EFFECTS OF RESTRICTED HAY INTAKE ON BODY WEIGHT AND METABOLIC RESPONSES TO HIGH-INTENSITY EXERCISE IN THOROUGHBRED HORSES

O. Rice, R. Geor, P. Harris, K. Hoekstra, S. Gardner, J. Pagan,
Kentucky Equine Research, Inc., Versailles, KY, and the Equine Studies Group, WALTHAM Centre for Pet Nutrition, Leicestershire, UK.

Summary

The purpose of the present study was to determine the effects of restricted hay intake on the metabolic responses of horses to high-intensity exercise. Four conditioned Thoroughbred horses were studied in a 2 x 2 crossover design. Initially, the length of time required for adaptation to *ad libitum* (AL) intake of grass hay was determined. Thereafter, the metabolic responses to sprint exercise (SPR) were examined in 2 dietary periods, each 5-days in duration: 1) AL, where horses had free choice access to hay; and 2) Restricted (RES), where hay intake was restricted (~1% of bwt) for 3 days before the exercise test. For SPR, feed and water were removed 4 h before exercise. After measurement of bwt, horses completed a warm up followed by 2 min at 115% of maximum oxygen uptake, then a 10-min walking recovery (REC). During the 3 days before SPR, hay intake in AL averaged (± SE) 10.1 ± 0.9 kg, whereas intake during RES was 4.3 ± 0.2 kg. Pre-exercise bwt was significantly lower in RES (528 ± 5 kg) than in AL (539 ± 4 kg). During SPR, total mass-specific VO_2 was higher (P=0.02) in RES (243 ± 8 ml/kg/2 min) than in AL (233 ± 10 ml/kg/2 min). Conversely, accumulated oxygen deficit was higher (P<0.01) in AL (89.4 ± 2.2 ml O_2/kg) than in RES (82.4 ± 1.7 ml O_2/kg). Peak plasma lactate was also higher in AL (22.2 ± 1.2 mM) than in RES (19.1 ± 2.1 mM), and VO_2 during REC was 10% higher (P=0.12) in AL. In conclusion, compared to *ad libitum* feeding, 3 days of restricted hay intake reduced bwt by 2%. This reduction in body weight was associated with an increase in the mass-specific rate of oxygen consumption during sprint exercise, with a corresponding decrease in anaerobic energy expenditure.

Dietary fiber, Oxygen deficit, Anaerobic metabolism, Plasma lactate

Introduction

The amount of energy needed to run is directly related to the weight being moved (horse, rider and tack) and the speed of running (Taylor and Heglund 1982). Addition of weight to horses increases the energy cost of locomotion (Thornton et al. 1987). Conversely, the acute reduction in body weight following administration of the loop diuretic furosemide results in decreased anaerobic energy expenditure during brief, high intensity exertion (Hinchcliff 1999) and an increase in the relative maximal rate of oxygen consumption measured during incremental treadmill exercise (Bayly et al. 1999).

Diet can have a marked effect on body weight in horses. Specifically, high roughage diets increase the mass of ingesta in the equine large intestine, the result of greater water consumption compared to low fiber diets and the ability of fiber to bind to water (Meyer

1995). High fiber diets are desirable for horses engaged in endurance sports because the larger reservoir of fluid and electrolytes in the hind gut compared with a low fiber diet may lessen the severity of dehydration during prolonged exercise (Warren et al. 1999). On the other hand, the increase in body weight when horses consume a high fiber diet (Warren et al. 1999) will mandate an increase in energy expenditure at any given running speed and may be detrimental to performance, particularly during high-intensity exertion.

Anecdotally, racehorse trainers restrict the amount of hay fed to horses before racing. However, to date, no study has examined the effect of restricted hay intake on body weight, nor the effects of this dietary manipulation on exercise performance. Accordingly, the purpose of the present study was to determine the effects of restricted hay intake on the metabolic responses of horses to high-intensity exercise. We hypothesized that, compared to *ad libitum* hay intake, a regimen of restricted hay feeding starting 3 days before a standardized exercise test would decrease body weight and reduce energy expenditure during running.

Materials and Methods

Four conditioned Thoroughbred horses (age 8-12yrs, bwt 540 ± 17 kg) were studied in a 2 x 2 crossover design. Initially, the length of time required for adaptation to *ad libitum* (AL) intake of grass hay was determined. Acclimatization to AL was assumed when intake did not vary by more than 2 kg for 5 consecutive days. The horse's diet consisted of grass hay, 3.6 kg of unfortified sweet feed (45% cracked corn, 45% whole oats, 10% molasses), and 60 g of a vitamin-mineral supplement (MicroPhase, KER, Inc.). Horses also had access to salt blocks while in their stalls. *Ad libitum* access to grass hay was provided when the horses were stabled (approximately 21 hours per day). Each morning, 9 kg of hay were provided in a hay net; the hay net was checked at frequent intervals throughout the day and, when necessary, additional hay was provided. Daily (24 h) intake of hay was measured and recorded as the total amount fed minus the hay left, either in the hay net or on the floor of the stall. Prior to the morning feeding (0700 h), each horse was weighed. These data provided an additional indicator of intake stabilization. The horses were exercised daily (3 days/week on a high-speed treadmill and 4 days/week on a mechanical walker). For two hours per day, the horses were turned out to pasture. Muzzles were worn to prevent grazing.

Study Protocol

Once the duration of adaptation to AL hay intake was determined, the metabolic responses to a single high-speed exercise protocol (SPR) were examined in 2 dietary periods, each 5-days in duration: 1) AL, where horses had free choice access to hay (as described above); and 2) Restricted (RES), where hay intake was reduced and offered at 1% of bwt (as fed basis) for 3 days before the exercise test. Hay feeding at 1% of bwt corresponds to the generally recommended minimum for performance horses. Preliminary data indicated that this level of feeding represented about a 50% reduction from AL provision. In RES, horses received 3 equal meals of hay at 0700 h, 1200 h and 1600 h. The last hay ration, for both groups, was given at 0700 h on the day of the SPR. To simulate North American race-day management, for both groups hay and water were removed from the stall 4 h pre SPR. All SPR trials were conducted in the early afternoon. Following a 10 day re-acclimatization to AL hay feeding, horses switched treatments. Horses received only light exercise (mechanical walker and turn out) the day before the SPR.

Prior to the study, each horse undertook an incremental exercise test for determination of the maximal rate of oxygen uptake (VO_{2max}). The incremental exercise test consisted of the horse running on a high speed treadmill inclined at 4° for 90 s at 4 and 6 m/s, with subsequent increases of 1 m/s every 60 s until the horses were unable to maintain their position on the treadmill. VO_{2max} was determined when oxygen consumption increased by <4ml/kg/min despite a 1 m/s increase in running speed. From linear regression analysis (speeds below VO_{2max}), the running speed that would elicit 115% of VO_{2max} was calculated for each horse.

After measurement of bwt, horses completed a warm-up (5 min walk, ½mile trot, ½ mile canter, and 2 min walk) followed by 2 min at a speed calculated to elicit 115% of VO_{2max}, then 10-min walking and 5-min standing recovery (Rec). Oxygen consumption (VO_2) and carbon dioxide production (VCO_2) were measured at 15 s intervals during the 2-min sprint and at 1, 3, 5, 10 and 15 min of Rec. Blood samples for measurement of plasma lactate (LAC) and total protein (TP) concentrations and packed cell volume (PCV) were obtained pre-exercise, at the end of the warm up, during the last 10 s of the sprint, and at 5, 15 and 30 min of Rec. Plasma LAC was measured using an automated analyzer (YSI 2300), PCV by the microhematocrit method, and TP by refractometry. Accumulated oxygen deficit (AOD) was calculated by subtracting the actual VO_2 measured during the SPR, from estimated O_2 demand. Oxygen demand was calculated from the speed-VO_2 relationship, determined by measuring VO_2 at each speed during the incremental exercise test. The area under the VO_2 vs time curve during 15 min of Rec was also calculated. The data were analyzed using a Students *t* test or by a 2-way repeated measures ANOVA depending on the variable. Significance was taken at $P<0.05$. The data are presented as mean ± SE.

Results

VO_{2max} and treadmill speed at VO_{2max} of the 4 horses were 145.4 ± 3.1 ml/kg/min and 11.1 ± 0.3 m/s, respectively. Treadmill speed for the SPR was 12.7 ± 0.2 m/s, corresponding to 113 ± 2% of VO_{2max}. There was considerable individual variation in the length of time required for stabilization of hay intake after introduction of AL (7 to 12 days). One horse did not acclimatize to AL inasmuch as hay intake did not stabilize according to the criterion established prior to the study. Nonetheless, by 7 days of AL all horses were consuming at least 9 kg of hay per day. During the 3 days before the SPR, daily hay intake in AL was significantly ($P<0.01$) higher (10.1 ± 0.9 kg) than in RES (4.3 ± 0.2 kg). Hay intake during RES corresponded to approximately 0.9% of bwt per day. In RES, there was a significant decrease in bwt during the 3 days before the SPR (Fig. 1). Pre-exercise, bwt was 2% lower ($P<0.05$) in RES than in AL.

During SPR, the absolute rate of oxygen consumption did not differ between treatments, but total mass specific VO_2 was higher ($P=0.02$) in RES (243 ± 8 ml/kg/2 min) than in AL (233 ± 10 ml/kg/2 min). Conversely, AOD was 8% higher ($P<0.01$) in

AL than in RES (Fig. 2). Plasma lactate concentrations were higher ($P<0.05$) in AL than in RES at the end of SPR and after 5 min of Rec. However, PCV and TP did not differ between treatments at any time point (Table 1). Total VO_2 during REC was 10% higher ($P=0.12$) in AL (55.2 ± 5.1 L) than in RES (47.6 ± 3.2 L).

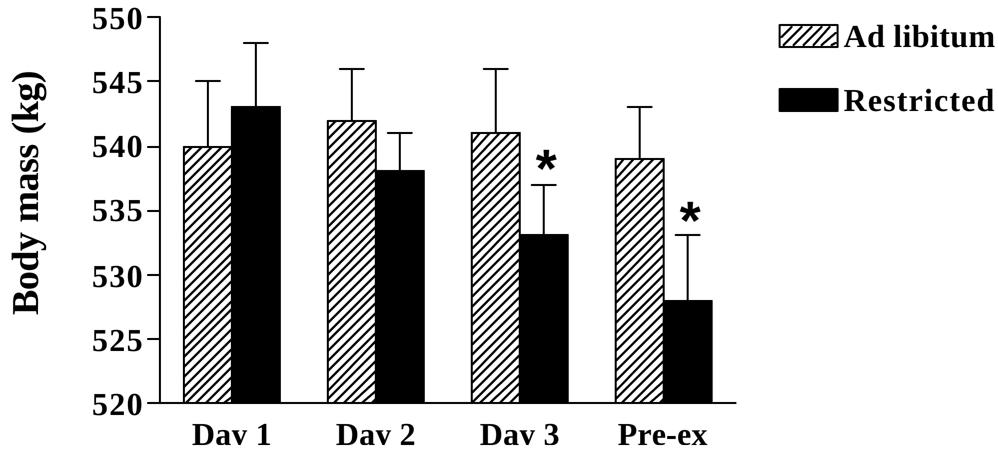

Figure 1. Body weight in the *Ad libitum* and Restricted hay intake groups for the 3-day period preceding the exercise test. Pre-ex = Body weight measured 5min before the exercise test. *Significant ($P<0.05$) difference *Ad libitum* vs. Restricted.

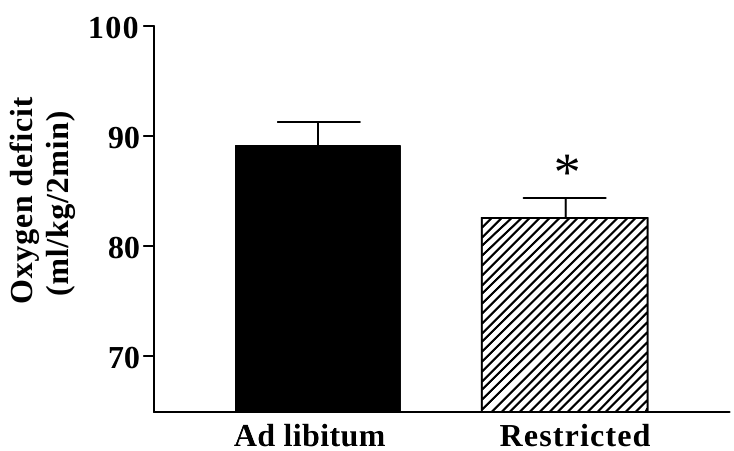

Figure 2. Accumulated oxygen deficit during 2 min of exercise at 115% of maximal oxygen uptake in the *Ad libitum* and Restricted treatments. *$P<0.05$ Restricted vs *Ad libitum*.

Table 1. Packed cell volume, plasma total protein and lactate concentrations during the sprint exercise test.

Variable		R	W/u	S	R5	R15	R30
PCV (%)	AL	41.5±1.4	50.7±1.9	58.9±1.7	57.2±1.4	5.03±1.6	44.4±2.0
	RES	40.9±1.3	52.1±2.1	58.7±1.9	56.7±1.3	49.4±1.2	43.7±1.5
TP (g/dL)	AL	6.2±0.2	6.7±0.2	7.3±0.3	6.9±0.2	6.5±0.1	6.1±0.1
	RES	6.3±0.2	6.7±0.3	7.5±0.2	7.0±0.2	6.5±0.2	6.0±0.2
LAC (mM)	AL	0.58±0.02	1.08±0.17	17.88±1.9	23.7±1.8	14.9±1.7	6.53±0.8
	RES	0.51±0.01	0.89±0.19	15.22±2.2*	19.4±1.2*	13.6±2.6	7.4±2.42

Values are mean ± SE for 4 horses. AL, *ad libitum*; RES, restricted; PCV, hematocrit; TP, total protein; LAC, plasma lactate; R, Rest; W/u, warm up; S, sprint; R5, 5 min post-recovery; R15, 15 min post-recovery; R30, 30 min post-recovery. *Significant difference from AL.

Discussion

The main findings of the present study were that 1) compared to *ad libitum* hay feeding, 3 days of restricted (1% of body weight) hay intake was associated with an approximately 2% decrease in body weight, and 2) the reduction in body weight associated with restricted hay feeding resulted in an increase in the mass-specific rate of oxygen consumption during sprint exercise, with a corresponding decrease in anaerobic energy expenditure.

It should be emphasized that this study was not designed to compare the different hay feeding practices employed by racehorse trainers. Racehorses are rarely provided with free choice access to hay and typical intake is approximately 1% of body weight, the amount offered during RES. Furthermore, although hay feeding is often restricted before a race, this is normally done acutely (e.g. the day before a race) rather than the 3-day period of restricted intake used in the present study. Nonetheless, the results of our study do provide evidence that the level of hay feeding can affect body weight and the metabolic responses to high-intensity exercise.

Previous studies in horses have demonstrated that dietary fiber intake affects the weight of ingesta in the hindgut (Meyer 1995) as well as overall body mass (Pagan and Harris 1999; Warren et al. 1999). In the present study, pre-exercise body weight was approximately 11 kg lower in RES than in AL even though hay intake differed by only 5 to 6 kg. There are at least two possible explanations for this discrepancy. First, as water intake tends to parallel dietary fiber intake (Warren et al. 1999), it is possible that the lower body weight in RES was, in part, due to a reduction in water intake and the fluid mass in the hindgut. Second, it is probable the effects of reduced fiber intake on the mass of ingesta in the large intestine are cumulative, as evidenced by the widening of the difference in body weight between the two groups during the 3 days of restricted hay feeding (Fig. 1). It is also interesting to note that the magnitude of the weight reduction observed in the RES treatment was similar to that reported after administration of the diuretic furosemide (1.0 mg/kg IV), a drug purported to confer an ergogenic effect during racing (Hinchcliff 1999).

The anaerobic contribution to energy expenditure during SPR was lower in RES than in AL as evidenced by lower values for accumulated oxygen deficit (Fig. 2) and peak plasma lactate concentrations (Table 1). Although it is tempting to conclude that these alterations in energetic response are due to the reduction in body weight in RES, further study is required to verify this hypothesis. Nonetheless, there is substantial evidence that acute weight reduction of the magnitude observed in this study results in a decrease in anaerobic energy expenditure during high intensity exercise. Specifically, the pre-exercise administration of furosemide decreases VCO_2 and blood lactate concentration during incremental exercise and decreases lactate concentration and accumulated oxygen deficit during exercise at 120% of VO_{2max}. Importantly, these effects of furosemide are reversed by the carriage of weight equal to that lost after administration of furosemide (Hinchcliff 1999), suggesting that the alterations in energetic responses are attributable to the loss of body weight rather than a direct effect of the drug.

Currently, it is recommended that performance horses receive hay at a minimum of 1% of bwt per day to satisfy requirements for long stem fiber and minimize digestive upsets. In this context, relative to the restriction protocol used in this study, more severe or longer term restrictions of hay intake are not recommended. Nonetheless, on the basis of our results, further studies that examine the relationship between fiber intake, body weight, and exercise metabolism and performance are warranted. As soluble fiber has greater water holding capacity than insoluble fiber, future studies should also examine the effects of fiber type on body weight and high-intensity exercise responses.

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