Recent developments in equine nutrition

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Summary

Recent studies on five aspects of equine nutrition are described. Compared to *ad libitum* hay feeding, intake restricted to 1% of body weight was associated with a decrease of approximately 2% in body weight and resulted in an increase in the mass–specific rate of oxygen consumption during sprint exercise, with a corresponding decrease in anaerobic energy expenditure. It is recommended that performance horses receive hay at 1% of bodyweight to minimise digestive upsets. Measurements of respiratory gaseous exchanges showed that, compared with Arabian horses, the higher aerobic and anaerobic capacities of the Thoroughbred contributed to their performance during high intensity exercise whereas the Arabian may be better adapted for endurance exercise because of a greater use of fat; this difference may reflect variation in muscle fibre types. Exercise training of mature Thoroughbreds appeared to increase requirement for zinc, but not for copper and manganese. The addition of corn oil to a grain meal delayed solid–phase gastric emptying which may contribute to the blunted glycaemic response following a meal with that addition. In 218 weanlings on six farms, hyperglycaemia and hyperinsulinaemia were found to be associated with the incidence of osteochondrosis; glycaemic responses of individuals were not surely related to the occurrence of lesions, but it is suggested it would be prudent to give foals concentrates that produce a low glycaemic response.

Keywords: equine, nutrition, exercise, digestibility, gastric emptying, skeletal disease

Introduction

Significant advances have been made over the past 30 years in our understanding of equine nutrition, but many questions still remain unanswered about how to feed and manage horses. Over the past 12 years, Kentucky Equine Research (KER) has conducted numerous research studies that have addressed questions relevant to the horse feed industry. This paper will review five of the most recent of these studies.

Hay intake and performance

The amount of energy that a horse needs to run is directly related to the weight being moved (horse, rider and tack) and the speed of running; addition of weight increases the energy cost of locomotion. Diet can have a marked effect on body weight (W). Specifically, high roughage diets increase the mass of ingesta in the equine large intestine, the result of a greater water consumption compared with low fibre diets and the ability of fibre to bind to water. High fibre diets are desirable for horses engaged in endurance sports because the larger reservoir of fluid and electrolytes in the hind gut than with a low fibre diet may lessen the severity of dehydration during prolonged exercise. On the other hand, the consequent increase in body weight will increase energy expenditure at any given running speed and may be detrimental to performance, particularly during high–intensity exertion.

Traditionally, racehorse trainers restrict the amount of hay fed to horses before racing in an attempt to improve performance. However, no study has examined the effect of this practice on exercise performance; KER therefore conducted a study to determine the effects of restricted hay intake on the metabolic responses of horses to high–intensity exercise (Rice *et al*. 2001). 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.

Four conditioned Thoroughbred horses (age 8–12 years, 540 ± 17 kg W) 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 h 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 per week on a high–speed treadmill and 4 days per week on a mechanical walker. For two hours per day, the horses were turned out to pasture; muzzles were worn to prevent grazing.

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 two dietary periods, each of 5 days duration:

(i) AL, where horses had free choice access to hay (as described above)

(ii) Restricted (RES), where hay intake was reduced and offered at 1% of W (as fed basis) for 3 days before the exercise test.

Hay feeding at 1% of W corresponds to the generally recommended minimum for performance horses, and 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, 1200 and 1600 h. The last hay ration, for both groups, was given at 0700 h on the day of the SPR and, to simulate North American race–day management, the hay and water were removed from the stalls of all animals 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 W, horses completed a warm–up (5 min walk, 0.5 mile trot, 0.5 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 microhaematocrit 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.

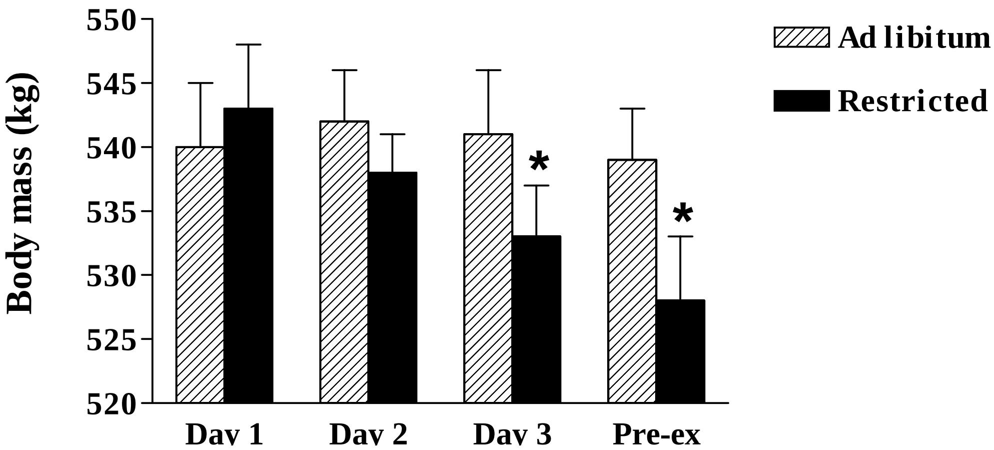

Figure 1 Body weight in the Ad libitum and Restricted hay intake groups for the 3–day period preceding the exercise test. Pre–ex = Body weight measured 5 min before the exercise test. *Significant (*P*<0.05) difference Ad libitum vs. Restricted.

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 W per day. In RES, there was a significant decrease in W during the 3 days before the SPR (Figure 1). Pre–exercise, W 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 (Figure 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, but PCV and TP did not differ between treatments at any time. 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).

The main findings of this study were that

- 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
- 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. The anaerobic contribution to energy expenditure during exercise was lower in RES than in AL as evidenced by lower values for accumulated oxygen deficit (Figure 2) and peak plasma lactate concentrations.

Currently, it is recommended that performance horses receive hay at a minimum of 1% of W per day to satisfy requirements for long stem fibre 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 fibre intake, body weight, and exercise metabolism and performance are warranted.

Arabs vs. Thoroughbreds

Few studies have formally compared indices of athletic performance in different breeds of horses. Rose and colleagues (Rose *et al*. 1995) described indices of exercise capacity in Thoroughbred and Standardbred racehorses that were examined because of poor performance. They reported that aerobic capacity and total run time, measured during an incremental exercise test, were significantly greater in the Thoroughbreds. However, as these horses were examined for performance problems, it is difficult to apply the findings to normal racehorses.

In a recent KER study (Prince *et al*. 2001), we examined selected measures of exercise capacity and metabolism in a small group of Thoroughbred and Arab horses of similar age, training background, and diet. Both breeds of horses are used for several athletic disciplines, ranging from sprint racing to endurance events. However, anecdotal evidence indicates that Thoroughbreds have superior high intensity exercise capacity, whereas Arabian horses are regarded as

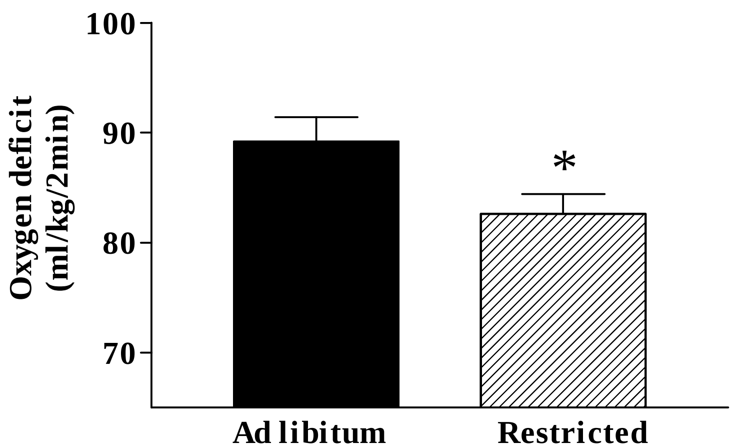

Figure 2 Accumulated oxygen deficit during 2 min of exercise at 115% of maximal oxygen uptake in the Ad libitum and Restricted treatments. *$P<0.05$ Restricted vs. Ad libitum.

superior performers during endurance exercise. We hypothesized that the facility of Thoroughbred horses for high intensity exercise would be reflected in greater aerobic and anaerobic capacities when compared to the Arabian. We also hypothesized that respiratory exchange ratio (RER) (VCO_2/VO_2) would be lower in the Arab horses during low intensity exercise, reflecting a greater use of fat for energy.

The metabolic responses to low and high intensity exercise were compared in 5 Arabian (AR) and 5 Thoroughbred (Tb) horses. For 2 months before the study, horses were fed an identical diet and undertook a similar exercise training program. Horses then completed three treadmill (3º incline) trials:

1 an incremental test (MAX) for determination of aerobic capacity, V_{LA4}, and lactate threshold (LT; the percentage of VO_{2max} when plasma lactate = 4 mM)

2 a sprint test (SPR) for estimation of maximal accumulated oxygen deficit (MAOD) in which horses ran until fatigue at 115% VO_{2max}

3 a 90 min test at 35% VO_{2max} (LO).

There was a minimum of 7 days between tests and the order of the SPR and LO trials was randomized. For all tests, VO_2, VCO_2, and respiratory exchange ratio (RER) were measured throughout exercise. For MAX, horses ran for 90 s at 4 and 6 m/s, with subsequent increases of 1 m/s every 60 s until fatigue. Blood samples were obtained during the last 10 s of each speed increment. In SPR, MAOD was calculated by subtracting actual VO_2 from estimated O_2 demand. In LO, samples for measurement of plasma glucose and free fatty acids (FFA) were obtained at 0, 5, 15, 30, 45, 60, 75, and 90 min of exercise. Data were analyzed using Student's t test or 2–way repeated measures ANOVA.

VO_{2max} ($P<0.001$) and running speed ($P<0.05$) at VO_{2max} were higher in Tb (154 ± 3 ml/kg/min at 12.9 ± 0.5 m/s) than in AR (129 ± 2.5 ml/kg/min at 11.8 ± 0.2 m/s). Run time to fatigue during MAX was greater ($P<0.05$) in Tb (10.5 ± 0.5 min) than in AR (9.3 ± 0.3 min), but V_{LA4} and LT were not different between groups. Run time during SPR (Tb 149 ± 16; AR 109 ± 11 s) and MAOD (Tb 88 ± 4; AR 70 ± 6 ml O_2/kg) were higher ($P<0.05$) in the Tb group (Figure 3). During LO, FFA were higher ($P<0.05$) in AR than in TB between 60 and 90 min, while RER was lower ($P<0.05$) from 60 to 90 min of exercise. The higher aerobic and anaerobic capacity of the Tb horses likely contributed to their superior high intensity exercise performance. Conversely, the AR may be better adapted for endurance exercise as evidenced by the greater use of fat. These metabolic differences may reflect breed variation in muscle fibre types.

Trace mineral requirements

Very little research has been conducted to determine the trace mineral requirements for athletic horses. In a previous KER study evaluating different forms of selenium, horses supplemented with inorganic Se demonstrated a significant increase in urinary Se excretion after a single bout of exercise (Pagan *et al.* 1999). These findings suggest that exercise increases the requirement for Se. Are the requirements for other microminerals also affected by exercise and training? To answer these questions, KER conducted a study (Hudson *et al*. 2001) to:

1 determine the digestibility and retention of copper, zinc and manganese over four different levels of intake (basal, 50% of NRC added, 100% of NRC added, and 200% of NRC added)

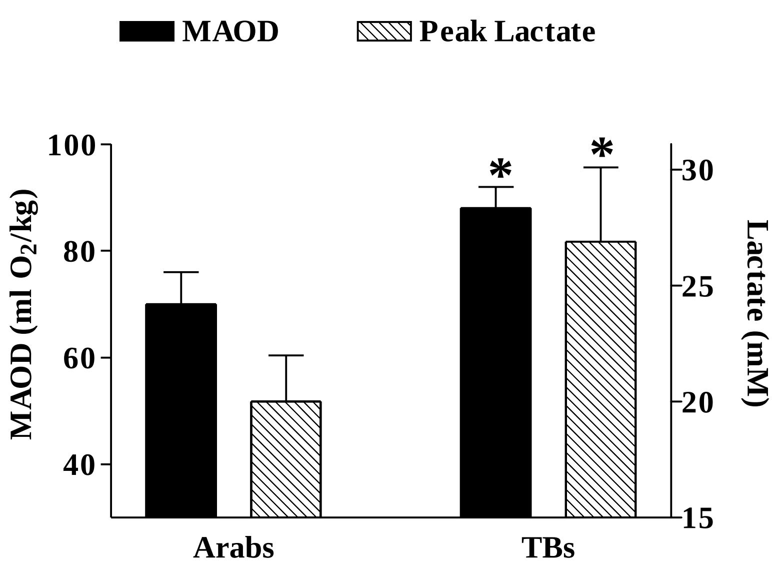

Figure 3 Maximum accumulated oxygen deficit and peak lactate concentrations for the Arabian and Thoroughbred horses during a single high speed exercise test at 115% of maximum oxygen uptake.

2 determine how regular exercise and training alters the requirements for these trace minerals.

Six mature Thoroughbred geldings were used: 3 unworked (NOEX) and 3 horses in regular exercise training (EX); mean age 11.2 ± 2.6 yr, body weight 534 ± 46 kg. They were studied in a 16 week longitudinal experiment that consisted of 4 periods, each with a 23–day adaptation period followed by a 5–day complete collection digestion trial. In period 1, horses were fed a diet of unfortified sweet feed and timothy hay (basal intake) that provided approximately 85%, 160% and 65% of the NRC recommendations for Cu, Mn and Zn, respectively. In periods 2, 3 and 4 respectively, horses were fed the basal diet plus a supplement that provided 50, 100 and 200% of the NRC (1989) requirements for Cu, Zn and Mn. The supplement was a blend of organic and inorganic trace minerals. During each adaptation period horses were housed in box stalls at night and given a minimum of five hours paddock turnout during the day (except during digestion trials). Muzzles were worn to prevent grazing. EX horses were conditioned on a high–speed treadmill and mechanical walker and on the third day of the 5–day digestion trial completed an exercise test that simulated the speed and endurance test of a 3–day event. With the treadmill set at a 3° incline, horses completed a 10 min walk at 1.4 m/s (Phase A), 10 min trot at 3.7 m/s (Phase A), 2 min gallop at 10.7 m/s (Phase B), 20 min trot at 3.7 m/s (Phase C), 10 min walk at 1.4 m/s (Phase C), and an 8 min canter at 9.0 m/s (Phase D). Two days prior to the digestion trial, horses were fitted with collection harnesses (Equisan Pty. Ltd., Melbourne, Australia) that allow the complete and separate collection of faeces and urine.

Daily fecal output was measured and samples of faeces were frozen for subsequent proximate and trace mineral analysis (Dairy One DHIA Forage Testing Laboratory, Ithaca, NY). Composite feed and faecal samples were analyzed for Cu, Zn and Mn contents by ICP radial spectrometry. For each mineral, and over the 4 levels of intake, external balance data were calculated and the Lucas procedure was used to estimate the true digestibility (slope of the linear regression of nutrient retention against level of intake), endogenous losses (the y intercept) and the maintenance requirement (when y = 0). An unpaired Students *t* test was used to compare results for NOEX and EX.

The results of linear regression analysis (Lucas procedures) are presented in Table 1 with data for true digestibility, endogenous losses, and estimated daily maintenance requirements. Concerning the conditioning status of the horses, there was a significantly ($P = 0.04$) higher zinc requirement in the EX group than in the NOEX group. Although there were no other significant differences between NOEX and EX, there were trends for lower true digestibility of manganese ($P = 0.059$) and zinc ($P = 0.09$) in the EX group. Results of the present study suggest that exercise training results in a higher requirement for Zn, but does not affect the true digestibility and maintenance requirements of Cu and Mn in mature Thoroughbred horses.

Corn oil affects gastric emptying

The ^{13}C–octanoic acid breath (or blood) test has been recently developed as a non–invasive method for measuring the rate of solid–phase gastric emptying (GE) (Wyse *et al*. 2001). We used this method to test the hypothesis that GE is delayed following ingestion of a grain plus corn oil meal compared to a meal of grain alone (Geor *et al*. 2001). Four mature (10–12 y) Arabian horses were studied in a 2 x 2 factorial design. Factor A was the habitual ration, either a control (CON; hay plus sweet feed [SWF]), or an isocaloric fat–supplemented ration (FAT; hay, SWF and corn oil). Factor B was the type of meal consumed for the GE test (SWF, 2 g/kgW vs. SWF 2 g/kgW plus 10% corn oil [OIL]). Each habitual diet period lasted 10 weeks, with 6 weeks in between when all of the horses were fed the control ration. GE studies were performed during weeks 4 and 8 in each period. Within each dietary period, and in random order, horses were tested in both the SWF and OIL conditions. The 4 treatment combinations being: CON/SWF, CON/OIL, FAT/SWF, and FAT/OIL. For assessment of solid–phase GE, the test meals were labeled with 1 g of ^{13}C–octanoic

Table 1 Comparison of the true digestibility, endogenous loss, and estimated daily requirements for copper (Cu), zinc (Zn) and manganese (Mn) in unworked (NOEX) horses (n = 3) and physically conditioned (EX) horses (n = 3). Data are mean ± SD.

		Cu	Zn	Mn
Digestibility (%)	NOEX	41.8 ± 17.6	25.4 ± 11.4	57.9 ± 10.0
	EX	54.5 ± 11.7	14.3 ± 3.9+	40.2 ± 11.8+
Endogenous loss (mg/d)	NOEX	15.7 ± 1.60	65.2 ± 25.6	304.8 ± 95.1
	EX	20.3 ± 18.0	69.6 ± 35.9	163.6 ± 67.9
Requirement (mg/d)	NOEX	44.2 ± 23.6	274.4 ± 87.5	528.6 ± 168.6
	EX	35.0 ± 24.6	461.3 ± 133.2*	408.3 ± 107.1

* *P*< 0.05 EX vs. NOEX
+ *P*< 0.1 EX vs. NOEX

acid. Blood samples for measurement of plasma glucoseconcentration and ^{13}C–enrichment were collected at 30 min and immediately before ingestionof the test meal and at frequent intervals thereafter for 7 h. Three indices of blood ^{13}C–enrichment were calculated: half–dose recovery time ($t_{½}$), the time to peak blood ^{13}C–enrichment (t_{max}), and the gastric emptying coefficient (GEC).

The glycaemic response was markedly decreased in the OIL trials (CON/OIL; FAT/OIL) compared to the SWF trials (CON/SWF, FAT/SWF; Figure 4). This effect of corn oil was not altered by habitual diet. In one horse for both the CON/OIL and FAT/OIL trials, the blood ^{13}C vs. time curve was altered such that it was not possible to calculate $t_{½}$ and t_{max}. Excluding data from this horse, addition of corn oil to the meal of SWF was associated with a significant decrease in GEC and a significant increase in $t_{½}$ and t_{max}, as shown in Table 2.

Based on this study, we conclude that:

- the addition of corn oil to a meal sweet feed results in a delay in solid–phase GE
- the effect of oil on GE is not affected by short–term adaptation to a fat–supplemented diet
- the slowing of GE may contribute to the blunted glycaemic response following a grain meal containing corn oil. It has not been determined if oil also affects glucose absorption or starch digestion.

Glycaemic response and osteochondritis dissecans (OCD)

Hyperglycaemia and/or hyperinsulinaemia have been implicated in the pathogenesis of osteochondrosis (Glade *et al*. 1984; Ralston 1995). More specifically, foals that experience an exaggerated and sustained increase in circulating glucose and/or insulin in response to a carbohydrate (grain) meal may be predisposed to development of osteochondrosis. Studies *in vitro* with foetal and foal chondrocytes suggest that the role of insulin in growth cartilage may be to promote chondrocyte survival or to suppress differentiation and that hyperinsulinaemia may be a contributory factor to equine osteochondrosis (Hensen *et al*. 1997).

Rutgers University was recently granted a United States patent for diagnosing a predisposition for equine osteochondritis dissecans (OCD) using an oral glucose tolerance test (US Patent # 5,888,756). This patent was based on the premise that foals exhibiting an exaggerated glycaemic response to an oral glucose challenge were more susceptible to developing OCD. Kentucky Equine Research has licensed the rights to this patent and we recently conducted a large study to evaluate its effectiveness in identifying Thoroughbred weanlings that are at risk of developing skeletal disease (Pagan *et al.* 2001).

Two hundred and eighteen Thoroughbred weanlings (average age 300 ± 40 days, average body weight 300 ± 43 kg) on six central Kentucky farms were studied during December 1999 and January 2000. A glycaemic response test was conducted by feeding a

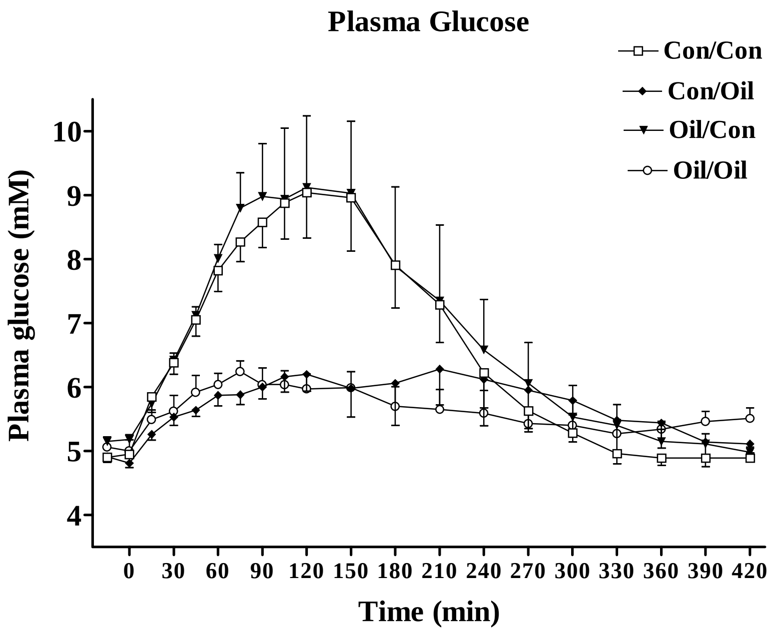

Figure 4 Glycaemic response with and without added corn oil.

meal that consisted of the weanling's normal concentrate at a level of intake equal to 1.4 g nonstructural carbohydrate (NSC) per kgW. Two of the farms fed a pelleted concentrate, while the other four used a textured sweet feed mix. All of these concentrates were fortified with levels of protein and minerals deemed suitable for weanlings. The NSC content of the farms' feeds ranged from 40% to 50%, and the test meal size equaled 963 g ± 170 g. A single blood sample was taken 120 min post feeding for the determination of plasma glucose and insulin concentrations. The test meal was fed between 0700 and 0800 h and the weanlings had not received any other grain for at least 12 h. Weanlings on five of the six farms spent the night before the test on pasture while one farm confined the weanlings in box stalls with access to grass hay throughout the evening.

The glycaemic index (GI) of each feed was also determined using four mature Thoroughbred geldings at the KER research farm. These feeds were again given as a single meal at a level of intake equal to 1.4 g NSC/kgW. Blood samples were taken immediately pre–feeding and at 30 min intervals for 4 h post feeding. GI was calculated from the area under the glucose response curves (AUC) for each feed.

The overall incidence of OCD on these farms was recorded until the horses were sold as yearlings in July or September at ages ranging from 16–20 months. For the purpose of this study, OCD was defined as osteochondrotic lesions occurring in the fetlock, hock, shoulder, or stifle that were treated surgically. These lesions were either diagnosed after the foal showed clinical signs of lameness or joint effusion, or after routine radiographic examinations that were performed in January and February of the foal's yearling year. Lesions identified radiographically that did not require surgery were not included in the results.

Twenty–five of the 218 weanlings (11.5%) had OCD lesions that were treated surgically. There was a wide range in the incidence of OCD among farms (Table 3).

Plasma glucose and insulin 2 h post feeding were significantly higher in weanlings with OCD than in unaffected foals ($P<0.05$). Insulin/glucose ratios, however, were not significantly different. The incidence of OCD was significantly higher in foals whose glucose and insulin values were greater than one standard deviation above the mean for the entire population in the study (Table 4). Elevated insulin/glucose ratios did not appear to be correlated with an increased incidence of OCD.

Each weanling's body weight was measured at the time of the response test and expressed as a percentage of a reference set of body weights collected from 350 fillies and 350 colts raised in Kentucky (Pagan *et al*. 1996). Each body weight was compared to the same age and gender in the reference data set. There was no difference between normal foals and OCD foals in relative body weight.

There were strong positive correlations between mean glucose (r = 0.84; $P<0.01$) and insulin (r = 0.93; $P<0.01$) response on each farm and the incidence of OCD. Much of the differences in glycaemic response among farms was probably due to the GI of the feed since there was also a strong positive correlation (r = 0.88; $P<0.05$) between the GI of each farm's feed and the farm's weanling glucose response.

In this study, a high glucose and insulin response to a concentrate meal was associated with an increased

Table 2 Effect of adding corn oil on the gastric emptying coefficient (GEC), half–dose recovery time ($t_{½}$), and the time to peak blood ^{13}C–enrichment (t_{max}). Values are means ± SD.

Treatment	GEC	$t_{½}$ (h)	t_{max} (h)
CON/SWF	2.96 ± 0.15	2.25 ± 0.55	1.20 ± 0.21
CON/OIL	2.10 ± 0.14	3.87 ± 0.39	2.08 ± 0.30
FAT/SWF	3.02 ± 0.09	2.21 ± 0.45	1.24 ± 0.37
FAT/OIL	2.05 ± 0.21	4.11 ± 0.66	2.14 ± 0.28

Table 3 Incidence of OCD on individual farms.

Farm	Total foals (n)	OCD foals (n)	OCD (% of foals)
1	24	0	0
2	19	6	32
3	27	2	7
4	51	4	8
5	74	9	12
6	23	4	17

Table 4 Relationship between glucose, insulin, and insulin/glucose ratio and the incidence of OCD.

	Glucose		Insulin		Insulin/glucose ratio	
Standard deviations from mean	Percent of population	OCD %	Percent of population	OCD %	Percent of population	OCD %
< 1 SD	11.0	0.0	10.1	0.0	15.1	6.0
± 1 SD	72.9	10.1	78.0	11.2	68.3	12.1
> 1 SD	16.1	25.7	11.9	23.0	16.5	13.9

incidence of OCD. Glycaemic responses measured in the weanlings were highly correlated with each feed's GI, suggesting that the GI of a farm's feed may play a role in the pathogenesis of OCD. GI characterizes the rate of carbohydrate absorption after a meal and is defined as the area under the glucose response curve after consumption of a measured amount of carbohydrate from a test feed divided by the area under the curve after consumption of a reference meal (Jenkins *et al*. 1981). In rats, prolonged feeding of high GI feed results in basal hyperinsulinaemia and an elevated insulin response to an intravenous glucose tolerance test (Pawlak *et al*. 2001). In foals, hyperinsulinaemia may affect chondrocyte maturation, leading to altered matrix metabolism and faulty mineralization, or altered cartilage growth by influencing other hormones such as thyroxine (Glade *et al*. 1984; Jeffcott and Hensen 1998).

Within each farm, there was not a significant difference in glycaemic response between horses that had lesions and normal individuals. Therefore, using this type of glycaemic response test in older weanlings to identify individuals that may be predisposed to OCD does not look promising. Perhaps diet induced hyperglycaemia or hyperinsulinaemia predisposes every weanling to OCD, but other factors such as biomechanical stress or trauma are needed to produce a clinically relevant lesion. Since this study used older weanlings, it remains unclear whether a response test using a more standardized oral glucose challenge (i.e. dextrose) can be used to identify younger individuals that are predisposed to OCD.

Based on the results of this study, it would be prudent to feed foals concentrates that produce low glycaemic responses. More research is needed to determine if the incidence of OCD can be reduced through this type of dietary management.

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