Strategies to Increase Voluntary Drinking After Exercise (21-Nov-2003)

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Abstract

Voluntary drinking during early recovery from prolonged exercise is important for replacement of water and electrolytes lost in sweat, especially when horses may be transported shortly after finishing a competition. In a series of studies, we have found that offering horses an initial drink of salt water at 20ºC, followed by plain water at 20ºC, is an effective strategy to increase the total volume of fluid imbibed during the first hour of recovery from exercise.

1. Introduction

Replacement of water and electrolytes lost in sweat during prolonged exercise is important for continued work as well as for prevention of medical problems that may develop during exercise or in the early recovery period. However, both human and equine athletes fail to completely replace body fluid losses by voluntary drinking during the first few hours of the recovery period, despite free access to various rehydration solutions [1,2]. This condition, measured as persisting body weight (BW) loss, has been termed both "voluntary dehydration" and "involuntary dehydration" and has been attributed to blunted thirst [3,4].

Because sweating results in loss of both water and electrolytes, exercise-induced dehydration results in lesser increases in plasma osmolality and sodium concentration ([Na+]') than dehydration induced by water deprivation. Because the primary stimulus for thirst is an increase in plasma tonicity, [5] attenuation of these increases with sweating seems to be an important factor for limiting thirst and rehydration during and after exercise.

Management factors may also delay rehydration after exercise. Specifically, after many competitive events, horses are often prevented from drinking or offered only a small initial drink immediately after finishing. Free access to water is subsequently provided later after horses have been cooled down. This traditional practice has no basis in science but has been propagated over the centuries because providing an unlimited amount of water to hot horses has been suggested to cause colic or laminitis [6]. Thus, the objective of our first study [7] was to determine whether providing only a small initial drink of water could limit rehydration after exercise by producing a rapid decline in plasma tonicity and attenuating thirst when water was again provided later. We hypothesized that limiting immediate water intake (WI) by horses dehydrated by endurance exercise would decrease total WI during the initial hour of recovery, and thereby, potentate the magnitude of involuntary dehydration. It has been well documented in both human and equine athletes that restoration of body fluids and recovery of BW after exercise is more rapid and complete when rehydration solutions containing electrolytes (primarily Na+) are used in place of plain water [8,9]. However, most previous exercise studies have investigated the effects of "forced" hydration by instructing human subjects to drink specific amounts or, in horses, by administering solutions through a nasogastric tube. In contrast, there has been limited investigation of voluntary drinking during or after exercise in either species. In human subjects with varying degrees of dehydration, the volume of fluid drank during a 1-h recovery period, although insufficient to replace BW loss, was correlated with the increases in plasma osmolality and [Na+] during exercise [1]. Recent studies in our laboratory have shown a similar relationship between the increase in plasma tonicity and voluntary WI by horses dehydrated by endurance exercise or furosemide administration coupled with overnight withholding of water [10,11].

Anecdotally, competitors in endurance events have reported that training their horses to drink "salt water" improved overall drinking and recovery from exercise. An initial drink of salt water would maintain exercise-induced increases in plasma tonicity and could lead to greater voluntary WI when plain water was offered a few minutes later during the early recovery period. However, data were needed to determine if this practice was truly effective before such a recommendation could be
made to competitors. Thus, in a second study, [12] we tested the hypothesis that horses dehydrated by a combination of furosemide administration and prolonged exercise would voluntarily drink a greater total volume of fluid during the first hour of recovery when they were first offered salt water, compared with water, during the initial 5 min of recovery.

In addition to electrolyte content, more subtle factors including temperature and flavoring of rehydration solutions may also affect voluntary intake by human athletes [13-15]. The influence of water temperature has been fairly well documented in human athletes: after exercise, cool water is both preferred and drank in greater volumes in comparison to water at temperatures at or above ambient temperature [13-15]. In addition, cool or cold water ingested during and after exercise can act as a heat sink and lower core temperature [16]. There have been no studies in horses examining the effects of water temperature on drinking responses or core temperature changes during or after endurance exercise. Thus, we performed a third study [17] to test the hypothesis that horses dehydrated by a combination of furosemide administration and prolonged exercise would drink a greater total volume of a cool (10º) rehydration fluid than fluid at ambient (20º) or near body (30º) temperatures during the first hour of recovery. In addition, drinking cool fluid was hypothesized to produce a more rapid decrease in core temperature.

2. Materials and Methods

Study 1
To determine whether limiting the volume of the initial drink provided to horses after completion of exercise affected total WI during the first hour of recovery, BW loss, voluntary WI, and [Na+] were measured in six 2-yr-old Arabian horses before, during, and after a treadmill exercise test simulating a 45-km endurance ride. The horses performed the exercise test three times, and immediately after completion were offered (1) 4 l of water; (2) 8 l of water; or (3) an unlimited amount of water (UW). This initial drink was offered in a hand held bucket from 0 to 5 min of the recovery period, with the horses standing on the treadmill (water had not been offered at any prior point during the exercise test). After 5 min, horses were walked off the treadmill, cooled out, and further voluntary WI was determined with the horses free in a stall without feed from 20 to 60 min of recovery.

Study 2
To determine whether providing an initial drink of salt water to horses after completion of exercise affected total fluid intake (FI) during the first hour of recovery, BW loss, voluntary FI, and [Na+] were measured in six 2-yr-old Arabian horses before, during, and after furosemide administration (1 mg/kg, IV, 2 h before exercise) and a treadmill exercise test simulating a 45-km endurance ride. Furosemide administration was used in this study in conjunction with prolonged exercise, to achieve a BW loss approaching 5% (compared with ~3% BW loss in Study 1 with exercise alone). The horses completed the exercise test three times, and immediately after completion were offered unlimited amounts of (1) 0.45% NaCl solution; (2) 0.9% NaCl solution; or (3) water (W). As in Study 1 the initial drink was offered in a hand-held bucket from 0 to 5 min of the recovery period with the horses standing on the treadmill. After 5 min, horses were walked off the treadmill, cooled out, and further voluntary drinking of plain water was determined with the horses free in a stall without feed from 20 to 60 min of recovery.

Study 3
To determine whether the temperature of the rehydration fluid provided to horses after completion of exercise affected total FI during the first hour of recovery, BW loss, FI, and [Na+] were measured in six 2 to 3-yr-old grade horses before, during, and after furosemide administration (1 mg/kg, IV, 2 h before exercise) and a treadmill exercise test simulating a 30-km endurance ride. The horses completed the exercise test three times, and immediately after completion were offered unlimited amounts of 0.9% NaCl at (1) 10º (2) 20º or (3) 30º. Based on the results of Study 2, we elected to provide 0.9% NaCl at various temperatures as the initial rehydration solution followed by water at various temperatures for the remainder of the first hour of recovery. As in the previous studies, the initial drink of salt water was offered in a hand-held bucket from 0 to 5 min of the recovery period, with the horses standing on the treadmill. After 5 min, horses were walked off the treadmill, cooled out, and further voluntary drinking of plain water at each of the three temperatures was determined with the horses free in a stall without feed from 20 to 60 min of recovery.

In all three studies, changes in measured parameters were examined by either a one-way or two-way repeated measures analysis of variance assessing effects of treatment and time. When significant (P < 0.05) effects were found, a Student-Newman-Keuls test was performed to examine for specific differences between treatments and time points.

3. Results

Study 1
During exercise, horses lost 3.3 ± 0.3%, 3.2 ± 0.1%, and 3.3 ± 0.2% (P > 0.05) of BW and [Na+] increased by 3.4 ± 0.6, 3.3 ± 0.4, and 3.1 ± 0.2 mmol/l (P > 0.05) for 41, 81, and UW, respectively. WI during the first 5 min of recovery was 4.0 ± 0.0, 8.0 ± 0.0, and 10.0 ± 0.0 liters for 41, 81, and UW, respectively.
Study 2
By the end of exercise, horses lost 5.2 ± 0.2%, 5.6 ± 0.3%, and 5.7 ± 0.2% (P > 0.05) of BW, and FI during the first 5 min of recovery was 10.5 ± 0.7, 11.6 ± 0.8, and 11.6 ± 1.51 (P > 0.05) for W, 0.45% NaCl, and 0.9% NaCl, respectively. After 20 min of recovery, [Na+] had decreased with W but remained unchanged from the end exercise values for both saline solutions. From 20 to 60 min of recovery, further WI was 0.9 ± 0.4, 5.0 ± 0.5, and 6.9 ± 0.71 (P < 0.05) for W, 0.45% NaCl, and 0.9% NaCl, respectively. Thus, total FI was 11.4 ± 0.5, 16.6 ± 0.7, and 18.5 ± 1.71 (P < 0.05) for W, 0.45% NaCl, and 0.9% NaCl, respectively, and persisting BW loss after 60 min of recovery was greater (P < 0.05) for W (3.4 ± 0.1%) than for the two saline solutions (2.3 ± 0.2% for 0.45% NaCl and 1.9 ± 0.3% for 0.9% NaCl).

Study 3
The combined effects of furosemide administration and 30 km of treadmill exercise resulted in BW losses of 4.2 ± 0.3%, 4.5 ± 0.3%, and 4.5 ± 0.2% (P > 0.05) of BW for 10º, 20º, and 30º treatments, respectively. Fluid intake during the first 5 min of recovery was 9.8 ± 2.5, 12.3 ± 2.1, and 9.7 ± 2.01 (P > 0.05) for saline at 10º, 20º, and 30º, respectively. Although not a significant finding, horses offered 0.9% NaCl at 20º tended to take fewer (P = 0.07), longer drinks than when saline at either 10º or 30º was offered. From 20 to 60 minutes of recovery, drinking of water at 20º (7.7 ± 0.8 l) and 30º (6.6 ± 1.2 l) was greater (p < 0.05) than that at 10º (4.9 ± 0.5 l). Thus, total FI was 14.7 ± 2.5, 19.9 ± 2.5, and 16.3 ± 2.41 for rehydration fluids at 10º, 20º and 30º, respectively (p < 0.05, value for 20º water greater than that for 10º water). After 60 min of recovery, BW was not different from the pre furosemide values for any of the treatments, but BW loss for 10º and 30º treatments (0.8 ± 0.5% and 0.5 ± 0.8%, respectively) tended (P = 0.15) to be greater than the value for the 20º treatment (-0.3 ± 0.8%) for which a mild gain in BW was actually observed. Although the amount of metabolic heat transferred to the initial saline drink was correlated with the decrease in core temperature during the initial 5 min of recovery, heat transfer to ingested fluid was likely responsible for dissipation of, at most, 5% of the heat generated during endurance exercise.

4. Discussion
The results of Study 1 demonstrate that offering horses a small drink of water immediately after exercise did not substantially blunt the thirst response when water was again provided after a short cooling down period. Thus, our hypothesis that limiting immediate WI by horses dehydrated by endurance exercise would decrease total WI during the initial hour of recovery, and thereby potentate the magnitude of involuntary dehydration, was not supported. Although the decrease in [Na+] from the end of exercise to 20 min of recovery was not significantly different between the three treatments, the smallest decrease was found when horses were offered an initial drink limited to 4 l. Furthermore a significant positive linear correlation was found between [Na+] after 20 min of recovery and WI between 20 and 60 min of recovery (data not presented), supporting that plasma tonicity was an important stimulus for thirst and greater WI from 20 to 60 minutes of recovery by the horses limited to an initial drink of 4 l. Of interest, involuntary dehydration was also observed (~1% persisting BW loss, range, 0 - 2.8%) with a mean loss of 4.3 ± 0.7 kg) at the end of the recovery period with all treatments despite free access to water from 20 to 60 min of recovery. The fact that the magnitude of the persisting BW loss was inversely correlated to total WI during the recovery period (data not presented) also supports inadequate thirst as the primary mechanism responsible for involuntary dehydration.

Although most riders of endurance horses recognize the importance of offering their horses frequent opportunities to drink during and after competition, it is still common for competitors in other types of equine events to limit drinking or completely restrict horses from drinking during and for the initial 15 - 30 min after exercise. Although we did not investigate complete water restriction (by including a no WI treatment) in this study, the findings when horses were limited to 4 l of water suggest that horses completely restricted from drinking would also likely drink a similar total volume when water would be offered after 15 - 30 min of recovery. Furthermore we have observed little interest in drinking by horses exercised in a similar laboratory setting immediately after completion of fatiguing high-intensity exercise, even when horses were dehydrated by as much as a 4% BW loss by furosemide administration before exercise (unpublished data). In the latter experiments, a dramatically increased respiratory rate and effort in the immediate post-exercise period seemed to interfere with drinking, yet immediate WI was observed when horses were returned to a stall after 20 min of recovery. Thus, complete water restriction after high-intensity exercise (e.g., racing) is probably an acceptable management practice that does not likely limit recovery as long as unlimited water would be provided within 30 min of completion of exercise.

The results of Study 2 demonstrate that offering salt water as the initial rehydration solution to horses dehydrated by
furosemide administration and endurance exercise can be an effective strategy to increase total FI during the early recovery period. Although initial rehydration with either 0.45% or 0.9% NaCl did not result in full replacement of body fluid losses, it decreased the magnitude of dehydration to ~2% (for 0.9% NaCl) after the initial hour of recovery. Although provision of salt water in this study was short in duration, the data are relevant to horses competing in endurance events that may have limited time to recover before being subjected to a long trailer ride.

Of the previous studies investigating rehydration during and after endurance exercise in horses, only one has evaluated voluntary drinking of different rehydration fluids [18]. In that 62-km field study under mild ambient conditions, horses were offered frequent access to either plain water or a 0.9% NaCl solution during the exercise bout and the initial hour of recovery. At the end of exercise, horses drinking plain water had replaced 38% of their BW loss while those drinking a 0.9% NaCl solution had replaced of 45% of their estimated losses. Although this difference was small, horses that had been offered water alone only drank a further 2 l, whereas those provided the 0.9% NaCl solution drank 14 l of water from 1 to 3 h of recovery and had much greater recovery of BW loss. In our study, horses were not offered any rehydration fluid during the exercise bout but initial drinking of a saline solution also resulted in greater subsequent WI and recovery of BW from 20 to 60 min of recovery. Taken together, the results of both studies demonstrate that saline solutions can be effectively used, in a variety of manners, to improve rehydration and recovery after endurance exercise.

Of interest, the volume of rehydration solution imbibed during the initial 5 min of recovery in Study 2 was not different for any of the treatments (range, 8 - 15.5 l). This suggested that composition of the rehydration solution was not an important factor in determining initial fluid intake. Because the volumes drank were similar to the capacity of the equine stomach, satiation or cessation of drinking was likely a consequence of gastric filling as has been described in rats [19]. This suggestion is further supported by the observation that the majority of initial drinking also occurred within the first 2 min after rehydration fluid was offered.

The results of Study 3 demonstrate that temperature of rehydration fluid influences voluntary drinking in horses recovering from furosemide- and exercise-induced dehydration. Compared to either cooler (10º) or warmer (30º) temperatures, offering fluid at near ambient temperature (20º) resulted in the greatest voluntary FI by the end of the initial 60-min recovery period. Thus, our hypothesis that horses dehydrated by a combination of furosemide administration and prolonged exercise would drink a greater total volume of a cool (10º) rehydration fluid than fluid at ambient (20º) or near body (30º) temperatures during the first hour of recovery was refuted. In addition to differences in the volume imbibed, the pattern of drinking also varied as there was a tendency for horses to take fewer, longer drinks when offered NaCl solution at 20º compared with 0.9% NaCl at 10º or 30º, during the initial 5 min of recovery. As in Study 2, the mean volume of 0.9% NaCl drank by horses in this study during the first 5 min of recovery did not exceed ~12 l, irrespective of temperature. This finding, coupled with the fact that the majority of saline drinking occurred within the first 2 min after completing the exercise bout, provides further support for a role of gastric filling in initial thirst satiation.

Human athletes that become both dehydrated and hyperthermic during exercise show a preference for water at 5 - 15º [13-15]. Although colder water is preferred after exercise, offering a progressively colder drink (<10º) can actual decrease volume consumed [13]. As a result, hyperthermia, rather than dehydration, has been suggested to be a more important mechanism for the preference for colder water, [13] where oropharyngeal cooling has been advanced as a mechanism of greater thirst satiation and decreased intake of colder water [20,21]. Further, gastric emptying is slower for cold solutions than for warm solutions [22]. Thus, intake of cold water could prolong satiation by slowing gastric emptying rate. Core temperature of horses at the end of exercise in Study 3 was not increased from pre-exercise values; thus, lack of hyperthermia could potentially explain why these horses failed to drink greater volumes of fluid at 10º. Furthermore, drinking fluid at 10º could have had produced greater oropharyngeal cooling and may have contributed to more rapid satiation and less intake of fluid at this temperature (supported by the tendency to take shorter drinks of the 10º fluid). Although equine endurance athletes cannot rate a fluid preference like their human counterparts, our data suggest that, like dehydrated-normothermic human athletes, dehydrated-normothermic equine athletes exercising under moderate environmental conditions may prefer to drink rehydration fluids at near ambient temperature (20º).

Taken together, the results of this series of studies can provide practical recommendations that can be made to owners of horses participating in prolonged exercise events. First, although limiting the volume of water initially provided to horses dehydrated by endurance exercise had no detrimental effect on total WI during the initial 60 min of recovery, we observed no adverse effects of allowing unlimited water or saline drinking immediately after cessation of exercise. Thus, allowing horses free access to rehydration fluids after exercise would seem a prudent recommendation; furthermore, they are unlikely to drink a volume greater than stomach capacity in the initial few minutes after exercise. Second, providing salt water as the initial rehydration fluid maintained an elevated [Na+] and resulted in greater total FI and recovery of BW loss during the first hour of recovery, compared with offering only plain water. Thus, offering salt water, at a concentration up to 0.9% NaCl, as the initial drink at rest breaks and after completion of exercise is recommended as long as horses are provided access to plain water within a few minutes after drinking salt water. Third, because dehydrated-normothermic horses voluntary drank the greatest amount of fluid at near ambient (20º) temperature, rehydration solutions should be provided at near hose-end temperature (~17 - 18º) for horses competing in temperate climates. Although these recommendations may improve rehydration in the
early recovery period, it is important to remember that complete rehydration may take a couple of days after endurance
competition, and ingestion of several meals is likely needed for full replacement of electrolytes lost in sweat. During this
period of persisting body fluid and electrolyte depletion, continued observation is necessary because delayed-onset medical
problems can develop during the 2 to 3-day period after prolonged exercise.

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