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Energy requirements of exercising horses: scientific bases and recommendations

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Energy expenditure of exercise is predicted from VO2 / mn / Kg Body Weight in most countries using two different models: either the model of Meixner et al 1981 for trot and gallop and for walk from data of Brody 1945, Hoffman et al 1967, Nadal’jak 1961 and Zuntz and Hagemann 1898, or the model of Pagan and Hintz 1986b, both performed in sport horses. Requirements are performed either directly from energy expenditure (analytical method) or / and from feeding trials (global method) depending on the countries. In this last approach the energy expenditure of exercise is loaded with the ancillary effects of anticipation, remanence and the general elevation of energy metabolism related to training and exercise. Requirements are given per hour of exercise in some countries. In all countries total requirements (maintenance + exercise) are either tabulated for different classes of body weight or expressed as times of maintenance requirements for different classes of body weight, according to a scale of intensity which may vary between countries. Requirements are proposed by NRC in the USA 1989, INRA 1990 in France, by GEH 1994 in Germany, by CVB 1996 in The Netherlands, and by Nordic countries in 2002. These proposals are discussed using either the maintenance requirement as a reference or/and the unitary cost of one hour of exercise that is achieved at different intensities. Refinement of the analytical method is proposed to predict energy expenditure from the heart rate (a new model), and to include the anaerobic part of energy metabolism due to lactate accumulation. The scale of the intensity of exercise might be harmonised between countries referring to new proposals. Hence further evolution is suggested whatever the energy systems used in the different countries.
Effects of dietary energy source and physical conditioning on insulin sensitivity and glucose tolerance in horses

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Introduction

There is evidence that diets rich in starch and sugar lower glucose tolerance and insulin sensitivity in horses, but the extent to which physical activity modifies these effects is unknown. Therefore, the objective of this study was to determine the effects of dietary energy source on measures of insulin sensitivity and glucose tolerance, both in the sedentary state and after a subsequent period of physical conditioning.

Material and methods

Fourteen horses underwent a euglycemic-hyperinsulinemic clamp (EHC) and an oral glucose tolerance test (OGTT) after each of the following study periods: Baseline (B) in which horses were fed only forage cubes for 3 wk; Diet (D) in which horses received either a high starch and sugar (S, n = 7) or a high fat and fiber (F, n = 7) concentrate with forage cubes for 6 wk; and Diet x Exercise (DxE) in which the horses remained on the assigned ration and completed 7 wks of physical conditioning. The data were analyzed by repeated measures ANOVA.

Results

Aerobic capacity (VO2peak) was increased by 10% after DxE in both S and F. Insulin sensitivity (average glucose disposal per unit of insulin during the last 90 min of the EHC) in S horses was 30% lower (P < 0.05) in D when compared to B (1.97 ± 0.70 vs. 1.39 ± 0.43), but was not different from B after physical conditioning (1.91 ± 0.65 x 10^-2 mg·min^{-1}·kg^{-1} per uU/mL). The S diet also resulted in a greater (P < 0.05) OGTT insulin response (area under the insulin curve) in both D (8823 ± 4522 uU·mL^{-1}·min^{-1}) and DxE (7578 ± 2413 uU/mL/min) when compared to B (4557 ± 2507 uU/mL/min). In F, insulin sensitivity and glucose tolerance were unchanged.

Conclusion

The feeding of a diet rich in starch and sugar resulted in decreased insulin sensitivity and impaired glucose tolerance but the effect on insulin sensitivity was mitigated after a subsequent period of exercise training, suggesting that physical activity modifies the effects of dietary energy source on insulin action in horses.
Effect of dietary glycemic index after exercise on plasma concentrations of substrates used for muscle glycogenesis

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Introduction

Effect of dietary glycemic index after exercise on blood concentrations of substrates used for muscle glycogenesis Exercise depletes muscle glycogen stores, which could subsequently impair performance. Muscle glycogen replenishment is determined by substrate availability. We studied the effects of feeding meals of varying glycemic indices on blood concentrations of substrates for glycogenesis in horses with exercise-induced glycogen depletion.

Material and methods

In a 3-way crossover study, 7 horses received each of 3 isocaloric diets for 72 hours after undergoing glycogen-depleting exercise: 1) a high soluble-carbohydrate diet, which induced a high-glycemic (HGI) response, 2-3) a low soluble-carbohydrate, or a mixed soluble-carbohydrate diet (control group), which both induced a similar low-to-moderate glycemic (LGI) response. Muscle biopsies and venous samples were collected before and up to 72 h after exercise.

Results

Feeding HGI diets resulted in a higher ($P < 0.001$) rate of muscle glycogenesis over 72 h compared to horses fed LGI diets. Plasma glycerol, triglyceride, lactate, serum NEFA and total protein concentrations, and hematocrit were significantly ($P < 0.001$) higher after exercise compared to before exercise. Whereas no significant overall dietary effect was observed on these metabolites over 72 h, there was a tendency for glycerol, NEFA and triglyceride concentrations to be lower for horses fed LGI compared to horses fed HGI diets over 6 h after exercise ($P < 0.05, 1, 6$ and $1$ h after exercise, respectively).

Conclusion

These data suggest that horses fed LGI meals after exercise did not have any significant shift of substrate utilization toward neoglucogenesis, which could have contributed to the slower rate of muscle glycogenesis compared to horses fed HGI meals.
Glucose delivery via the gastrointestinal tract limits early postexercise muscle glycogen synthesis

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Introduction

We tested the hypothesis that glucose delivery from the gastrointestinal tract limits the rate of muscle glycogen storage in horses and predicted that early postexercise glycogen storage would be enhanced with IV glucose administration but not with an equivalent oral dose.

Material and methods

On 3 occasions in a randomized design, 7 horses completed treadmill exercise (EX) that depleted muscle glycogen concentration (GLY) by ~50%. After EX the horses received the following: 1) IV glucose infusion (IV: 0.5 g/kg/h for 6 h), 2) oral glucose boluses (OR: 1 g/kg at 0, 2, 4 h postEX), or 3) no glucose (CON). Blood samples (for glucose (GLU) and insulin (IN) concentrations) were collected before EX and during a 6-h postEX period (REC). Muscle biopsies for GLY and glucose synthase activity (GS) were taken preEX, postEX, 3 h REC and 6 h REC.

Results

Throughout REC avg GLU (mM) was higher in IV (15.4 ± 3.0) and OR (6.5 ± 0.9) than in CON (4.4 ± 0.5) and GLU increase during IV was more than 2-fold greater than during OR. Avg IN (fU/mL) in IV (75 ± 19) and OR (35.2 ± 10.1) was also greater than in CON (7.2 ± 2.1). PostEX GLY (mmol/kg dw) was not different (IV, 254 ± 31; OR, 249 ± 26; CON, 230 ± 30) but glycogen storage rates (mmol/kg dw/h) were higher in IV than in CON and OR during the initial and final 3 h of REC, respectively (IV: 14.6 ± 5.5, 32.6 ± 9.9; CON: -1.2 ± 2.1, 7.9 ± 4.0; OR: -4.0 ± 3.9, 17.9 ± 6.2) resulting in higher postREC GLY in IV (396 ± 29) than in OR (287 ± 23) and CON (250 ± 35). GS was unaffected by treatment.

Conclusion

Intravenous glucose, but not an equivalent oral dose, increased glycogen storage rate suggesting intestinal glucose uptake and/or hepatic metabolism of absorbed glucose limits the rate of postexercise glycogen storage in horses given oral supplemental carbohydrate.
Interval exercise alters feed intake as well as leptin and ghrelin concentrations in Standardbred mares

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Introduction

Horses in training tend to become inappetant; however, the mechanism responsible for this training-induced inappetance is not known. Therefore, 8 Standardbred mares (12 ± 2 yrs, 505 ± 31 kg) underwent interval exercise tests (IET) and parallel control tests before and after 8 wks of training to test the hypothesis that training would alter the feed intake (FI) and hormonal and/or biochemical (active ghrelin, leptin, glucose, insulin and cortisol) responses to high-intensity exercise.

Material and methods

Plasma samples were taken before (0 min), during (last 10 sec of velocities eliciting 40%, 100%, and 20% VO2max), and post-exercise (30 min, 60 min, 24 hr) for RIA and colorimetric measurement of the concentrations of the above parameters. Samples were also collected before and after feeding at 1530 (at 1525 and 1630). Horses were trained at a work intensity of 70% HRmax 30 min/d, 5 d per wk in an Equi-ciser®. All mares were fed total mixed ration haycubes that were available free choice for 16 h/d, with FI measured daily.

Results

There were no changes \((P > 0.05)\) in any variable during the parallel control trials. However, there was a mismatch between FI and digestible energy (DE) requirements \((P < 0.05)\) with EX horses not meeting their DE requirements during the post-training IET. During all IET, ghrelin, glucose and cortisol increased \((P < 0.05)\) during EX. Leptin only increased \((P < 0.05)\) during EX in the post-training IET. Insulin remained low during EX, but increased \((P < 0.05)\) post EX.

Conclusion

High-intensity EX appeared to be associated with decreases in FI and alterations of leptin and ghrelin. More research is needed to determine if there is a relationship between alterations of these hormones and changes in feed intake in horses.
Homeostasis of amino acids during a training season and after feed intake in response to supplemental gelatine

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Introduction

The Objective of the study was to elucidate amino acid (AA) homeostasis during a training season and the effect of a gelatin supplement (GS).

Material and methods

Over 12 weeks, 10 untrained horses (2 year of age) were fed a diet providing per kg BW 0.3 MJ DE/d and 2 g digestible protein/d; 5 horses received 60 g GS/d (= 4-14 % of the intake of Ala, Arg, Gly, Lys, Pro); 5 horses served as controls. The horses underwent a training on a high-speed treadmill: incremental standardized exercise tests (5-6 steps a 4 min; 5-10 m/s) at the start, mid and end of the training period and every second day alternating an interval exercise (3 x 4 min at VLa10, and 3x5 min at VLa2) or a low-speed exercise session (VLa2 for 45 min). Blood samples for AA and keratan sulphate (KS, in selected samples) were obtained during the training (at rest, 2 h ppr, d0, 13, 27, 37, 50, 64, 77) and in response to a single meal (hourly, 0-8 h ppr).

Results

Within the initial 13 days, most AA showed a significant increase and smaller changes afterwards. The GS resulted in higher levels for Gly, Pro, Ser, Thr. Changes ppr were revealed by significant increases up to peaks between 60 and 180 min after the start of the intake (Asp, Cys, Glu excepted). A response to GS was detected for Gly, Pro, Ala, Leu, Thr and Val. The KS concentrations in the blood of the controls were unchanged throughout the training season while the GS-fed horses showed a significant decrease.

Conclusion

Several AA in the blood respond rapidly to GS at the start of training. The distinct postprandial AA curve reflects the dynamics in AA absorption in general and the availability of AA from GS. The change in KS indicates an interaction between gelatin intake and cartilage metabolism. However, it is still unclear if that reflects a sufficient joint protecting principle.
Effect of amino acids and glucose administration after exercise on the turnover of muscle protein in the hindlimb femoral region of Thoroughbreds

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Introduction

In humans, muscle protein synthesis is accelerated by administering amino acids (AA) and glucose (Glu) because of increased availability of AA and increased insulin secretion, which has a protein anabolic effect. The objectives of this study were to establish the effect of AA and Glu administration after exercise on muscle protein turnover in horses.

Material and methods

The measurements of the rate of synthesis (Rd) and rate of degradation (Ra) of muscle protein in the hindlimb femoral region of thoroughbred horses were conducted using the isotope dilution method assessing differences between the artery and iliac vein. Six adult thoroughbreds received a continuous infusion of L-[ring-2H5] phenylalanine during the study, as follows: a stable period for plasma isotope concentration (60min), resting period (60min), treadmill exercise (15min) and recovery period (240min). All horses were given five solutions (saline, 10%-AA, 10%-Glu, 5%-AA and 5%-Glu (5-Mix) and 10%-AA and 10%-Glu (10-Mix)) over 120min after exercise, and the Rd and Ra of muscle protein in the hindlimb was measured.

Results

The average Rd during the 75-120min after 10-Mix was administered was significantly greater than for the other solutions ($P < 0.05$). The next most effective after the 10-Mix was 10%-AA, and there was no change between Rd after 10%-Glu or saline.

Conclusion

These results showed that the administration of AA after exercise accelerated Rd in the hindlimb femoral region. This effect was amplified when glucose was administered together with AA, either because of increasing insulin secretion, or because glucose met energy demands during recovery, thus sparing AA.
The effects of oral vitamin E supplementation on vitamin and antioxidant status in intensely exercising horses

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Introduction

The objective of this study was to evaluate the effects of 3 levels of vitamin E supplementation on vitamin and antioxidant status in intensely exercised horses in order to identify the optimal level of vitamin E for these horses.

Material and methods

Twelve unfit Standardbreds were divided into three groups orally supplemented with 0 (CON), 5,000, (MOD), or 10,000 (HI) IU/d of dl-a-tocopheryl acetate. The crossover design consisted of three 4-wk supplementation periods with 4-wk wash out periods in between. After each period, the horses underwent a treadmill interval exercise test. Blood samples and heart rate (HR) were collected before, during, and post exercise. Data was analyzed using ANOVA with repeated measures and the Pearson product moment correlation in SAS.

Results

The CON group had lower HR throughout the test compared to the MOD and HI groups ($P < 0.05$). There was an increase in plasma retinol (RET), B-carotene (BC), red blood cell total glutathione and glutathione peroxidase with exercise ($P < 0.05$), but all groups returned to the baseline after 24 h. Plasma á-tocopherol (TOC) increased from the baseline with exercise ($P < 0.05$); treatment differences were observed at 24 hr ($P < 0.05$). The HI group had lower BC compared to the MOD group (0.51 ± 0.2 vs. 1.10 ± 0.2 ug/mL, respectively, $P < 0.05$), but was not different from CON (0.77 ± 0.2 ug/mL) throughout the test. Correlations were found between TOC and BC ($r = 0.33$, $P < 0.0001$), and between TOC and RET ($r = -0.24$, $P = 0.0004$) for all groups.

Conclusion

Horses supplemented with vitamin E at nearly 10-times the 1989 NRC recommended level did not experience lower oxidative stress compared to control horses. Additionally, the lower BC levels observed in the HI group may indicate that vitamin E has an inhibitory effect on BC absorption.
Double blind investigation of the effects of oral supplementation of combined glucosamine hydrochloride (GHCL) and chondroitin sulphate (CS) on the stride characteristics of veteran horses

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Introduction

Oral chondroprotective supplements are commercially popular for veteran horses prone to joint degeneration, yet lack conclusive scientific support. The aim was to quantify the effects of an oral joint supplement (combination GHCL, CS and N-acetyl-D-Glucosamine) in vivo on stride parameters of veteran horses.

Material and methods

Twenty veteran horses were randomly assigned to a treatment group (n = 15) or placebo group (n = 5). Normal gait characteristics were recorded at walk and trot pre-treatment using digital video footage. Stride length, swing: stance duration and range of joint motion were assessed using two dimensional motion analysis. Treatment (or placebo) was administered daily for twelve weeks at the manufacturer’s recommended dosage. Gait was re-assessed every four weeks using the pre-treatment protocol. Double blind control was implemented throughout. Relationships between variables were analysed using ANOVA in Minitab Version 14.

Results

Improvements occurred in the treated horses by week eight. The range of joint motion increased in all the joints of treated horses, although only significantly in the elbow (P < 0.05), stifle and hind fetlock (P < 0.01). Stride length increased significantly (P < 0.05) with treatment in walk and trot.

Conclusion

These findings support recent in vitro research demonstrating a reduction in cartilage degeneration with high doses of GHCL and CS combined (Dechant et al. 2005). Oral GHCL and CS supplementation may improve welfare by slowing the progression of degenerative joint disease.
How closely are apparent energy intake and workload correlated?

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Introduction

Horse owners tend to base their feeding regimens on perceived workload. This study evaluated the anecdotal belief that individual horses, of similar size, with apparently similar workloads often seem to require different energy intakes.

Material and methods

Eight, mature, experienced riding school horses (mixed breed), maintaining a constant body weight, were observed in standard flat working lessons with four different instructors at an equine training college. The horses were paired according to body weight (BW) and whether they had a high or low estimated energy intake. Heart rate (HR) was monitored as well as the time spent on various exercises during the lessons. Relative workload (RW) was determined for each horse by dividing its average HR per lesson by its estimated maximum HR. Perceived workload (PW) was estimated by each instructor for each horse using a scale of 1 to 5.

Results

The RW of all horses was 40% HRmax (± 5%). Rider weights were not significantly different (P > 0.05). Age was correlated (P < 0.01) with average HR (r² = 0.44), peak HR (r² = 0.36) and RW (r² = 0.29). Horses’ height was also correlated with average HR (r² = 0.17; P < 0.05), peak HR (r² = 0.28; P < 0.01), and RW (r² = 0.18; P < 0.05), but BW was not correlated to any of these (P > 0.05). High or low energy intake did not correlate with RW (P > 0.05) or PW (P > 0.05). Neither PW (median 2; range: 1-5) nor RW differed significantly between instructors (P > 0.05).

Conclusion

These results suggest the amount of energy needed to maintain bodyweight cannot necessarily be estimated simply on the basis of the intensity and duration of structured exercise. Other factors including age, individual digestive efficiency, body condition and energy utilised through non-structured activity (e.g. box walking) may be involved.
Exercise response, metabolism at rest and digestibility in athletic horses fed high fat oats

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Introduction

High starch intakes increase the risk for metabolic disorders and therefore alternative feedstuffs are of interest. High fat oat varieties have a lower starch and higher energy content than regular oats and may therefore be useful in this context. The aim was to investigate digestibility, metabolism and exercise response when high fat oats replaced regular oats in the diet of athletic horses.

Material and methods

Twelve Standardbred trotters were fed regular oats (C), high fat oats (F), and a mixture (50:50) of C and F (M), together with hay silage (30:70), in a Latin square design trial. High fat oats replaced regular oats in a 0.9 to 1.0 ratio in diets F and M, to equalise the daily energy intake from oats. On day 17 in each experimental period, the horses were subjected to a standardised near-maximal treadmill exercise test with collection of blood samples and muscle biopsies before and after exercise. This was followed by a three-day period of total collection of faeces and urine.

Results

Body weight (BW) remained constant throughout the study. There were no significant effects of dietary treatments on BW, heart rate, plasma lactate and glucose, and muscle glycogen and lactate concentrations following exercise. However, plasma insulin was reduced both before and during exercise on diets F and M compared to diet C. The total tract digestibility of dry matter, fat, protein, NDF and organic matter were higher ($P < 0.05$) for diet F than for diet C.

Conclusion

High fat oats can replace regular oats in the diet of athletic horses without any adverse effects on metabolism and exercise response. Due to the high energy content and a high digestibility of dietary components in high fat oats the daily allowance of oats can be reduced and thus also the intake of starch.
Effects of a high fat diet and aerobic training on carbohydrate and fat utilization during a maximal incremental exercise

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Introduction

This research analyses the combined effect of two diets (low and high-fat content) and training on carbohydrate and fat utilisation during a maximal exercise test.

Material and methods

Twelve low-trained Arabian horses were randomly assigned to two groups and fed a high-fat diet (Group 1, \(n = 6; 12.2\%\) fat d.w.) or a low-fat diet (Group 2, 3.4% fat) and trained for 10 weeks. Treadmill training consisted in 25 min at 80% anaerobic threshold (AT), 6 days/week, with mean speeds of 4.7 ± 0.6 m/s (3% slope). Two treadmill exercise tests were performed before and after training (1.7 m/s for 5 min, 3.5 m/s for 5 min, increasing 1 m/s every 3 min) to fatigue; 3.5 m/s for 5 min and 1.7 m/s for 5 min) at a 3% slope. Heart rate, O2 uptake, CO2 production and respiratory exchange ratio (RER) were measured continuously. Venous blood samples were withdrawn before and after the exercise tests and plasma glucose, creatinine and lactate concentrations were measured. AT was calculated by the RER method.

Results

Pre-training differences were not detected between both groups. Training induced increased AT and time to fatigue, whereas heart rate response to exercise significantly decreased in both horse groups. After training, VO2 and RER were higher in group 1 at rest and at velocities lower than 5 m/s. HR, time to fatigue, AT and plasma biochemistry at rest and after the treadmill exercise did not differ between both groups after training.

Conclusion

A high-fat diet combined with an aerobic treadmill training improved lipid utilisation at the training velocities, although plasma lactate accumulation was not affected.
Dietary energy sources affect minimal model parameters in trained Arabian geldings during endurance exercise

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Introduction
Glucose metabolism is affected by dietary energy source, possibly modifying exercise performance and increasing the risk of metabolic disorders. This study applied the Minimal Model during rest and constant low-intensity exercise in 12 trained Arabians adapted to a starch and sugar feed (SS) or a fiber and fat feed (FF).

Material and methods
For 8 weeks, Arabians were exercise trained and adapted to the feeds. Horses then underwent two frequently sampled i.v. glucose tolerance tests (FSIGT), with at least one week recovery between the tests. For each test, the horses received 600 mg/kg BW glucose through a venous catheter at 0 min of the test and 10 mIU insulin/kg BW at 20 min. For the exercise FSIGT each horse warmed up for 25 min on the treadmill, reaching 57% of their predetermined lactate threshold which was maintained. The 0 min glucose dose was then applied and sampling proceeded identical to the resting test, but concluded 150 min, rather than 240 min, after the glucose dose.

Results
Exercise increased insulin sensitivity (SI) \( (P < 0.001) \), glucose effectiveness (Sg) \( (P < 0.001) \) and disposition index (DI) \( (P = 0.003) \) and decreased the acute insulin response to glucose (AIRg) \( (P = 0.008) \). Compared to FF horses, SS adapted Arabians had higher basal insulin \( (P = 0.068) \) and basal glucose \( (P < 0.001) \) and lower SI \( (P = 0.070) \) and DI \( (P = 0.058) \). Exercise increased SI \( (P = 0.075) \) and DI \( (P = 0.069) \) more in FF horses than SS horses.

Conclusion
Adaptation to high carbohydrate feeds like SS may decrease insulin sensitivity and impair energy regulation. Such changes are further revealed under the increased energy demand of endurance exercise. Impaired metabolic regulation may be avoided by replacing dietary sugar and starch with fat and fiber.
Plasma glutamine concentrations in the horse following feeding with and without oral glutamine supplementation

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Introduction

Pharmacological benefits of glutamine supplementation have been shown in athletically and clinically stressed humans. In the horse, infection and intense exercise have also been shown to significantly decrease plasma concentrations, but little is known on how best to supplement. This study evaluated whether the ingestion of different foodstuffs, with or without L-glutamine (G) or a peptide (Pep) containing 31.5% w/w G in a water-stable form, could affect plasma glutamine concentrations (P-GC).

Material and methods

Nine feeds (molasses sugar beet-pulp (mSB); naked oats (nO); commercial mix (CM); mSB with 30 or 60mg/kg bwt G or the G-molar equivalent of Pep; and CM with 60mg/kg bwt G or equivalent Pep) were offered to 6 healthy adult horses on different days following overnight food restriction. The changes in P-GC were monitored for 8h post-feeding.

Results

After 1.5h ÄP-GC were –0.9 ± (SD)10.2% (mSB), +12.5 ± 7.1% (nO) and +44.7 ± 15.9% (CM; \( P < 0.05 \)). ÄP-GC with mSB supplemented with G was +60.9 ± 30.0% (30mg; \( P < 0.05 \)) and +156.8 ± 34.6% (60mg; \( P < 0.05 \)) at 1h; ÄP-GC with Pep was 51.0 ± 31.0% (30mg equiv, \( P < 0.05 \)) and +91.1 ± 9.5% (60mg equiv, \( P < 0.05 \)) at 1h. After 10d of supplementation with 60mg/kg bwt G, ÄP-GC following a further 60mg/kg bwt G challenge showed a similar increase at 1h of +154.3 ± 37.9%; pre-values were unchanged. G and Pep added to CM, increased P-GC by 246.3 ± 55.3 (+ 99.2%) and 252.3 ± 94.2 µmol/L (96.7%) at 1.5h with concentrations still above pre-values at 8h (\( P <0.05 \)). Apart from the CM (with or without supplement), pre P-GC was always regained by 4h. Plasma NH3 and plasma protein concentrations were unaffected by supplementation with G or Pep.

Conclusion

This study showed that the P-GC may be modified by appropriate supplementation with no apparent adverse effects.
Effects of an oral sodium chloride load at different levels on acid-base balance and renal mineral excretion in horses

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Introduction

Oral NaCl has the potency to contribute relatively more to serum sodium than serum chloride. This may support acidification, causing the necessity for compensation, and has to work in parallel to osmoregulation. The aim of the study was to investigate the effects of oral NaCl at different levels on acid-base balance and renal mineral excretion.

Material and methods

Four slightly working horses were fed a mixed diet marginal in sodium and chloride and consecutively 0, 50 and 100 g NaCl/d, for 4 days each. At the last 2 days of each period, 3 times a day, venous blood and urine were sampled and analysed to characterise acid-base status (blood: pH, pCO2, base excess, standard base excess [SBE], standard bicarbonate [SBC]; urine: pH, bases, acids, NH4+, net acid-base excretion [NABE], base-acid quotient [BAQ]), mineral equilibrium (blood and urine: Ca, P, Mg, Na, K, Cl) and volume (blood: packed cell volume [PCV], total protein [TP]; urine: creatinine). The fractional renal clearance (FC) of minerals was calculated.

Results

50 g NaCl/d caused a clear decrease in blood and urinary pH (P < 0.05) which was not linearly continued when the higher salt dose was fed. Blood SBE and SBC dropped rectilinearly (P < 0.05). Final blood pCO2, NABE and the diuresis-independent BAQ (P < 0.05) decreased, too. Creatinine uncovered a high elevation of urinary volume (P < 0.05) while blood PCV and TP revealed the expected regulation of plasma volume. Consequently, a much higher increase in FCNa (P < 0.05) than in FCCl (P < 0.05) was measured which may contribute to acidosis. Indeed, serum chloride and renal excretion of minerals (Ca, Mg, Na, K, Cl) rose (P < 0.05).

Conclusion

At least 50 g/d NaCl added to a diet with marginal amounts of sodium and chloride may cause a compensated metabolic acidosis, at least transiently. The mechanism is still unclear. Long term effects should be investigated, especially why acidosis may limit exercise performance and why the results indicate elevated mineral losses.
Feed digestibility, passage rate and fecal microflora in horses conditioned to perform 60 and 90 km endurance races

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Introduction

Feed digestibility values obtained from horses at maintenance are usually applied to horses in training. Now, several studies have demonstrated that exercise can affect feed digestibility, partly explained by changes of digesta mean retention time (MRT). We wanted to evaluate the effect of a long-term endurance conditioning on digestive physiology in order to optimize the nutrition of this class of horses.

Material and methods

Eight Arabians fed 30% pelleted concentrate feed (2.4 kg/day) and 70% meadow hay (6 kg/day) underwent a regular endurance training program for 5 months. Feed digestibility, passage rate and fecal microflora were determined before the training period (P0), and after each horse performed a 60 km (P60) and a 90 km (P90) race. Digestibility of dry matter (DMd), organic matter (OMd), neutral detergent fiber (NDFd), acid detergent fiber (ADFd), fat (Fd) and gross energy (GEd) were determined by a 4-day partial fecal collection (2 grab samples/day at 08:30 and 17:30). MRT of pellets, hay and water was determined by a 56 hour partial fecal collection (grab samples every 2 hours) by reference to Ytterbium, Europium and Cr-EDTA markers respectively. pH, bacterial concentrations (total anaerobes bacteria, lactate-utilizers, Lactobacilli and Streptococci), D and L-lactate and VFA were determined in fecal samples.

Results

P0 and P60 were performed in February and May 2005 respectively. P90 just finished the 30 of June. Analysis will be conducted immediately. Our first results show that conditioning influences the digestive physiology.

Conclusion

We do not want to draw any conclusions before obtaining the results for all periods.
Effects of crude protein intake from forage-only diets on exercise response and acid

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Introduction

Vbase balance in Standardbred trotters Diets for athletic horses often contain large amounts of concentrates to provide enough energy. Feeding concentrates increases the risk for metabolic disorders and stereotypic behaviour and high-energy forage might be better. Early cut forage is high in energy as well as in crude protein (CP), which will result in an excessive CP intake. The aim was to investigate how CP intake affects nitrogen and acid-base balance, and exercise response in horses on high-energy forage diets (100-120 MJ ME/day).

Material and methods

Two forage-only diets consisting of mainly high-energy grass silage (11.1 MJ ME/kg DM) were fed for 23 days in a crossover design to six Standardbred trotters in race conditions. The forages were high in CP (HP, 16-17.5 % CP) or provided recommended intakes of CP (RP, 10.5-11.5 % CP). At the end of each period faeces and urine were collected for 72 hours and two race-like exercise tests were performed, a standardised treadmill test (ST) and a field test on a track (FT). Blood samples were taken before, during and after the tests.

Results

When the horses were fed the HP diet they had significantly (P<0.05) higher water intakes (20.8±0.4 vs. 16.4±0.4 L/day), urine volumes (11.5±0.4 vs. 10.6±0.2 L/day), plasma urea levels (6.4±0.2 vs. 5.6±0.2 mmol/L) and lowered urinary pH (7.03±0.02 vs. 7.46±0.04) compared to RP while body weight was unchanged. During and following the ST and FT there were no differences between diets in breathing frequency, heart rate, plasma protein and lactate, blood pH and HCO3.

Conclusion

The data suggest that athletic horses are able to handle excess forage protein (> 60% of requirements) during race-like exercise and recovery. Furthermore, the data indicates that they can consume sufficient energy from a forage-only diet to maintain body weight.
Mineral balance in horses fed sodium zeolite

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Introduction

A Sodium zeolite A (SZA) is gaining popularity as a dietary silicon (Si) supplement to aid in the prevention of skeletal injuries to performance horses. The mechanism of action has yet to be fully elucidated. Likewise, the affect of feeding SZA on mineral balance in horses has not been reported. While no negative side effects have been reported in horses, the feeding of SZA to increase dietary Si concentrations has the accompanying effect of increasing dietary aluminum (Al). Since Al is known to decrease phosphorus (P) absorption in ruminants, it is important to determine if feeding SZA alters the absorption of these minerals in the horse.

Material and methods

Eight mature Arabian geldings were pair-matched by weight and randomly assigned to either a control group (C) or a Si-supplemented group (SS). In addition to their regular ration fed to both groups, SS was fed 200 g SZA per day. The horses were maintained in their groups for a 10-d diet adaptation period. They were fitted with total collection devices and total feces and urine were collected over a 3-d period. Blood was collected at the end of the trial. Plasma, feces and urine were analyzed via inductively coupled plasma spectroscopy for Si, Ca, P and Al.

Results

In the plasma, only Si differed between treatments, being greater in SS (1.02 ± 12 ppm) than in C (.53 ± .12 ppm; P=.03). Of primary concern, apparent digestibility of P was not different between treatments being 23.7 ± 4.3% in SS and 13.3 ± 4.3% in C (P=.14). Likewise, there were no differences in the amount of Ca, P or Al retained.

Conclusion

Unlike what has been reported in ruminants, SZA did not reduce the availability of P, nor did it increase the amount of Al being retained. Hence, concerns over potential mineral imbalances being created are alleviated.
Effect of dietary acid load on serum osteocalcin in Thoroughbred and Quarter racehorses

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Introduction

This study examined the impact of dietary acid load (DAL) on bone turnover since increased bone turnover may predispose performance horses to skeletal injury. Racehorses are typically fed a diet rich in grain products yet these diets have a high DAL and decrease blood pH which may result in mobilization of calcium from bone to act as a buffer. This physiologic phenomenon has been described in humans and other mammals. In sheep, consumption of a high DAL results in the loss of bone mineral, osteopenia, increased bone fragility and increased serum osteocalcin (OC). DAL has also been implicated as a contributor to the development of osteoporosis in humans. In young racehorses under the pressures of growth and bone remodeling due to high impact exercise, DAL may hinder appropriate bone development and predispose the equine athlete to injury. The aim of this study was to determine if OC as a marker of bone turnover is higher in racehorses consuming an acidifying diet.

Material and methods

50 racehorses in race training at Arapahoe Park in Denver, Colorado were used. DAL was indirectly determined by measuring blood pH, ionized calcium, serum strong ion difference (Na+K-Cl), and dietary intake of grain, supplements and hay (by weight). These were compared to serum OC using an analysis of variance. Body weight, gender, age and time in training which may also alter serum OC were also examined as potential confounders.

Results

The results of this study are currently under analysis.

Conclusion

Increased serum OC in the face of dietary induced metabolic acidosis may implicate DAL as a major confounder in the development of orthopedic injury in racehorses. Redevelopment of feeds to lower the DAL may decrease the risk of orthopedic injury in performance horses.
The effect of milk basic protein supplementation on bone metabolism during training of the juvenile thoroughbred racehorses

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Introduction

Bone diseases are a significant problem in juvenile horses undergoing training. Nutritional techniques that minimize the occurrence of bone disease would be beneficial. Some nutrients such as protein and Ca are known to affect bone metabolism. Moreover, attention is focused on other nutrients that have been identified as affecting bone metabolism including vitamin K, casein phospho-peptide and milk basic protein, which is a natural protein present in trace amounts in milk. Milk basic protein has been reported to suppress bone resorption and promote bone formation in laboratory animals, humans, and cell culture experiments. Therefore, we examined the effect of milk basic protein supplementation on bone metabolism in juvenile horses during training.

Material and methods

Twenty 2-year-old horses in training were used for 3 months in this study. The treatment group (TG) was fed a basal diet with 1g of milk basic protein and the control group (CG) was fed a basal diet only. Blood samples were collected every month to determine serum Ca and biochemical markers of bone metabolism. Radiographs of the left third metacarpal were taken to determine radiographic bone aluminum equivalence (RBAE) at the start and end of the study.

Results

Serum osteocalcin concentration was significantly higher 2 months after the beginning of the study in TG compared to that in CG. TG showed a significantly higher total RBAE change compared to that in CG. However, there was no significant difference in serum Ca or ICTP.

Conclusion

These findings confirmed that milk basic protein regulates bone metabolism during training of juvenile thoroughbred racehorses.
Silicon and osteochondrotic lesions in two-year-old Standardbreds

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Introduction

Osteochondrosis (OC) is a disturbance of cartilage cell differentiation leading to abnormal endochondral ossification and glycosaminoglycan loss. Silicon (Si) deficiency depresses articular cartilage and glycosaminoglycan content, and causes defective endochondral bone growth. Silicon may reduce OC lesion size by increasing glycosaminoglycan concentration and improving endochondral bone growth.

Material and methods

Initial radiographs were taken on clinically sound, two-year-old Standardbreds (n = 44) on private facilities to identify OC defects in the distal third metacarpus/tarsus or osteochondral fragments at the dorsal aspect of the joint and defects/fragments at the distal tibia and on the trochlear ridges of the talus. Affected horses (n = 8) were pair-matched by facility and affected joint(s) and assigned to the control group (CO) to be fed 200 g whole-grain flour or the Si supplemented group (SS) to receive 200 g bioavailable Si for 120 days. Follow-up radiographs of affected joints were taken at 120 days on horses that remained sound. If lameness became evident, follow-up radiographs were taken at the time of lameness onset and the horse was removed from the study. Radiographs were digitized and the length and height of the OC defects/fragments were measured.

Results

Four horses had fetlock lesions and four horses had tarsal lesions for a total of 12 affected joints. Due to the onset of lameness, four horses did not complete the full study duration. There was no effect of treatment, time, or treatment*time on lesion length (P > 0.22), height (P > 0.51), or area (P > 0.67).

Conclusion

Silicon supplementation did not alter the radiographic appearance of OC lesions. Silicon may not affect OC healing, but further research should investigate the role of Si in OC prevention.
Effects of different levels of calcium and phosphorus intake on calcium homeostasis in exercising horses

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Introduction

The study was conducted to obtain information on the effects of different levels of Ca and P intake on calcium homeostasis in exercising horses.

Material and methods

5 trained horses were given 3 different daily dietary Ca and P supplements in the order indicated: 33 g Ca and 19 g P (~100% NRC, low intake), 64 g Ca and 38 g P (moderate), and 96 g Ca and 56 g P (high). The horses were accustomed to the diets over a 21-day period before undergoing a standardized exercise test (SET) on a treadmill. SET comprised 5 steps (each step 4 min duration, 3% slope; first step 5 m/s, increasing increments of 1 m/s). Blood samples were taken at defined times.

Results

During exercise, blood lactate, plasma intact parathyroid hormone (iPTH), and plasma inorganic P increased ($P < 0.05$); blood pH and blood ionized Ca++ (adjusted to a pH of 7.4) declined ($P < 0.05$); and total plasma Ca and Mg (MgT) remained constant. The most marked drop in Ca++ and highest lactate peaks during SET occurred after low Ca and P intake at 7, 8, and 9 m/s ($P < 0.05$). After exercise (120min), Ca++ levels were always above resting levels, with Ca++ levels the highest after high Ca intake (Ca++ mmol/L: low 1.58 ± 0.07; moderate 1.63 ± 0.04; high 1.65 ± 0.02; $P < 0.05$). At the same time, iPTH returned to basal levels 120min after exercise, with PTH levels the highest after low Ca intake (iPTH pg/mL: low 45.6 ± 72.8; moderate 11.6 ± 13.6; high 2.6 ± 2.3; $P < 0.05$). During recovery (30min, 120min and 24h after exercise) MgT levels were depressed after high Ca intake ($P < 0.05$).

Conclusion

These results suggest that high dietary Ca and P intake did not impair PTH responses during exercise and rest, but might have depressed Mg metabolism.
Urine excretion of dietary contaminants fed to horses for several days

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Introduction

Most horse racing and international competition authorities completely ban the use of any substance which could affect horse performance. However, the origin of certain substances can be due to horse feed (compounded feed and raw materials) and not to a real illegal drug taking. The aim of this study was to evaluate the urinary concentrations in horses fed different contaminants for several days.

Material and methods

Horses in training (9 Thoroughbreds, 6 Arabians and 9 French saddle horses) were housed in individual free stalls without any access to pasture during the study. They received their usual diet and a carrot containing one capsule of two metabolically independent molecules (caffeine, theophylline, theobromine, atropine, scopolamine, bufotenine or dimethyltryptamine) for three days. The daily dose of contaminants was divided in half doses fed with the morning and the evening meals of the horses. On days two and three, urine samples were collected after exercise, three hours after the morning meal. The experiment was repeated on the same horses in order to test two different levels for each molecule; at least seven days separated the two dose test. The samples were immediately frozen for further analysis by chromatography coupled to mass spectrometry.

Results

Urine samples from six horses were tested for two levels of theobromine, five for caffeine theophylline, atropine, scopolamine and dimethyltryptamine, and three for bufotenine. A daily intake margin, which does not induce a positive result to the doping analysis, was determined for theobromine, theophylline, atropine, bufotenine and dimethyltryptamine.

Conclusion

Further research is needed in order to gain more confident results on caffeine and scopolamine. These results will contribute to more strictly select raw materials included in the horses’ diet.
Effect of gastrogard on markers of performance in gastric ulcer-free Standardbred horses

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Introduction

A large percentage of athletic horses develop gastric ulcers and many of those horses are treated with omeprazole (Gastrogard®). Unfortunately, no data have been published on the effects of the drug on markers of performance in animals without ulcers. Therefore, ten unfit, healthy, ulcer free, Standardbred mares (4-10 yrs, ~475 kg) were used to test the hypothesis that omeprazole would alter markers of aerobic and anaerobic performance.

Material and methods

Mares were administered either control (oral applesauce, CON, 20 mL) or omeprazole (oral paste GG, 4mg/kg SID) in a random crossover fashion with the investigators blind to the treatment. Treatments were administered for seven days prior to performing an incremental exercise test (GXT) on a high-speed treadmill. Endoscopic examinations were performed just prior to the trial to verify that the mares were ulcer free. During the GXT the mares ran on a treadmill up a 6% grade to measure maximal oxygen consumption (VO₂max), run time (RT), velocity at VO₂max, maximal velocity (Vmax), hematocrit (HCT), plasma lactate concentration (LA), and plasma protein concentration (TP). The measurements were recorded at rest, at the end of each 1 min step of the GXT and at 2 and 5 min post-GXT. Data were analyzed using ANOVA for repeated measures and t-tests for paired comparisons.

Results

The results are presented as means ± SE for CON vs. GG. There was no effect (P>0.05) of omeprazole on VO₂max (116 ± 5 vs. 121 ± 5 mL/kg/min); velocity at VO₂max (8.6 ± 0.2 vs. 8.8 ± 0.2 m/s); RT (349 ± 50 vs. 347 ± 48 s); Vmax (9.7 ± 1.0 vs. 9.6 ± 5.9 m/s); 2 min recovery plasma LA (17.0 ± 1.3 vs. 17.4 ± 1.6 mMol/L). Nor were there any changes (P>0.05) in the relationship between treadmill speed and VO₂, HCT, TP, or plasma [LA]. The power of the analysis was greater than 80% (alpha level set at 0.05).

Conclusion

Omeprazole does not appear to improve physiological markers of performance in healthy, ulcer free, horses. These data may benefit various authorities responsible for deciding administration and timing policies of Gastrogard as well as clinicians and horse owners.