods of dehydration for the maintenance of plasma and effective circulating volumes.

CONTROL OF BODY WATER BALANCE

Drinking and production of concentrated or dilute urine are the mechanisms by which water balance is finely tuned. Both thirst and renal water conservation are triggered primarily by increases in plasma osmolality (P_{osm}) (directly related to plasma sodium concentration) and secondarily by decreases in effective circulating volume and blood pressure. The initial response to a mild increase in P_{osm} is secretion of arginine vasopressin (AVP or antidiuretic hormone) from the neurohypophysis, resulting in enhanced renal water conservation, whereas thirst, resulting in drinking, is a secondary response to even greater increases in plasma tonicity (**Fig. 1**). Despite being a less sensitive defense to a decrease in total body water, thirst and drinking responses are reviewed first.

Thirst and Drinking Behavior

There are 2 main stimuli for thirst in mammals: increased P_{osm} and hypovolemia/hypotension.[4,14] The former is mediated through osmoreceptors in the anterior hypothalamus that have a high threshold for activation (about 295 mOsm/kg in humans). Hemodynamic stimuli are mediated by afferent input to hypothalamic osmoreceptors from both low- and high-pressure baroreceptors. Both osmotic and hemodynamic stimuli can produce their dipsogenic effect, in part, by activating a local renin-angiotensin-aldosterone system in the central nervous system.[4,14,15] Studies in horses, ponies, and donkeys have shown that both increased P_{osm} (induced by water deprivation or infusion of hypertonic saline) and hypovolemia (induced by furosemide administration) are stimuli for thirst.[16–20] As mentioned earlier, after a period of water deprivation, dehydrated equids seem to be able to replace water deficits within 15 to 30 minutes of gaining access to water. The increase in P_{osm} associated with water deprivation is also corrected in this same period, indicating that imbibed water is rapidly absorbed from the gastrointestinal tract.[16] Drinking also seems to directly