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The effect of exercise intensity and use of an electrolyte supplement on plasma electrolyte concentrations in the Standardbred horse

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Abstract

Eleven Standardbred horses were tested to assess plasma electrolyte fluctuations during different intensities of exercise (at rest, immediately following 20 minutes of jogging and immediately following a two-minute race), with and without an orally administered electrolyte supplement two hours prior to sample collection. Exercise treatments were repeated after horses were given an oral dosage of an electrolyte supplement two hours prior to sample collection. Data was analyzed using a repeated incomplete 6 x 6 Latin-square design with a 3 x 2 factorial arrangement of treatments (exercise x supplement). Jogging horses had an elevated heart rate as compared with resting horses and plasma potassium concentrations that were higher than those of the other two treatments ($P < 0.05$). Racing horses had the highest heart rate of the three treatments and plasma sodium concentrations that were higher than those of resting and jogging horses ($P < 0.05$). Provision of an electrolyte supplement significantly increased heart rate, as well as blood potassium and sodium concentrations. Further studies on dietary electrolyte supplementation would benefit from investigating additional performance and recovery parameters, with focus on the hydration status of the horse before, during and after exercise.

Keywords: Standardbred; athletic performance (equine); race horse; electrolyte; exercise intensity

Onze chevaux Standardbred ont été testés pour évaluer les fluctuations des électrolytes plasma au cours de différentes intensités d'exercice (au repos, immédiatement après 20 minutes de jogging et immédiatement après une course de deux minutes), avec et sans un supplément d'électrolyte administré par voie orale deux heures avant le prélèvement des échantillons. Les

traitements d'exercice ont été répétés après que les chevaux aient reçu une dose orale d'un supplément d'électrolyte deux heures avant la collecte de l'échantillon. Les données ont été analysées à l'aide d'un modèle 6 x 6 latin-carré incomplet et répétitif avec un arrangement factoriel 3 x 2 (exercice x supplément). Chevaux de jogging avaient une fréquence cardiaque élevée en comparaison avec les chevaux au repos et les concentrations plasmatiques de potassium qui étaient plus élevées que ceux des deux autres traitements ($P < 0.05$). Les chevaux de course ont eu le taux le plus élevé du cœur des trois traitements et les concentrations plasmatiques de sodium qui étaient plus élevées que ceux de repos et de jogging chevaux ($P < 0.05$). La fourniture d'un supplément d'électrolyte n'a pas affecté de façon significative l'un quelconque des paramètres mesurés dans cette expérience, mais cela n'indique pas qu'elle était inefficace. D'autres études sur la supplémentation en électrolyte alimentaire bénéficierait de l'étude des paramètres de performance et de récupération supplémentaires, en mettant l'accent sur l'état d'hydratation du cheval avant, pendant et après l'exercice.

Mots clés: Standardbred; performance sportive (équine); cheval de course; électrolyte; intensité de l'exercice

Electrolytes play an important role in the sustainability of the competitive horse. Dietary electrolytes, such as chloride, sodium and potassium, are needed for basal processes in the body, including maintaining osmotic pressure, movement of electrical impulses and muscle contraction (Assenza et al., 2014). There are no electrolyte storage mechanisms (Frape, 1988) thus, they must be provided in the diet.

A diet high in forages generally provides adequate ionic properties to the horse by serving as an electrolyte and water reservoir (Harris, 2009; Coenen, 2005). Many athletic horses are fed diets with a lower forage and higher starch composition than non-competitive horses. These diets are higher in energy and conducive to a lower body weight and reduced heart rate during exercise, although an increase in body weight of horses fed higher forage diets may be due to the water-holding capacity of the forage (Connysson et al., 2010). This increases their likelihood of becoming deficient in electrolytes.

Athletic horses may have a higher requirement for electrolytes than the non-competitive horse, as there is a positive correlation between activity level and metabolic demand (Assenza et al., 2014; Piccione et al., 2007). Effectively, physical exercise induces several stress responses and metabolic and hematological adaptations are necessary to re-establish homeostatic equilibrium (Arfuso et al., 2016; Piccione et al., 2015; Fazio et al., 2011; Piccione et al., 2010). During exercise, water and electrolytes are excreted from the body through sweat, resulting in fatigue and muscle weakness.

Electrolyte deficiency can result in recurrent episodes of painful muscle spasms, ulcers, colic, rhabdomyolysis, lethargy, neurologic dysfunctions, nervousness, aggression and exhaustion (Johnson, 1995) and is related to insufficient levels of potassium in the muscle tissue to meet the metabolic demands of the horse. During periods of exercise, potassium will exit the muscle cells and enter the bloodstream (Hess et al., 2005). The amount of potassium entering the bloodstream is dependent on the intensity and duration of the workload (Piccione et al., 2007). This is a transient effect, as potassium levels in the blood will peak and then begin to decline as exercise progresses (Piccione et al., 2007; Hess et al., 2005), which can be attributed to losses in the sweat (Harris and Snow, 1992).

The objective of this study was to investigate the influence of varying intensities of exercise and oral electrolyte supplementation on heart rate and on plasma sodium, chloride, potassium concentrations in the Standardbred race horse. An electrolyte supplement was also investigated in order to determine its influence on plasma electrolyte concentrations and racing speed of horses undergoing various states of physical activity.

Materials and Methods

Eleven pacing Standardbreds (3 geldings, 8 mares; 2-11 years old, mean body weight = 653.6 ± 45.1 kg; mean body condition = 3.1 ± 0.4 , based on a Henneke scale of 1 to 9, Henneke et al., 1983) undergoing intensive race training were included in this experiment with informed owner consent.

All horses resided at Truro Raceway in Truro, NS, Canada (45.377188°N , -63.271047°W) year-round and participated in home races routinely from May to the end of December. These horses participated in harness racing, where they were individually placed in a lightweight harness and raced as a specific gait (pace), while pulling a two-wheeled sulky, and a jockey. At this location, they raced on a 0.5 mile (0.805 km) dirt racetrack. Horses were jogged regularly (almost daily) and raced weekly.

Subjects remained on their regular training and race schedules and samples were taken in accordance from December 4-21, 2015. Average ambient temperature was $1.96 \pm 4.71^\circ\text{C}$. Horses had free, unrestricted, access to water in their stalls and were fed a consistent diet of a complete pelleted feed and sweet feed three times / day (approximately 0.83 kg of grain / horse / day) and their hay supply was refilled multiple times daily. Animals were managed in

accordance with the Canadian Council on Animal Care (CCAC, 2009) under the Dalhousie University, Faculty of Agriculture, Animal Care and Use Protocol #2014-074.

Each horse underwent the following three exercise sessions, after which blood samples were immediately collected: 1) resting; 2) jogging (while pulling a sulky and jockey) and 3) racing (while pulling a sulky and jockey). These treatments were performed under two separate conditions 1) no electrolyte supplement was provided to the horse and 2) an electrolyte supplement was provided to the horse two hours prior to exercise (Table 1). No additional changes were made to the diet of each horse for any of the treatments. The electrolyte supplement (Quench Electrolyte, orange flavor; Strictly Equine, Wecan Sales, Beamsville, ON, Canada) used was ingested as a powdered form diluted with water (approximately 30 g electrolyte supplement in 20 ml water / dose) and administered using an oral syringe two hours prior to sampling. The supplement contained (/30 g): sodium chloride, 18 g (60 %); potassium chloride, 6 g (20 %); dextrose, 4.8 g (16 %); inactive ingredients (silicon dioxide and flavor), 0.9 g (3 %); magnesium oxide, 0.240 g (0.8 %) and calcium carbonate, 0.060 g (0.2 %).

At the time of blood sample collection, heart rate was determined by using a stethoscope behind the left elbow. Samples from individual horses were taken approximately 5-6 days apart in a stall or while the horse was on cross-ties and under control of the handler via halter and lead rope. Blood samples were collected by jugular venipuncture into lithium heparin vacutainer tubes. Once separated, plasma was pipetted into storage test tubes. Samples were stored in a -80 °C freezer (for less than one month). To analyze samples, they were thawed and centrifuged using a Thermo Scientific CL10 centrifuge (Fisher Scientific, Toronto ON, Canada) at 1500 rpm for 5 minutes. Plasma potassium, sodium and chloride concentrations were analyzed using a VetLyte Electrolyte Analyzer (Idexx Laboratories, Westbrook, ME, USA). For race treatments,

original race times were recorded, as well as race times, taking variant into consideration (an adjustment made for favorability of track condition, taking factors such as weather and the speed of the other horses into consideration).

Samples were not collected from all 11 horses for all six treatments (Table 1). At various points throughout the trial, three horses developed non-related health issues and were removed from the study. Immediately following each heat or race, Truro Raceway has a policy of testing the horse who places first for banned substances, in addition to randomly selecting others in the competition. One horse from the racing treatment that was provided with an electrolyte supplement was randomly selected for testing and was unavailable for sample collection.

Statistical analysis of heart rate and electrolyte results was performed using the Mixed procedure of SAS 9.3 (Littell et al., 1996). Horse was the experimental unit. Outliers were removed and data was checked for normality. If normality was not met (sodium and chloride values), a log transformation was applied to the data and letter values depicting statistical significance were assigned to the original means. All data are expressed as means $\pm$ standard error. Heart rate and electrolyte data was analyzed using a replicated incomplete 6 x 6 Latin-square design with a 3 x 2 factorial arrangement of treatments (exercise x supplement). Differences between means were determined using the Tukey-Kramer test and were significant when $P < 0.05$. Interactions for exercise x supplement were determined. Analysis of Variance for the race speeds of the horses in the racing treatments (supplemented and unsupplemented) was conducted using the General Linear Model procedure of SPSS version 19.0 (IBM Corp. Released 2010. IBM SPSS Statistics for Windows, Version 19.0. Armonk, NY, USA). Differences between means were determined using the Ryan-Einot-Gabriel-Welsch F-test and were significant when $P < 0.05$.

Results and Discussion

Heart rate and blood plasma electrolyte concentrations resulting from this study are shown in Table 2. Exercise significantly affected heart rate ($P<0.05$), which increased with work intensity. The significant differences in heart rate between all three exercise treatments indicates significant differences in the physiological states of the animals undergoing the three different exercise conditions.

Exercise had a significant effect on plasma potassium concentrations. Plasma potassium concentration was higher in jogging horses than those in a resting or racing state ($P<0.05$). During high intensity exercise, plasma potassium concentrations increase rapidly (Piccione et al., 2007; Hess et al., 2005), before returning to post warm-up levels (Harris and Snow, 1992). The lack of significantly different plasma potassium levels in resting and racing horses concurs with the findings of White et al. (1991).

Exercise had a significant effect on plasma sodium concentration. After resting and jogging (a lower intensity form of exercise for a longer duration), plasma sodium levels were not significantly different, but increased substantially during a race ($P<0.05$). Results were similar to those of Piccione et al. (2007), who observed a significant increase in plasma sodium concentration in horses undergoing one hour of intense exercise. Levels remained elevated one hour after rest. In the same horses, walking for one hour did not result in plasma sodium concentrations that were significantly different from resting levels.

No significant changes were observed in the plasma chloride concentrations of the horses who participated in this trial ($P>0.05$). These chloride concentrations are similar in range to values reported by Larsson et al. (2013), although in some instances, they identified pre- and

post-race differences in the plasma chloride concentrations of endurance horses ($P<0.05$). White et al. (1992) found plasma chloride concentrations of Thoroughbred race horses who raced for a time of approximately one to two minutes, to be significantly lower than resting levels, whereas Piccione et al. (2007) observed a significant, extended increase in plasma chloride concentrations in horses exercised for one hour. As compared with resting levels, Assenza et al. (2014) observed significantly reduced serum chloride concentrations in horses who took part in a three-day jumping competition, however, when the conditions were repeated a week later, the serum chloride concentrations increased and were not significantly different from resting levels. Both Piccione et al. (2007) and Assenza et al. (2014) attributed their results to water balance.

The oral administration of an electrolyte supplement significantly affected heart rate and blood potassium and sodium concentrations ($P<0.05$), but not blood chloride concentrations ($P>0.05$). There were significant interactions between exercise and supplement for potassium and sodium ($P=0.05$ and 0.00 , respectively). Most notably, but not surprisingly, the plasma sodium concentrations of supplement-fed horses at rest (146.10mmol/L) were significantly higher ($P<0.05$) than those of horses at rest that had not been provided with an oral supplement (141.36mmol/L).

The race times of supplemented horses was faster, although differences between means were not significant ($P>0.05$). Taking variant into account, horses not provided with an electrolyte supplement ran 0.5 mile (0.805 km) in 124.5 ± 2.4 seconds, whereas horses provided with an electrolyte supplement ran 0.5 mile (0.805 km) in 91.5 ± 56.5 seconds (not taking variant into account, these times convert to 126.2 ± 1.2 and 92.8 ± 57.3 seconds for unsupplemented and supplemented horses, respectively) ($P=0.12$).

Based on the results obtained in the present study, exercise showed a significant effect on heart rate and plasma sodium and potassium concentrations, whereas, no influence of exercise on plasma chloride concentrations was found. Oral administration of an electrolyte supplement also led to a statistically significant increase in heart rate and blood potassium and sodium concentrations. To further evaluate these findings, measurements could be expanded to include water consumption, sweat loss, blood glucose and lactic acid. A comparison of both physically fit and unfit horses would provide further insight on how the body reacts to exercise. To determine the ideal absorption time of a supplement, experiments involving different dosage times relative to exercise treatments should be investigated. Finally, the use of heart rate monitors and equine treadmills would allow for precise measurements by minimizing errors due to time between exercise and sample collection.

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Table 1

Detailed description of each treatment used in this study.

Treatment	<i>n</i>	Description
Resting, no supplement	11	Sample taken when horse was in a calm, relaxed state, and distant from grain feeding times or exercise activities. No electrolyte supplement given prior to this sample collection.
Jogging, no supplement	10	Sample taken within 1 minute of completing a jogging session (19.31 kph $\pm$ 8.05 kps for 20 minutes). No electrolyte supplement given prior to this sample collection.
Racing, no supplement	8	Sample taken within 1 minute of completing a full exertion race session (48.28 kph $\pm$ 4.83 kph for 2 minutes). No electrolyte supplement given prior to this sample collection.
Resting, supplement	11	Sample taken when horse was in a calm, relaxed state, and distant from grain feeding times or exercise activities. Electrolyte supplement given 2 hours prior to this sample collection.
Jogging, supplement	8	Sample taken within 1 minute of completing a jogging session (19.31 kph $\pm$ 8.05 kps for 20 minutes). Electrolyte supplement given 2 hours prior to commence of jogging session.
Racing, supplement	7	Sample taken within 1 minute of completing a full exertion race session (48.28 kph $\pm$ 4.83 kph for 2 minutes). Electrolyte supplement given 2 hours prior to commence of race session.

kph=kilometers per hour.

kps=kilometers per second.

n=number of samples collected per treatment.

Table 2

Heart rate and plasma electrolyte concentrations ($\pm$ standard error) of horses who have undergone various states of exercise and horses that have and have not been provided with an electrolyte supplement.

Parameter	Heart rate (bpm)	Potassium (mmol/L)	Sodium (mmol/L)	Chloride (mmol/L)
Main Effects				
Exercise				
Resting	37.1 $\pm$ 2.1 ^c	4.67 $\pm$ 0.19 ^b	143.73 $\pm$ 0.52 ^b	104.19 $\pm$ 0.41
Jogging	64.6 $\pm$ 2.5 ^b	6.23 $\pm$ 0.23 ^a	143.83 $\pm$ 0.57 ^b	104.44 $\pm$ 0.46
Racing	92.6 $\pm$ 2.6 ^a	4.94 $\pm$ 0.25 ^b	151.10 $\pm$ 0.75 ^a	105.50 $\pm$ 0.51
Electrolyte supplement				
Unsupplemented	61.7 $\pm$ 2.0 ^b	4.97 $\pm$ 0.18 ^b	145.65 $\pm$ 0.50	104.42 $\pm$ 0.37 ^b
Supplemented	67.8 $\pm$ 2.0 ^a	5.59 $\pm$ 0.18 ^a	146.79 $\pm$ 0.51	105.66 $\pm$ 0.38 ^a
Treatment (Exercise x supplement)				
Resting, unsupplemented	37.1 $\pm$ 3.0 ^c	4.82 $\pm$ 0.27 ^b	141.36 $\pm$ 0.71 ^c	104.27 $\pm$ 0.57
Jogging, unsupplemented	57.4 $\pm$ 3.7 ^b	5.69 $\pm$ 0.32 ^{ab}	143.78 $\pm$ 0.79 ^{bc}	104.00 $\pm$ 0.63
Racing, unsupplemented	90.5 $\pm$ 3.5 ^a	4.40 $\pm$ 0.32 ^b	151.80 $\pm$ 1.06 ^a	105.00 $\pm$ 0.72
Resting, supplemented	37.1 $\pm$ 3.0 ^c	4.53 $\pm$ 0.27 ^b	146.10 $\pm$ 0.75 ^b	106.10 $\pm$ 0.60
Jogging, supplemented	71.8 $\pm$ 3.5 ^b	6.78 $\pm$ 0.32 ^a	143.87 $\pm$ 0.83 ^{bc}	104.88 $\pm$ 0.67
Resting, supplemented	94.7 $\pm$ 4.0 ^a	5.47 $\pm$ 0.34 ^{ab}	150.40 $\pm$ 1.06 ^a	104.00 $\pm$ 0.63
P-Values				
Exercise	<0.001	<0.001	<0.001	0.27
Supplement	0.03	0.02	0.11	0.03
Treatment	0.10	0.05	0.00	0.72

bpm=beats per minute.

^{abc} Means within rows with different superscripts are significantly different ($P < 0.05$).