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EVALUATION OF VARIOUS ELECTROLYTE REPLACERS FOR HORSES

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SUMMARY

The effectiveness and cost of horse electrolyte supplements in horses were investigated. The three products tested were 4 Salts® (Ridley AgriProducts), NaCl (table salt) and Humidimix® (Vetsearch International) and these were fed according to the manufacturers' recommendations.

The trial was based on a split plot Latin square design. Four thoroughbred geldings were randomly allocated to one of four treatments (control plus 3 electrolytes). Frusemide (1 mg/kg BW i/m) was used to simulate the fluid and electrolyte loss of moderate exercise in the horses. Blood and urine samples were collected prior to administration of frusemide and at 3, 5 and 24 h post injection. The samples were analysed for Na, Cl, K, Mg and creatinine. The fractional excretion ratio (FER) was calculated to quantify the horse's electrolyte clearance and to determine the time the horses took to return to pre-injection levels.

For the three electrolyte treatments, the horses returned to pre-frusemide injection levels within 24 h. However, 24 h after the frusemide injection the Mg FER values for the horses receiving no electrolytes were significantly lower than the pre-injection levels. Because the implications of this decrease are unknown it is recommended that horses in moderate work and being fed good quality roughage diets may need to be fed an electrolyte supplement. Given the lack of variability between the electrolyte treatments, the added costs of feeding Humidimix® and 4 Salts® (compared to salt) cannot be justified.

Keywords: electrolytes, horses

INTRODUCTION

Horses that are worked hard, fast or for extended periods, subjected to humid and hot weather, or travel long distances require some form of electrolyte supplementation to replace increased losses in sweat and urine and restore their electrolytes to normal levels (Schott and Hinchcliff 1998; Sosa León *et al*.1998). There is a large range of electrolyte supplements for horses available on the market. These products claim to aid in preventing dehydration and other clinical disorders, therefore potentially reducing decreases in performance associated with such conditions.

It can be difficult to standardise the fluid and electrolyte loss of horses in exercise, and instead, experimental protocols have been described that make use of diuretics to increase the excretion of water and electrolytes. Frusemide is a loop diuretic, which increases the excretion of water and electrolytes from both the kidney and the gut of the horse. Its use induces dehydration in the horse similar to that caused by exercise- induced sweat losses (Alexander 1982). Its effects are short lasting and the majority of the associated increase in urinary volume is complete by 2-4 h after administration. The use of the drug and subsequent increased fluid losses do not cause any obvious clinical signs in the horse (Freestone *et al*. 1988).

MATERIALS AND METHODS

Experimental design, animals and diets

The trial was based on a Latin square design. Each supplemental treatment ran for two weeks, with a one-week rest period in between when the horses received no supplementary electrolytes. Four thoroughbred geldings, aged 5 to 14 years and weighing 490 - 545 kg were used. The horses had received little or no exercise prior to the trial and none during the trial. They were stabled at night, given access to paddocks (bare of feed) during the day and fed a maintenance ration of 3 kg/d Wesfeeds Pony Cubes (10.5% CP), 2 kg/d oaten chaff and 3.5 kg/d oaten hay. The four treatments were no supplement (control) or 45 g/d of either 4 Salts® (Ridley AgriProducts), NaCl (Saltpack Pty Ltd), or Humidimix® (Vetsearch International). Clean water was freely available at all times.

Procedures

Every week the horses were weighed, pulse rates taken and blood and urine collected before they received their morning feed. After receiving the supplement for one week, the horses were injected with frusemide (1 mg/kg i/m) following the collection of venous blood (10 mL) and urine (50 mL) samples. The horses were then fed (as normal). Blood and urine samples were taken again 3, 5 and 24 h after the injection (exact times recorded). Plasma was harvested from the blood, and the urine and plasma samples stored frozen for subsequent analysis of Na, Cl, Mg, K and creatinine levels. Na and K levels were determined using ion selective electrodes, Cl levels by the thiocyanate method, Mg levels by the calmagite method and creatinine levels by the Jaffe method.

Fractional excretion ratio (FER)

The electrolyte balance of the horses was assessed from the amounts of the electrolyte excreted in urine. Because the clearance of creatinine by the horse is almost constant, the clearance of any electrolyte can be compared against the clearance of endogenous creatinine to determine the rate of renal electrolyte output (Coffman 1980). This eliminates the need for urine volume to be known. Electrolyte clearance (FER) as a percentage of creatinine (Cr) clearance was determined as:

$$\text{FER \%} = \frac{(\text{M})\text{urine}}{(\text{M})\text{serum}} \times \frac{(\text{Cr})\text{serum}}{(\text{Cr})\text{urine}} \times 100$$

where M = mineral under investigation, ( )urine = urinary concentration of the mineral, ( )serum = serum concentration of the mineral.

Statistical analyses

Data were subjected to analysis of covariance according to a split plot Latin square design where the allocation of treatments to horses and periods was based on a Latin square, and time (3, 5 and 24 h) was treated as a subtreatment. The covariate used for each analysis of each measurement was the same measurement at 0 h. Differences between treatment means were determined using the least significant difference (LSD) ($P<0.05$) procedure. Plots of residuals were used to assess the validity of the analysis of variance assumptions and where necessary the data were transformed to conform to these assumptions.

RESULTS

All animals maintained good health throughout the trial. Pulse rates remained relatively unchanged and were within the normal range for resting horses. The horses consumed all feed offered each day and there was no apparent problem with palatability of the electrolyte supplements.

The mineral content of the feeds and electrolyte supplements fed to the horses is shown in Table 1 and the total mineral intakes the horses received during the trial is shown in Table 2.

Table 1. Mineral content of feeds and electrolyte supplements

	Mg	Na	Cl	K
Wesfeeds Pony Cubes™ (%)	0.24	0.2	0.59	0.66
Oaten hay (%)	0.09	0.2	0.71	0.76
Oaten chaff (%)	0.13	0.65	1.2	1.48
4 Salts® (g/kg)	60	214.5	431.5	104
Humidimix® (g/kg)	9.2	117.9	438.7	209.6
NaCl (g/kg)	-	390.0	610.0	-

The mineral content of the feedstuffs was determined by analysis, however, the mineral content of the supplements was based on information provided by the product labels.

Table 2. Total mineral intake (g/d) for the dietary treatments

Treatment	Mg	Na	Cl	K
Control	12.9	14.3	66.4	76.0
4 Salts®	15.7	23.9	85.8	80.7
Humidimix®	13.4	19.6	86.1	85.4
NaCl	12.9	31.9	93.9	76.0

After injection with frusemide the horses experienced increased urination, particularly within the first 3 h. A logarithmic transformation ($\log_e$) was required for FER values of Na, Cl and Mg. Mean values for FER of Na, K, Cl and Mg at various times after the administration of frusemide and 5% LSDs are shown in Table 3. The mean FER values 3 h after frusemide injection were significantly higher

(P<0.05) than at 5 h, and FER values 5 h post frusemide were significantly higher than at 24 h. The horses returned to pre-frusemide injection levels or lower within 24 h for all treatments. There were no differences (P>0.05) between treatments for FER values for Na, K and Cl, indicating that electrolyte supplementation had no apparent effect on these measurements. While there was no difference between treatments for FER Mg at 0, 3 and 5 h (P>0.05), the control group was significantly lower (P<0.05) than the other groups at 24 h. Control animals had significantly lower (P<0.05) FER Mg values at 24 h than they did at the time of frusemide administration.

Table 3. Mean renal FER of Na, K, Cl and Mg under the different treatments

FER (%)	Time (h)	0	3	5	24	5% LSD
Na	Control	-6.31 (0.2)	-3.06 (4.7)*	-5.52 (0.4)	-7.60 (0.1)	*1.507*
	4 Salts®	-5.63 (0.4)	-3.37 (3.4)	-5.09 (0.6)	-9.20 (0.0)	
	Humidimix®	-5.81 (0.3)	-3.08 (4.6)	-5.49 (0.4)	-9.78 (0.0)	
	NaCl	-4.92 (0.7)	-2.66 (7.0)	-4.63 (1.0)	-9.91 (0.0)	
	5% LSD	*2.125*	*1.428*	*1.428*	*1.428*	
K	Control	48.0	96.7	46.6	57.6	*37.18*
	4 Salts®	31.0	84.7	54.4	26.8	
	Humidimix®	36.0	77.9	56.7	25.3	
	NaCl	30.0	125.3	54.4	42.3	
	5% LSD	*36.20*	*43.12*	*43.12*	*43.12*	
Cl	Control	-4.42 (1.2)	-2.63 (7.2)	-3.71 (2.4)	-7.36 (0.1)	*1.101*
	4 Salts®	-4.83 (0.8)	-2.48 (8.4)	-3.24 (3.9)	-7.35 (0.1)	
	Humidimix®	-4.77 (0.8)	-2.40 (9.1)	-3.49 (3.1)	-6.75 (0.1)	
	NaCl	-4.69 (0.9)	-2.09 (12.4)	-3.42 (3.3)	-6.74 (0.1)	
	5% LSD	*0.899*	*1.006*	*1.006*	*1.006*	
Mg	Control	-1.53 (21.7)	-1.04 (35.4)	-1.25 (28.7)	-2.66 (7.0)	*0.506*
	4 Salts®	-1.83 (16.0)	-1.04 (35.4)	-1.04 (35.3)	-1.92 (14.7)	
	Humidimix®	-2.01 (13.4)	-1.16 (31.3)	-1.33 (26.5)	-1.87 (15.4)	
	NaCl	-1.93 (14.5)	-1.42 (24.1)	-1.32 (26.7)	-1.54 (21.5)	
	5% LSD	*0.640*	*0.428*	*0.428*	*0.428*	

* Re-transformed means (%) shown in brackets

The cost (/kg) of the electrolyte supplements were $2.26, $14.00 and $0.25 for 4 Salts®, Humidimix® and NaCl (stock salt), respectively. For the trial table salt was used, however, as most horse owners use stock salt the price for this product was used in the determination of prices.

DISCUSSION

Horses sweating profusely or undertaking prolonged exercise can incur significant fluid and electrolyte losses (Meyer 1987; Sosa León *et al*. 1998). These losses, if not restored, can result in impaired thermo-regulatory responses and cardiovascular instability (McKeever 1998).

The FER values at time ‘0’ in this study were consistent with the range of previously observed values (0.0002-2.43 for Na; 1.0-42.74 for K; 0.012-3.47 for Cl; and 15-53 for Mg) (Edwards *et al.* 1989; King 1994), indicating that the horses were at ‘normal’ electrolyte balance prior to the commencement of each treatment.

The administration of frusemide resulted in an increased urinary output and increased excretion of electrolytes, which was consistent with other studies (Freestone *et al.* 1988; 1989). FER increased significantly (P<0.05) after the administration of frusemide then decreased over time. The post frusemide FER for Na, K and Cl were lower than those reported by Coffman (1980) (12, 207 and 9.5 %, respectively). Values may, however, have reached these levels prior to the first sample being collected (between 0 and 3 h). By 24 h post injection the FER values for Na, Cl and K had returned to pre-injection levels for all treatment groups, indicating that electrolyte homeostasis (for these elements) had been maintained.

Meyer (1987) suggests that horses in moderate work require 50 g Na, 70 g Cl, 44 g K and 14 g Mg per day to remain in electrolyte balance. In this study the horses were receiving 14.3 g Na, 66.4 g Cl, 76 g K and 12.95 g Mg per day from their basal feed (see Table 2), indicating that only Na was severely lacking in the diet prior to supplementation with electrolytes. Even after the electrolyte supplements were added none of the diets reached the recommended level for Na. Despite this apparent deficiency

FER Na levels for the horses still returned to pre-injection levels within 5 h after the administration of frusemide. The equine kidney has a high capacity to retain Na when intake is low, and excrete Na when the dietary intake is not limited (Schott and Hinchcliffe 1998). This is mediated through the effects of aldosterone on the renal tubule (Kaneko 1980). Even though the horses in this study were receiving low amounts of Na they were able to maintain Na homeostasis through conserving the mineral. King (1994) states that a low FER Na is an indication that the body is conserving Na and that only an increase in FER Na is of real diagnostic value.

The horses did not require any supplemental K as they were fed high quality hay and chaff (Coffman 1980). Ideally, supplements should be formulated and fed on the basis of both the diet and the level of exercise. Supplemental K appears necessary only in horses that are fed low levels of forages or worked hard in hot or humid conditions due to increased sweating and the high concentrations of K lost in the sweat.

The FER K increase observed could be a result of the horse's efforts to retain Na (Coffman 1980), due to the lack of Na in the diet. Prolonged lack of Na in the diet could potentially result in depletion of both Na and K over time.

Whilst the diet may have been marginal in Cl, the FER was still within the normal range for all treatments. This may have been due to the body's powerful drive for homeostasis. When Cl is limited the horse will absorb more K and H ions to preserve homeostasis (Kaneko 1980). The relationship between Na, Cl and K is highly complicated, however, if the diet is marginal in Na or Cl there appears to be some benefit in high levels of K being supplemented to offset the low Na and Cl levels.

The FER Mg levels returned to pre-injection levels within 24 h after the administration of frusemide, with the exception of the horses on the control diet, which had significantly lower ($P<0.05$) FER Mg values at 24 h than they did at the time of frusemide administration. Mg excretion is enhanced by frusemide (Pugh 1991) and also by aldosterone (Frape 1998). Because the horses on the control diet were receiving no supplemental Na, the frusemide induced fluid and electrolyte loss may have triggered aldosterone secretion, which then increased Mg loss, resulting in a lower FER Mg 24 h later. Tubular interaction between the active transport of NaCl and Mg reabsorption may also influence Mg excretion (Hansen 2000).

Further work is needed to identify the interactions between these electrolytes, and the implications for performance, and for tubular handling of other minerals such as calcium, which was not measured in this experiment. At this stage it is recommended that horses in moderate work and being fed good quality roughage diets may need to be fed an electrolyte supplement. However, given the lack of variability between the electrolyte treatments, the added costs of feeding Humidimix® and 4 Salts® (compared to salt) cannot be justified.

REFERENCES

ALEXANDER, F. (1982). *J. Vet. Pharmacol. Ther.* **5**, 153-60.
COFFMAN, J. (1980). *Vet. Med. Small Anim. Clin.***75**, 671-6.
EDWARDS, D.J., BROWNLOW, M.A. and HUTCHINS D.R. (1989). *Aust. Vet. J.* **66**, 60-3.
FRAPE, D. (1988). 'Equine Nutrition and Feeding'. 2nd Edition (Blackwell Science: Oxford).
FREESTONE, J.F., CARLSON, G.P., HARROLD, D.R. and CHURCH, G. (1988). *Am. J. Vet. Res.* **49**, 1899-1902.
FREESTONE, J.F., CARLSON, G.P., HARROLD, D.R. and CHURCH, G. (1989). *Am. J. Vet. Res.* **50**, 1334-9.
HANSEN, B. (2000). *In* 'Fluid Therapy in Small Animal Practice'. 2nd Edition. (Ed S.P. DiBartola) p. 175-88. (WB Saunders Company: USA)
KANEKO, J.J. (1980). 'Clinical Biochemistry of Domestic Animals'. 3rd Edition (Academic Press: New York).
KING, C. (1994). *J. Eq. Vet. Sci*. **14**, 464-8.
MCKEEVER, K.H. (1998). *Vet. Clin. North Am. Equine Pract.* **14**, 23-40.
MEYER, H. (1987). *In* 'Equine Exercise Physiology 2'. p. 652-6. (ICEEP Publications)
PUGH, D.M. (1991). *In* 'Veterinary Applied Pharmacology and Therapeutics'. 5th Edition. (Ed. Brander, G.C., Pugh, D.M., Bywater, R.J. and Jenkins, W.L.) p. 186-97. (WL Bailliere Tindall: London).
SCHOTT, H.C. and HINCHCLIFFE, K.W. (1998). *Vet. Clin. North Am. Equine Pract.* **41**, 175-201.
SOSA LEON, L.A., HODGSON, D.R., CARLSON, G.P. and ROSE, R.J. (1998). *Am. J. Vet. Res.* **59**, 898.

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