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Bodyweight, fluid and electrolyte, and hormonal changes in horses that successfully completed a 5 day, 424 kilometer endurance competition

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Summary

We previously demonstrated that horses competing in a 78 km endurance ride developed significant depletion of body fluid and electrolyte stores which persisted after an overnight recovery period. Consequently, we hypothesized that horses performing repeated bouts of endurance exercise may develop progressively greater losses of bodyweight (BW) and body fluid and electrolyte content. To test this hypothesis, 24 horses competing in a 5 day, 424 km endurance ride were studied. BW, serum electrolyte concentrations, serum osmolality, and serum aldosterone (ALD) concentration were measured at the start and finish of each day of the ride and on the morning after the final day of the ride. For the nine horses which successfully completed all 5 days of the ride, mean BW decreased by 6.2, 3.2, 4.0, 3.3, and 0.9% during days 1–5, respectively. Cumulative mean BW loss at the end of each day of the ride (in comparison to the pre-ride value) was 6.2, 6.3, 7.4, 6.8, and 4.6% after days 1–5, respectively. Daily and cumulative BW losses after day 5 were significantly less than for the previous four days, a finding that was likely related to the shorter duration and ease of the final day's ride. Persisting BW losses (after overnight recovery) of 3.2, 3.5, 3.6, 3.7, and 4.1% after days 1–5, respectively, were not significantly different. Although all values for serum electrolyte concentrations and serum osmolality remained within laboratory reference ranges throughout the study period, serum Na^+ concentration was significantly lower post-ride on day 5, in comparison to pre-ride values. Further, although considerable variability between horses was observed, ALD values increased after day 1 and remained elevated for the remainder of the study period. These data demonstrate that horses successfully performing repeated bouts of endurance exercise do not develop progressively greater BW losses but may experience progressive electrolyte depletion.

Keywords: horse, endurance exercise, bodyweight, electrolytes, aldosterone, recovery

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Veränderungen von Körpergewicht, Flüssigkeitsgehalt, Elektrolyten und Hormonen bei Pferden, die erfolgreich an einem Distanzritt über 424 Kilometer in 5 Tagen teilnahmen

In einer vorausgegangenen Studie wurde beschrieben, daß Pferde bei einem 78-km-Distanzritt signifikante Verluste an Flüssigkeit und Elektrolyten zeigten, die auch nach einer Erholung über Nacht noch bestanden. Deshalb wurde der Frage nachgegangen, ob Pferde, die wiederholten Ausdauerbelastungen unterzogen wurden, progressiv ansteigende Verluste an Körpergewicht, Flüssigkeit und Elektrolyten aufwiesen. Zur Beantwortung dieser Frage wurden 24 Pferde untersucht, die an einem Distanzritt über 424 km in 5 Tagen teilnahmen. Körpergewicht, Serumelektrolytkonzentration, Serumosmololität und Serum-Aldosteronkonzentration wurden täglich vor dem Start und nach Beendigung des Rittes und zusätzlich am Morgen nach dem letzten Reittag gemessen. Bei den 9 Pferden, die alle 5 Tage des Rittes erfolgreich beendeten, nahm das Körpergewicht an den einzelnen Reittagen 1 bis 5 im Mittel um 6,2; 3,2; 4,0; 3,3 und 0,9 % ab. Der kumulative mittlere Gewichtsverlust (verglichen mit dem Wert vor dem Ritt) an den Tagen 1 bis 5 betrug 6,2; 6,3; 7,4; 6,8 und 4,6 %. Der tägliche und kumulative Gewichtsverlust an Tag 5 waren signifikant niedriger als an den vier vorangegangenen Tagen, wahrscheinlich aufgrund der geringeren Dauer und Schwierigkeitsstufe des letzten Reittages. Der am nächsten Morgen noch bestehende Gewichtsverlust nach den Tagen 1 bis 5 war mit 3,2; 3,5; 3,6; 3,7 und 4,1 % nicht signifikant verschieden. Obwohl die Serumelektrolytkonzentrationen und Serumosmolalität sich während der gesamten Untersuchung im Normalbereich bewegten, war die Serum-Natriumkonzentration am Ende des 5. Reittages verglichen mit dem Wert vor dem Ritt signifikant geringer. Desweiteren war die Serum-Aldosteronkonzentration am Ende des ersten Reittages erhöht und fiel während der gesamten Untersuchung nicht wieder ab. Allerdings bestand eine erhebliche Variationsbreite zwischen den einzelnen Pferden. Die Daten zeigen, daß Pferde, die erfolgreich wiederholte Ausdauerbelastungen absolvieren, keinen progressiv ansteigenden Verlust an Körpergewicht aufweisen, wohl aber einen progressiv ansteigenden Elektrolytverlust erleiden können.

Schlüsselwörter: Pferd, Ausdauerbelastung, Körpergewicht, Elektrolyte, Aldosteron, Erholung

Introduction

Horses participating in endurance rides over distances of 50–200 km typically lose 3–7% of their bodyweight (BW) during competition (*Lawrence* et al. 1992, *Ecker* and *Lindinger* 1995). This BW loss, which may exceed 10% in an occasional horse (*Ecker* and *Lindinger* 1995), is predominantly due to loss of body fluid in the form of sweat. Since equine sweat is rich in electrolyte content, this fluid loss is accompanied by substantial depletion of body electrolyte content (*Schott* and *Hinchcliff* 1993).

Although a number of investigators have studied body fluid and electrolyte changes in endurance horses (reviewed in *Rose* 1986), little information exists about recovery from competition in prolonged endurance events in this species. *Ecker* and *Lindinger* (1993) reported a BW loss of 4.0% after 1 hr of recovery, in comparison to a value of 4.6% at the end of a 96 km endurance ride. In recent studies of 3-day-event horses, persisting losses of BW were found between 18 and 24 hr after completion of the endurance

phase of the competition (*Andrews* et al. 1995). In human athletes, changes in circulating concentrations or urinary excretion of fluid regulating hormones may persist for two to three days following participation in marathons, ultramarathons, or repeated long distance running (*Wade* et al. 1981, *Fellmann* et al. 1988, *Fellmann* et al. 1989, *Linjen* et al. 1989). In these studies, the most dramatic and long-lasting hormonal response was the increase in serum aldosterone concentration which was highly correlated with the decrease in urinary Na^+ excretion during the recovery period.

We recently studied 12 horses which, after successful completion of a 78 km endurance ride, maintained a 4.3% decrease in BW after ≈18 hr of recovery (on the morning after the ride) (*Schott* et al. 1995). In addition to this persisting BW loss, plasma aldosterone concentration (ALD) was highest on the morning after the ride (385.1 ± 80.5 pg/ml in comparison to values of 62.2 ± 12.3 and 228.5 ± 54.6 pg/ml at the start and finish of the ride, respectively). Unfortunately, further study of recovery could not be performed as the horses were transported home shortly after the final sampling time.

Since horses which successfully completed this 78 km endurance ride had fluid and electrolyte deficits which persisted after an overnight recovery period, we hypothesized that horses performing repeated bouts of prolonged endurance exercise may develop progressively greater losses of BW and body fluid and electrolyte content. If this hypothesis was substantiated, it would suggest that horses competing in multi-day endurance rides are at greater risk of developing exhaustion and associated medical problems (*Carlson* 1985). The null hypothesis, supported by anecdotal experience of riders, was that horses do not experience progressively greater losses of BW and body fluid and electrolyte content during multi-day endurance competitions.

Materials and methods

Horses and study protocol

This study was performed on horses participating in the Outlaw Trail Historical Endurance Ride which was held in the canyonlands of southwestern Utah on September 23–28, 1995. The competition, which was sanctioned by the American Endurance Ride Conference, consisted of a 5 day, 424 km ride during which horses completed 80–96 km each day. The ride course consisted of Forest Service roads and primitive trails. A number of areas of bare rock, slickrock, and deep sand were traversed. Along with the primitive nature of many trails, an additional challenge of the course was a number of elevation changes between the ride start (2,150 m) and high and low points of 3,350 and 1,450 m, respectively. Veterinary examinations were performed on the day before the ride and at one checkpoint during each day's ride, which included a mandatory 60 min rest period. Veterinary examinations were also performed within 60 min of completion of each day's ride for evaluation of ability to continue on each subsequent day. Ambient temperature, measured at the ride start (5:30 or 6:30 AM) and at the high point each day, ranged between –3°C on the morning of day 1 and 26.5°C during the afternoon of day 2. The relative humidity was generally low (30–50%) throughout the 5 day ride with the exception of the afternoon of day 4 when scattered rain showers occurred.

After being informed of the purpose and requirements of the study, 24 of a total of more than 75 riders consented to participate. Since about half of these participants had not planned on competing all 5 days, the majority of competitors planning to complete the entire ride volunteered for the study. The study horses were all of Arabian or part-Arabian breed with the exception of one Morgan gelding. Transportation distances prior to the ride were quite variable and ranged from 200 to more than 3,000 km. Further, the horses studied had a range of previous competitive experience, received varying diets and electrolyte supplements, and carried weights (rider and tack) ranging from 70 and 95 kg. No attempt was made to correct for these possible confounding factors.

Sample collection and analyses

Participating riders presented their horses for weighing on a battery powered, portable scale (TRU-TEST AG500 Series Agricultural Scale, Version 3.2, Tru-Test Inc., San Antonio, TX) during the hour prior to the start of each day's ride, at the finish of each day's ride (prior to drinking), and on the morning after completion. The scale was calibrated before and after each weighing session with 300 kg of weights and, since some horses were weighed with tack on in the morning, BW was corrected for dry tack weight when necessary. All post-ride BW data was collected with saddles removed from the horses. Thus, all values are reported as BW without tack.

After weighing, blood samples (40 ml) were collected from the jugular vein into a dry syringe and transferred to vacutainer tubes (Vacutainer Systems, Becton Dickinson, Rutherford, NJ) containing K_3-ethylenediamine tetra-acetic acid (EDTA tubes) or without anticoagulant (serum tubes). The EDTA samples were used to measure packed cell volume (PCV) and total plasma protein concentration (TPP) in duplicate on site by the microhematocrit method and refractometry, respectively. After clotting, serum tubes were centrifuged (15 min at 1500 g at 4°C) and serum was harvested into plastic screw top tubes and flash frozen and stored in liquid nitrogen until tubes were transferred to a –70°C freezer on return to the laboratory. Samples remained at –70°C until measurement of electrolyte concentrations (Abbott Spectrum Series Ilu, Abbott Laboratories, Abbott Park, IL), osmolality (AdvancedTM Micro-Osmometer Model 3MOplus, Advanced Instruments, Norwood, MA), and aldosterone concentration. The latter was measured with a commercially available radioimmunoassay kit (Coat-A-Countu, Diagnostic Products Corporation, Los Angeles, CA) which detects serum aldosterone concentrations ranging from 16–1200 pg/ml.

Data analysis

Values for each parameter measured are presented as means ± SE. The data were subjected to analysis of variance (Statistix 3.5, Analytical Software, St. Paul, MN) and when significant F ratios were found, a Scheffe's test (Statistix 3.5, Analytical Software, St. Paul, MN) was used to compare means for each sampling time. $P<0.05$ was considered significant unless otherwise indicated.

Results

Of the 24 horses sampled at the start of the ride, complete data sets were only collected on the nine horses which successfully completed all five days of the ride. Seven of the remaining 15 horses were lost after day 1 (one metabolic disorder, one bowed tendon, one lost shoe, and four riders elected to take a day off due to difficulty of the ride); four horses were eliminated after day 2 (two with metabolic disorders and two with sore backs); three were lost after day 3 (two became lame and one lost a shoe); and one horse became lame during the final day of the ride. There was no difference in mean age between horses that successfully completed all five days of the ride (10.1 ± 1.0 years) and horses

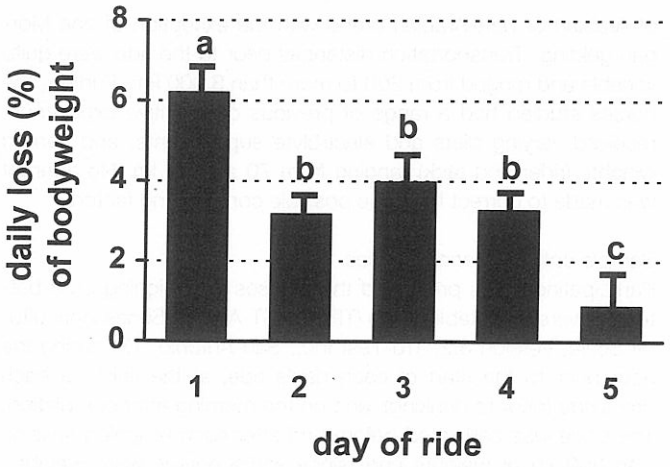

Fig. 1: Mean bodyweight loss in nine horses during each day of a 5 day, 424 kilometer endurance ride. Different letters above bars reflect significant differences ($p < 0.05$).

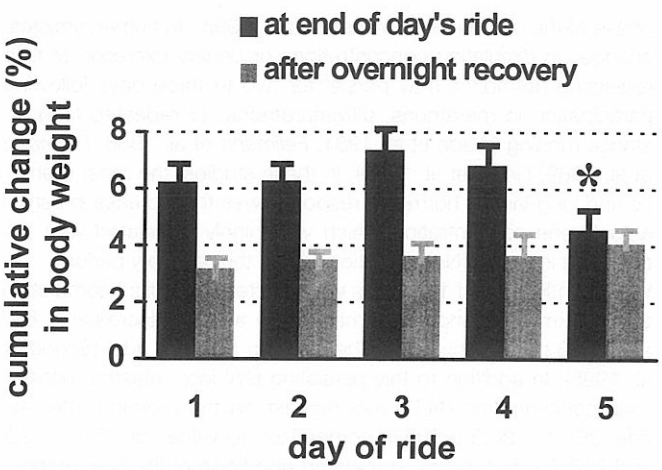

Fig. 2: Mean cumulative bodyweight loss (in comparison to the pre-ride value) in nine horses at the finish (black bars) of each day of a 5 day, 424 kilometer endurance ride and after overnight recovery (gray bars).
* above bars indicates a significant differences ($p < 0.05$) from other bars of the same shade.

which failed to complete the ride (10.2 ± 0.7 years); however, successful horses had more years of prior endurance competition (4.8 ± 1.0 years) than eliminated horses (2.9 ± 0.5 years). Finally, all of the horses studied received electrolyte supplements before, during, and/or after the ride.

For the nine horses successfully completing all five days of the ride, BW decreased by 6.2 ± 0.6, 3.2 ± 0.5, 4.0 ± 0.6, 3.3 ± 0.5, and 0.9 ± 0.9% during days 1–5, respectively (Fig. 1). Cumulative BW loss at the end of each day's ride (in comparison to the value on the morning of day 1) was 6.2 ± 0.6, 6.3 ± 0.6, 7.4 ± 0.8, 6.8 ± 0.7, and 4.6 ± 0.7% after days 1–5, respectively (Fig. 2 – black bars). Mean daily and cumulative BW losses after day 5 were significantly less than for the previous 4 days, a finding that was likely related to the ease and shorter duration of the final day's ride. Persisting BW losses (after overnight recovery) of 3.2 ± 0.3, 3.5 ± 0.3, 3.6 ± 0.4, 3.7 ± 0.7, and 4.1 ± 0.5% after days 1–5, respectively, were not significantly different (Fig. 2 – gray bars).

Values for BW, PCV, TPP, serum electrolyte concentrations, and serum osmolality for these nine horses are presented in Tab. 1. As expected, values for PCV and TPP tended to increase during each days' ride (with the exception of day 1) but TPP values on

Tab. 1: Mean ± SE values for bodyweight, packed cell volume (PCV), total plasma protein concentration (TPP), serum electrolyte concentrations, and serum osmolality for nine horses which successfully completed a 5 day, 424 kilometer endurance ride.

parameter	day 1 start	day 1 end	day 2 start	day 2 end	day 3 start	day 3 end	day 4 start	day 4 end	day 5 start	day 5 end	recovery
BW (kg)*	403 ± 12	378 ± 11	390 ± 12	378 ± 11	389 ± 11	373 ± 11	388 ± 11	376 ± 11	388 ± 12	384 ± 11	386 ± 12
PCV (%)	40.9 ± 1.2	39.8 ± 1.7	38.1 ± 1.4	40.9 ± 1.9	38.0 ± 0.9	41.4 ± 1.7	37.1 ± 0.9	40.6 ± 1.5	37.8 ± 0.6	41.4 ± 1.5	36.4 ± 0.9
TPP (g/dl)	6.88 ± 0.13	6.73 ± 0.18	6.55 ± 0.10	6.69 ± 0.12	6.43 ± 0.09	6.56 ± 0.15	6.43 ± 0.05	6.54 ± 0.09	6.17 ± 0.08[1]	6.45 ± 0.13	6.06 ± 0.10[1]
Na^+ (mEq/l)	143.6 ± 0.5	146.2 ± 0.9	144.0 ± 0.5a,	145.3 ± 1.0	143.0 ± 0.9	144.7 ± 0.8	143.6 ± 1.2	144.7 ± 0.8	142.3 ± 0.6	139.2 ± 0.6[1]	140.9 ± 0.7
K^+ (mEq/l)	4.47 ± 0.10	3.63 ± 0.16	4.10 ± 0.18	3.58 ± 0.18	3.83 ± 0.22	3.68 ± 0.11	4.11 ± 0.17	3.92 ± 0.19	4.27 ± 0.16	3.97 ± 0.17	3.60 ± 0.17
Cl^- (mEq/l)	109.8 ± 0.4	111.9 ± 1.3	110.3 ± 0.4	109.9 ± 1.3	109.2 ± 0.8	110.7 ± 1.0	109.9 ± 0.9	110.8 ± 1.2	109.5 ± 0.4	106.2 ± 0.7[2]	107.9 ± 0.5
osm (mOsm/kg)	283.4 ± 0.8	291.6 ± 1.4	286.4 ± 0.9	287.7 ± 1.3	284.8 ± 1.4	288.0 ± 1.3	285.6 ± 2.2	287.6 ± 1.7	282.4 ± 1.4[2]	283.4 ± 1.5	284.9 ± 0.8

* due to variation in pre-ride bodyweight values, statistical analysis was limited to the changes in bodyweight during the ride and recovery period (see Fig.1 and 2)

[1] significant difference from day 1 – start values at $p < 0.05$

[2] significant difference from day 1 – end values at $p < 0.05$

the mornings of day 5 and recovery were significantly decreased from the pre-ride value. Although all values for serum electrolyte concentrations and serum osmolality remained within laboratory reference ranges throughout the study period, serum Na^+ concentration was significantly lower post-ride on day 5, in comparison to the pre-ride value. Further, values for serum osmolality and serum Cl^- concentration at the start and finish of the ride on day 5, respectively, were significantly lower than the day 1 post-ride values. ALD values were variable between horses such that the only significant difference detected was a lower ALD value at the end of the ride on day 1 in comparison to all subsequent days of the ride (Fig. 3). Although variability precluded detection of further differences, ALD progressively increased over the first four days of the ride and reached the highest mean value (317 ± 95 pg/ml) at the end of day 4. After each overnight recovery period, mean ALD values were all greater than the value measured at the end of the ride on day 1.

Discussion

Bodyweight losses of progressively greater magnitude did not develop in the nine horses which successfully completed all five days of this multi-day endurance ride. In fact, after the 6.2% BW loss on day 1, horses recovered essentially all of the subsequent daily losses during the overnight recovery period (days 2–5). The greatest cumulative BW loss after day 3 and the lowest BW loss on day 5 were likely related to ride duration, which was longest and shortest on these respective days. Our findings were similar, although greater in magnitude, to the 2.5–3.5% BW losses reported for human athletes performing in marathons, ultramarathons, or repeated bouts of long distance running (*Wade* et al. 1981, *Fellmann* et al. 1988, *Fellmann* et al. 1989, *Linjen* et al. 1989).
Although there was a trend toward an increase in persisting BW loss after overnight recovery during this multi-day ride, this was not a significant observation. The values for persisting BW loss, ranging from 3.2% after day 1 to 4.1% after day 5, were similar to our previous finding of a 4.3% BW decrease in 12 endurance horses on the morning after successful completion of a 78 km ride

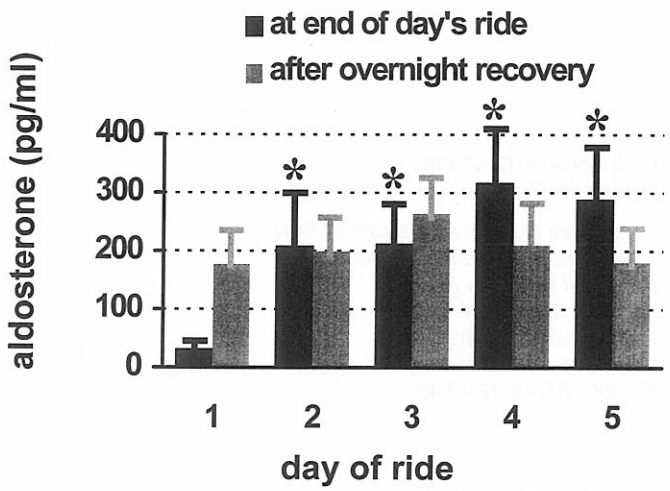

Fig. 3: Mean serum aldosterone concentration (pg/ml) in nine horses at the finish (black bars) of each day of a 5 day, 424 kilometer endurance ride and after overnight recovery (gray bars).
* above bars indicates a significant differences ($p < 0.05$) from other bars of the same shade.

(*Schott* et al. 1995), but were greater than the 1.8% BW loss observed in horses on the morning after completion of the endurance test of a 3-day event (*Andrews* et al. 1995). This discrepancy is likely related to a lesser total loss of BW in the 3-day-event horses (3.3%) in comparison to these endurance horses which experienced cumulative BW losses ranging between 4.6 and 7.4% after each day's ride. Since the 3-day event horses performed endurance exercise of shorter duration (distances of 16–19 km completed in 2–3 hr), total losses of fluid and electrolytes in sweat would be expected to be less in the event horses than in these endurance horses.
Unlike these endurance horses, persisting BW losses were not observed after an overnight recovery period in human athletes performing repeated bouts of long distance running (*Wade* et al. 1981). In both species, prolonged endurance exercise results in substantial depletion of liver and skeletal muscle glycogen content. However, due to species differences in dietary carbohydrate sources and skeletal muscle glycogen content (greater in horses than humans), repletion of skeletal muscle glycogen stores may be complete within 24 hr in human athletes (*Sherman* 1992) but may require 48–72 hr in endurance horses (*Hodgson* et al. 1983). Since skeletal muscle mass may account for 45–50% of total body mass of the horse (*Webb* and *Weaver* 1979) and glycogen may account for up to 3% of skeletal muscle mass (*Hodgson* et al. 1983), total skeletal muscle glycogen content may approach 6 kg in a 400 kg endurance horse. Using the unrealistic assumption that 100% of this skeletal muscle mass is used during endurance exercise, repletion of glycogen stores to only 50% of the pre-ride value would yield, at most, a 3 kg or 0.75% persistent decrease in BW. Thus, a difference in recovery of glycogen stores would explain only a small portion of the difference in BW recovery between equine and human endurance athletes. Another, and perhaps more important, factor which likely contributes to the species difference in recovery of BW is body composition. Although skeletal muscle mass is somewhat similar, accounting for 30–35% and 45–50% of total bodymass in humans and horses, respectively; the weight of gastrointestinal tract (GIT) contents in the horse (10–15% of bodymass) is considerably greater than that of man (1–2%) (*Mitchell* et al. 1945, *Webb* and *Weaver* 1979). A decrease in GIT content in these endurance horses was supported by development of a "tucked-up" appearance to the abdomen after the first day of the ride. If, for example, these endurance horses experienced a 25% decrease in GIT content over the first day or two of the ride, this loss could account for a 2.5–3.5% BW loss which could persist for the remainder of the ride. In addition to ride duration as a factor limiting the time available for eating, changes in management may have also contributed to a persisting loss of GIT content after overnight recovery. For example, different hay types and water sources may have influenced eating and drinking during the recovery periods.
Although glycogen depletion and a decrease in GIT content likely contributed to the persisting BW loss observed after overnight recovery in these horses, ALD values were similar or greater after overnight recovery than at the end of each day of the ride. Since aldosterone is cleared through the liver (*Fellman* et al. 1988), decreased hepatic blood flow during prolonged exercise would contribute to an increase in ALD during exercise but not during the overnight recovery period. Thus, the tendency for a further increase in ALD during overnight recovery implies that these horses were attempting to recover sodium losses throughout the duration of the ride and recovery. Unfortunately, urine and fecal samples were not available for analysis of sodium content to further

support a sodium retaining effect of aldosterone activity. Nevertheless, the persisting increase in ALD after day 1 indicates that an additional factor contributing to the persisting BW loss was a decrease in body fluid and electrolyte content. Although all values remained within normal reference ranges, the decreases in serum Na^+ and Cl^- concentrations and in serum osmolality observed on day 5 of the ride support progressive depletion of body electrolytes stores in these endurance horses, despite supplementation by the riders. The decrease in TPP observed on the final two mornings (day 5 and recovery) are of interest since this finding would suggest an increase in plasma volume, rather than fluid depletion. Although plasma volume expansion is a documented response to endurance training in horses (*McKeever* et al. 1988), the decrease in TPP could also be explained by protein loss during the course of the ride. Consequently, the reason for the observed decrease in TPP in these horses remains unknown.

In summary, the horses studied in this multi-day endurance ride did not develop progressively greater losses of BW but appeared to experience progressive electrolyte depletion. Interestingly, loss of horses from competition for development of metabolic problems (signs of colic) was only observed on the first two days of the ride. During days 3–5, the causes for elimination of other horses was development of a sore back or lameness. These observations are supportive of anecdotal experience that horses tend to perform better towards the end of these multi-day rides. Further, although there was no age difference between successful horses and horses which failed to complete the ride, successful horses had more years of prior endurance competition. Thus, although the results of this study suggest that multi-day rides are a humane equine endeavor, the latter observation warrants the attention of ride organizers. Since horses with less endurance training and competitive experience are less likely to complete a multi-day ride, successful completion of a number of single day rides should perhaps be required for entry into a multi-day ride.

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