THE LONG-TERM EFFECTS OF FEEDING FAT TO TWO YEAR OLD THOROUGHBREDS IN TRAINING

JOE D. PAGAN, IVAN BURGER[1] AND STEPHEN G. JACKSON
Kentucky Equine Research, Inc., Versailles, Kentucky, USA
[1]Waltham Centre for Nutrition and Care, Melton Mowbray, UK

A number of short-term studies (2-4 weeks) have demonstrated improved metabolic response to exercise with fat supplemented diets. No longer term studies have been conducted to evaluate how fat supplementation affects the health and metabolic response of horses to exercise over an extended training period. Therefore, the following seven month study was conducted using 12 two year old Thoroughbreds to evaluate the long-term effects of feeding a fat supplemented diet during medium intensity, aerobic training. The control group (n=6) was fed grass hay and a fortified sweet feed (CON) and the other group (FAT)(n=6) received hay, sweet feed, a supplement pellet and 400 ml of soybean oil. This amount of oil supplementation supplied about 12% of the DE intake of the FAT group. After 2, 4, and 7 months, the horses performed 2 standardized exercise tests (SETs) on a high speed treadmill. The first test (STEP) consisted of sequential steps of 800 m at speeds of about 4, 8,9,10, and 11 m/s. The second test (SET30) consisted of 30 minutes of trotting at about 4 m/s.

Hematological parameters

Hematological parameters measured in samples taken 4 hours after feeding before each STEP for both treatment groups were within ranges reported previously for two year old Thoroughbreds in training (Allen and Powell, 1982). Neither dietary treatment nor training affected any of these hematological parameters.

Serum chemistry

Values for AST, GT, SDH, total bilirubin, total protein, cholesterol and bile acids from resting samples taken before each STEP were within ranges normally reported for healthy horses (Blackmore and Brobst, 1981) and none was affected by diet. Cholesterol and bile acids were elevated in both treatment groups after 2 months of training compared with samples taken later in the study. At this point in the study, the horses were turned out at night in grass paddocks which were fairly lush with spring forage.

Resting plasma hormone levels

Concentrations of insulin, cortisol and thyroxine measured in blood samples taken 4 hours after feeding before each STEP are shown in table 1. Diet did not statistically affect any of these measurements. There was, however, a difference ($P<0.01$) between 2 month and 7 month cortisol and thyroxine concentrations for both treatment groups. Cortisol was higher and thyroxine was lower at 2 months of training than at 7 months.

Table 1. RESTING PLASMA HORMONE LEVELS[1]

Hormone	*Initial*	*2 months*	*4 months*	*7 months*
CONTROL Insulin (uU/ml)	39.46 ±5.4	55.98 ± 17.2	46.16 ± 11.3	86.54 ± 24.1
FAT Insulin (uU/ml)	43.29 ± 12.4	48.03 ± 15.4	51.30 ± 10.9	45.47 ± 3.84
CONTROL Cortisol (ng/ml)	59.94 ± 21.97	101.80 ± 28.05	43.09 ± 5.4	37.13 ± 4.7
FAT Cortisol (ng/ml)	45.41 ± 19.7	78.27 ± 17.6	42.90 ± 13.3	35.80 ± 3.3
CONTROL Thyroxine (ng/ml)	20.94 ± 4.4	15.47 ± 2.7	28.88 ± 5.9	25.65 ± 3.26
FAT Thyroxine (ng/ml)	16.93 ± 2.1	15.69 ± 3.9	26.11 ± 3.7	27.32 ± 2.0

[1] mean ± standard deviation

Table 2. V_{LA4} AND V_{200} DURING STEP[1]

	Initial	*2 months*	*4 months*	*7 months*
CONTROL V_{LA4} (m/s)	8.65 ± 0.72	10.16 ± 0.99	9.67 ± 0.59	10.08 ± 0.49
FAT V_{LA4} (m/s)	8.62 ± 0.60	9.62 ± 0.80	9.59 ± 0.49	10.03 ± 0.65
CONTROL V_{200} (m/s)	9.15 ± 0.65	9.54 ± 0.80	9.88 ± 0.46	10.33 ± 0.51
FAT V_{200} (m/s)	10.05 ± 1.00	10.07 ± 1.08	10.34 ± 0.52	10.78 ± 0.78

[1] mean ± standard deviation

Standardized step-wise exercise test (STEP)

V_{200} and V_{LA4} measured at the beginning of the experiment and after 2, 4, and 7 months of training are shown in table 2. Training significantly increased V_{LA4} and V_{200} in both treatment groups ($P<0.05$). Diet, however, had no effect on these measurements. Figures 1-3 show plasma glucose, insulin, and cortisol response during the 7 month STEP. Four hours before the 7 month STEP, CONTROL horses were fed 2.27 kg of sweet feed and FAT horses received 1.59 kg of sweet feed, 113 g supplement pellet and 200 ml of soybean oil. The horses received no hay the morning of the STEP.

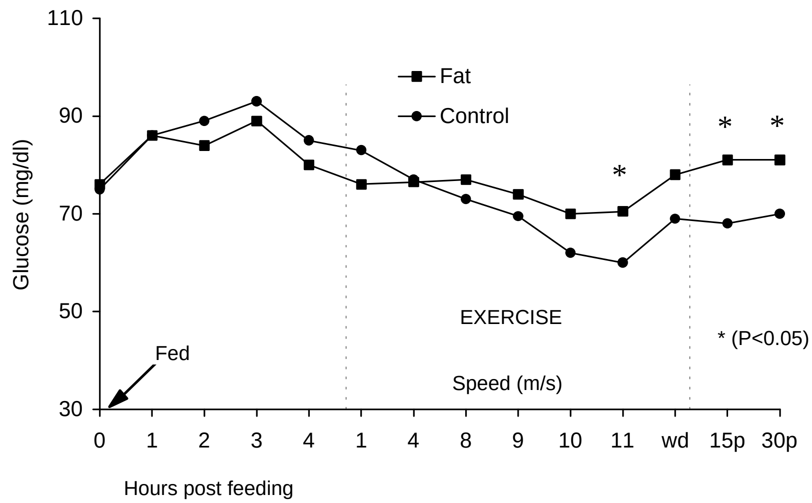

Figure 1. Plasma glucose response during STEP

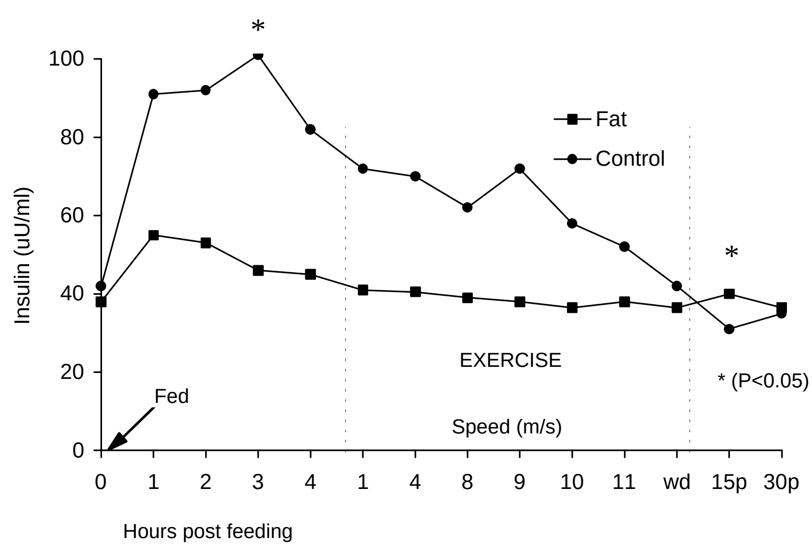

Figure 2. Plasma Insulin during STEP

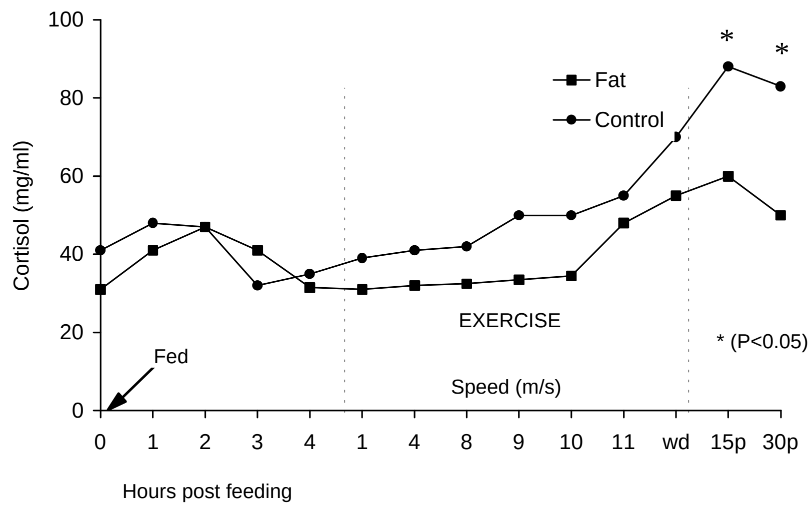

Figure 3. Plasma cortisol during STEP

GLUCOSE

Plasma glucose concentration was similar in the two treatment groups after an overnight fast. Glucose peaked in both groups 3 hours after feeding. After the onset of exercise, blood glucose decreased continually in the CONTROL horses from a pre-exercise level of 85.2 mg/dl to 61.2 mg/dl after the fastest exercise step (11 m/s). After the last exercise step, blood glucose was higher in the FAT horses (71.0 mg/dl) than in the CONTROL horses (61.2 mg/dl) (P<0.05). Fifteen minutes after exercise, glucose in the FAT group had returned to preexercise levels (81.8 mg/dl) and was higher (P<0.05) than in the CONTROL group (66.7 mg/dl).

INSULIN

Insulin was higher (P<0.05) 3 hours after feeding in the CONTROL group than in the FAT horses (102.9 vs 46.5 uU/ml). Insulin dropped throughout exercise and during recovery in the CONTROL horses. At 15 minutes after exercise, insulin was lower (P<0.05) in CONTROL horses (29.8 uU/ml) than in the FAT group (38.7 uU/ml).

CORTISOL

Cortisol was similar for both treatment groups before exercise. Cortisol increased in both groups throughout exercise and during recovery. At 15 and 30 minutes after exercise, cortisol was higher (P<0.001) in CONTROL horses than in the FAT group.

Discussion

A primary objective of this study was to determine whether feeding a fat supplemented diet to horses in training for an extended period of time (7 months) affected their health or athletic performance. Anecdotal reports have suggested that feeding fat supplemented diets to horses during intense training may lead to a number of problems including reduced packed cell volume (PCV), liver dysfunction, hypothyroidism and a generalized reduction in performance described as "running out of gas" near the end of a race. The results of this study do not support any of these reports. Hematological values taken throughout the 7 month training period were not affected by diet. Horses in the fat supplemented group had PCV , hemoglobin and RBC levels that averaged slightly lower than the CONTROL horses, but these differences existed at the beginning of the study before the horses were assigned to either diet. The horses were assigned to each diet based on V_{LA4} values determined during the initial SET and these differences in hematological values were simply a coincidence. None of these values changed significantly throughout the 7 month training period.

There was no evidence of liver dysfunction in either treatment group. GT is an enzyme which is found in highest concentrations in the liver, pancreas and kidney. Increases in plasma concentrations are associated with increased synthesis in the hepatobiliary system and GT has been used as a sensitive measurement of chronic hepatic damage (Snow *et al.*, 1987a). There was no difference in serum GT levels between diets. Both groups had normal levels throughout training. In addition, other serum chemistry that might indicate a problem with liver function (AST, SDH, total bilirubin, bile acids, cholesterol) was unaffected by diet.

Plasma total thyroxine (T4) was also unaffected by diet. Thyroxine concentrations were higher in both groups at 7 months than after 2 months of training (P<0.01). It has been reported that training increases thyroxine secretion in horses and humans, but changes in the ratio of bound to free thyroxine tend to cause total thyroxine levels to remain unaffected by exercise (Thornton, 1985). However, thyroxine levels tend to be highest during times of rapidly declining temperatures and tend to return towards the annual mean when temperatures reach a stable level of cold (Irvine, 1983). In warm weather, thyroxine concentrations tend to be low. The initial samples were obtained in early March when temperatures were consistently cold. The 2 month samples were collected in late April when temperatures were warmer and the 7 month samples were taken in early October when temperatures had begun to fall. Therefore, the variation that was seen in resting thyroxine concentrations may have been due to fluctuations in the environmental temperature.

V_{200} and V_{LA4} have been used to measure the state of fitness and endurance capacity of horses (Persson, 1983). Training significantly improved V_{200} and V_{LA4} in each treatment group. Diet, however, did not significantly affect heart rate or lactate response to exercise. These results do not agree with a previous study conducted in our laboratory (Pagan *et al.*, 1993), in which a diet containing 10% soybean oil resulted in a significant increase in both V_{200} and V_{LA4} compared to a control diet.

The differences in results between these two studies may be due to the composition of the control diet used in each study. In the present study, the control diet contained 42% oats and 31% corn as whole and coarse cracked grains, while in the previous study the control diet was pelleted and contained 36% ground oats and 43% ground corn. Since corn is higher in starch than oats, perhaps the total starch content of the diet affected the results. In addition, grinding corn increases its prececal digestibility in horses (Meyer *et al.*, 1993). The effect of starch intake and grain processing on metabolic response to exercise warrants further investigation.

Although diet had no effect on V_{200} or V_{LA4}, there were differences in hormonal and glycemic response to exercise. During the STEP there was a significantly greater drop in plasma glucose in the CONTROL fed horses. This drop was probably the result of increased uptake of glucose by the working muscle under the influence of insulin since plasma insulin was elevated in the CONTROL group before exercise began. An increase in insulin results in enhanced glucose uptake and glycogen synthesis, enhanced lipogenesis and decreased lipolysis (Lawrence, 1990). As a result, during exercise there will be increased use of blood glucose and a decreased use of fat as a result of lower FFA availability. An exercise induced hypoglycemia has been shown to cause fatigue during severe exercise lasting an hour or longer in humans (Costill *et al.,* 1977).

Replacing carbohydrate with fat reduced post feeding peaks in both insulin and glucose and thus reduced the fall in blood glucose during strenuous exercise. This response could be beneficial to horses performing prolonged strenuous exercise. These exercise tests were conducted 4 hours after feeding. It should be noted, however, that if exercise is performed after either an overnight fast or an 8 hour delay after feeding, these large drops in blood glucose concentration during strenuous exercise no longer occur even with high carbohydrate-low fat diets (Lawrence *et al.,* 1993, Pagan *et al.,* 1995).

Feeding a fat supplemented diet to reduce postprandial blood glucose and insulin response may be beneficial if feeding occurred 3-4 hours before exercise. In the present study, there were also no detrimental effects on performance during the SETs. While these tests were intense (HRs >210), they were still not maximal and tests of similar intensity have resulted in only small decreases in muscle glycogen (Pagan *et al.,* 1987). Thoroughbred racehorse training has been shown to reduce muscle glycogen by 19-25% (Snow and Harris, 1991) and racing can result in drops of 25-33% (Harris *et al*, 1987). Since muscle glycogen repletion depends on increases in both blood glucose and blood insulin (Snow *et al.*, 1987b) it is possible that feeding fat supplemented diets for an extended period of time to racehorses in race training may result in a progressive decline in muscle glycogen which may ultimately compromise the horse's racing performance. A combination of a low carbohydrate-high fat diet has been used in horses undergoing intense exercise to reduce muscle glycogen storage and decrease performance (Topliff *et al.*, 1983, Topliff *et al.*, 1985). The effect of feeding fat supplemented diets to racehorses for extended periods of time still needs to be resolved. The present study used training regimes and exercise tests that were more comparable in intensity to those used in sport horses than in Thoroughbred racing. Under these conditions, feeding a level of fat equal to about 9-10% of the daily grain ration caused no detrimental effects on either health or exercise response. All of the horse studied tolerated this level of fat in their diets and were able to maintain similar weight gains as CONTROL horses, but with reduced grain intakes. Adding fat reduced the fall in blood glucose experienced in the CONTROL horses during the STEP and this may help delay fatigue in horses exercising intensely for extended periods of time.

References

Allen, B.V. and Powell, D.G. (1983). Effects of training and time of day of blood sampling on the variation of some common haematological parameters in normal Thoroughbred racehorses. In Snow DH, Persson SO, Rose R. (eds): Equine Exercise Physiology. Cambridge, England, Granta Editions.

Blackmore, D.J. and Brobst, D. (1981). Biochemcial Values in Equine Medicine, The Animal Health Trust, Newmarket, England.

Costill, D.L., Coyle, E., Dalsky G., Evans, W., Fink, W. and Hoopes, W. (1977).

Effects of elevated plasma FFA and insulin on muscle glycogen usage during exercise. J.Appl. Physiol.:Respirat. Environ. Exercise Physiology. 43(4) 695-699.

Dickson, W.M. (1993). Endocrine glands. In Swensen, M.J. and Reece, W.O. (eds.): Duke's Physiology of Domestic Animals, eleventh edition, Cornell Unviersity Press, Ithaca,NY. pp. 657-660.

Harris, R.C., Marlin, D.J. and Snow, D.H. (1987). Metabolic response to maximal exercise of 800 and 2000 m in the Thoroughbred horse. J. Appl. Physiol. 63, 12-19.

Irvine,C.H.G. (1983). The role of hormones in exercise physiology. In Snow DH, Persson SO, Rose R. teds): Equine Exercise Physiology. Cambridge, England, GrantaEditions.

Lawrence, L.M. (1990). Nutrition and fuel utilization in the athletic horse. The Veterinary Clinics of North America, vol.6, no. 2, pp. 393-418.

Lawrence, L., Soderholm, L.V., Roberts, A., Williams, J. and Hintz, H. (1993). Feeding status affects glucoe metabolism in exercising horses. J. Nutr. 123:2152-2157.

Meyer, H., Radicke, S., Kienzle, E., Wilke, S. and Kleffken, D. (1993). Investigations on preileal digestion of oats, corn, and barley starch in relation to grain processing. Proc.13th ENPS, Gainesville, FL. pp. 92-97.

Pagan, J.D., Essen-Gustavsson, Lindholm, A., and Thornton, J. (1987). The effect of dietary energy source on exercise performance in standardbred horses . In Gillespie, J.R. and Robinson, N.E. (eds.) Equine Exercise Physiology 2, ICEEP Publications, CA, pp. 686-700.

Pagan, J.D., Tiegs, W., Jackson, S.G., and Murphy, H.Q. (1993). The effect of different fat sources on exercise performance in throughbred racehorses. Proc. 13th ENPS, Gainesville, FL. pp. 125-129.

Persson, S.G.B. (1983). Evaluation of exercise tolerance and fitness in the performance horse. In Snow DH, Persson SO, Rose R. (eds): Equine Exercise Physiology. Cambridge, England, Granta Editions.

Rodiek, A., Bonvicin, S., Stull, C. and Arana, M. (1991). Glycemic and Endocrine responses to corn or alfalfa fed prior to exercise. In Persson, S.G.B., Lindolm, A., and Jeffcott, L.B. (eds.) Equine Exercise Physiology 3, ICEEP Publications, CA. 323-330.

Snow, D.H., Gash, S.P., and Rice, D. (1987a). Field observations on selenium status, whole blood glutathione peroxidase and plasma gamma-glutamyl transferase activities in Thoroughbred racehorses. In Gillespie, J.R. and Robinson, N.E. (eds.) Equine Exercise Physiology 2, ICEEP Publications, CA, pp. 494-505.

Snow, D.H., Harris, R.C., Harman, J.C. and Marlin, D.J. (1987b). Glycogen repletion following differnet diets. In Gillespie, J.R. and Robinson, N.E. (eds.) Equine Exercise Physiology 2, ICEEP Publications, CA, pp. 701-710.

Snow, D.H. and Harris, R.C. (1991). Effects of daily exercise on muscle glycogen in the Thoroughbred racehorse. In Persson, S.G.B., Lindolm, A., and Jeffcott, L.B. (eds.) Equine Exercise Physiology 3, ICEEP Publications, CA pp.299-304.

Tabata, I, Ogita, F., Miyachi, M., and Shibayama, H. (1991). Effect of low blood glucose on plasma CRF, ACTH, and cortisol during prolonged physical exercise. J. Appl.Phys. 71(5): 1807-1812.

Thomton, J.R. (1985). Hormonal responses to exercise and training. The Veterinary Clinics of North America, vol. 1, no. 3, pp.477-496.

Topliff, D.R., Potter, G.D., Dutson, T.R., Kreider, J.L., and Jessup, G.T. (1983). Diet manipulation and muscle glycogen in the equine. Proc. 8th ENPS, Lexington, KY. pp.119-124.

Topliff, D.R., Potter, G.D., Dutson, T.R., Kreider, J.L., and Jessup, G.T. (1985). Diet manipulation, muscle glycogen metabolism and anaerobic work performance in the equine. Proc. 9th ENPS, East Lansing, MI. pp. 224-229.