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Fat adaptation affects insulin sensitivity and elimination of horses during an 80 km endurance ride

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Introduction

Feeding feeds rich in fat and fiber (FF) may avoid the adverse effects on insulin sensitivity and insulin signaling associated with chronic adaptation to meals of grain and molasses (starch and sugar, SS) (*Hoffman* et al. 2003; *Treiber* et al. 2005a). This adverse effect of SS has been observed in resting horses but not when they are physically conditioned (*Treiber* et al. 2005b). It was revealed, however, when the fit horses were subjected to endurance exercise on a treadmill—insulin sensitivity and related variables were lower in horses adapted to SS compared to FF (*Treiber* et al. 2005b). The present study tested the hypothesis that insulin sensitivity would be lower in horses adapted to SS than those adapted to FF during an endurance race.

Material and Methods

The effects of feeds rich in starch and fat on insulin sensitivity were compared in 40 endurance horses during an 80 km race in 3 dietary groups: one experimental feed (SS) was rich in starch (33%), low in fat (8%); another (FF) was low in starch (6%) and rich in fat (15%); and commercial concentrates (CC) were intermediate in starch (16%) and fat (11%). Feeds were isoenergetic (~3.3 Mcal/kg DM) and isonitrogenous (~12% CP). Horses were fed 1.7 to 5.1 kg/d with hay ad libitum for 3 mo prior to the race. Blood samples were taken the day before the race (PRE), within 3 minutes of arrival at each vet check (after 27, 48, 80km), and three hours post completion or elimination. Plasma samples were analyzed for glucose, insulin, cortisol, CK and AST. A proxy for insulin sensitivity as measured by the minimal model was calculated: RISQI = (1/sqrt [insulin])(*Treiber* et al. 2005c). Also, a proxy for pancreatic β-cell response to plasma glucose was calculated: MIRG =[800-0.30([insulin] -50)^2]/[glucose - 30](*Treiber* et al. 2005c). Effects of sampling time, completion of the ride, treatments and interactions were evaluated by ANOVA in a mixed model with repeated measures; non-parametric ANOVA compared finishers and eliminated horses for glucose, insulin, RISQI and MIRG.

Results

Reasons for elimination of 15 of the 40 horses (37.5%) were lameness (3: 1FF, 2 CC), exertional rhabdomyolysis (2: 1 CC, 1 SS), failure to recover heart rate in 30 min (3: 2 SS, 1 CC), labile heart rate (2: 1 FF, 1 SS), arrhythmias (2: 1 FF, 1 CC), slow gut sounds (1 CC), sore back (1 FF), and rider option (1 CC).

Eliminated horses had overall lower (P=0.037) RISQI (0.26±0.01 mU/L-0.5) than finishing horses (0.29±0.01 mU/L-0.5). Eliminated horses had overall higher (P=0.015) insulin (21.14±1.7 mU/L) than finishing horses (15.19±1.0 mU/L). Eliminated horses had higher insulin specifically at 48 km (P=0.012) and at REC (P=0.002) compared to finishing horses. Eliminated horses (analyzed without the rhabdomyolysis cases) had higher CK at 48 (P<0.001), and recovery (P <0.001) than finishing horses. Eliminated horses (analyzed without the rhabdomyolysis cases) had higher AST at 48 km (P=0.005), and recovery (P<0.001) than finishing horses. Eliminated horses had overall higher cortisol (131.1±10.2 ng/dl) than finishing horses (119.9±4.7 ng/dl). Specifically at recovery cortisol was lower (P=0.005) in finishers than eliminated horses.

Increases were found in plasma CK, AST, cortisol, and RISQI, and decreases in insulin and MIRG with sampling time (P<0.005). Horses fed SS and CC had overall lower (P=0.019) RISQI than FF fed horses. MIRG, however just had a trend to be lower (P=0.088) in FF fed horses compared to SS and CC fed horses. Horses fed SS (17.7±1.6 mU/L) and CC (18.6±1.8 mU/L) feeds had overall higher insulin than FF (13.6±0.9 mU/L) fed horses.

Horses on SS diets had higher plasma CK (11516±5116 IU/L) than FF (514±34 IU/L) or CC (461±40 IU/L) diets ($P < 0.001$). Eliminated horses on SS diet had the highest CK values compared to all other horses ($P<0.001$). Horses on SS diets had higher plasma AST (669±163 IU/L) than FF (273±7 IU/L) or CC (280±7 IU/L) diets ($P<0.001$).

Discussion

The results of this study suggest that insulin resistance can be a determining factor in the elimination of horses during endurance races. Furthermore, supplementation with feeds high in fat and fiber can attenuate insulin resistance as shown by a higher RISQI in FF fed horses.

Two horses were eliminated with signs of rhabdomyolysis and eliminated horses had higher muscle enzymes at 27, 48 km and at recovery. Higher enzymes were also found in SS fed horses. High fat/ low carbohydrate diets have been shown to lead to lower muscle enzymes after exercise in severely affected horses with recurrent rhabdomyolysis cases (*McKenzie* et al. 2003). Such diets have been recommended to reduce rapid glycogen synthesis in horses with polysaccharide storage myopathy (*Annandale* et al. 2004). Excitable horses are also more prone to rhabdomyolysis, and they may become calmer when fat adapted (*Holland* et al. 1996).

Higher plasma cortisol levels in eliminated horses indicate that eliminated horses were more stressed than finishers. Also diets rich in starch have been shown to increase cortisol during exercise, due to increased excitement (*Slade* et al. 1975, *Crandell* et al. 1999). Cortisol increases insulin resistance (*Guyton* and *Hall* 2001), which is could be compensated for with increased insulin secretion as observed in this study.

Exercise usually enhances insulin sensitivity (*Brun* et al. 1995; *Powell* et al. 2002). During exercise, glucose transport is driven by the Ca^{++} mediated GLUT-4 transport in addition to the insulin mediated GLUT-4 transport (*Richter* et al. 2004) leading to increases in insulin sensitivity. In all horses proxies indicated that insulin sensitivity increased with exercise throughout the race. In eliminated horses however, insulin sensitivity was overall lower. No differences in plasma glucose were found despite differences in insulin sensitivity, a result of compensation by an increased insulin response (MIRG).

Higher insulin could lead to decreased lipolysis (*Saltiel* and *Kahn* 2001) decreasing fatty acid oxidation during exercise, and contributing to decreased performance and elimination as observed in this study.

Lower insulin sensitivity (RISQI) in SS and CC horses, and in eliminated horses indicated that insulin resistance (low RISQI) was attenuated by fat and fiber feeding and also decreased the likelihood of elimination. Higher insulin sensitivity in finishers and fat and fiber fed horses may have allowed a more efficient glucose uptake by muscles, allowing energy to be obtained through fatty acid oxidation.

Conclusion

Fat and fiber feeding could avoid insulin resistance, improving the efficiency of energy utilization and performance of horses during endurance races. FF feeds could also reduce excitement and avoid increases in muscle enzymes. This study presents the first results to show a potential link between insulin resistance as a cause or effect of elimination during an endurance race.

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