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Effects of horse housing on musculoskeletal system post-exercise recovery

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RESEARCH ARTICLE

Abstract

This study examined the effects of two housing systems (control housing and loose housing) on musculoskeletal condition during recovery from race-like exercise in Standardbred horses. The hypothesis was that a loose housing system provides better conditions for musculoskeletal recovery than the control housing. Eight adult geldings (mean age 11 years) were used in a study with a cross-over design, with the control housing (CH) and loose housing (LH) treatments each run for 21 days. The horses had *ad libitum* access to forage and performed two similar race-like exercise tests (ET), on day 7 and day 14 in each treatment. Blood samples were collected before ET, at finish line, and at 7, 22, and 44 h of recovery and analysed for the muscle enzyme activities of creatine kinase and amino transferase. Before and three days after ET, hind leg fetlock joint region circumference and diameter, joint range of motion in right hock and carpus, mechanical nociceptive threshold in back muscle, and movement asymmetry were recorded. Overall circumference and overall diameter of hind fetlock joint region were lower in LH horses than CH horses (P=0.045 and P=0.017, respectively), but no other differences were observed. In conclusion, a loose housing system did not alter the recovery of musculoskeletal condition other than preventing a post exercise enlargement of the circumference and diameter of the hind fetlock joint region.

Keywords: Standardbred trotters, tape measure, slide calliper, algometer, management system

1. Introduction

According to publications on horse housing most horses are currently housed in individual box stalls in both Europe (Bachmann and Stauffacher, 2002; Hotchkiss *et al.*, 2007; Jordbruksverket, 2016; Petersen *et al.*, 2006) and North America (Henderson, 2007). Box stalls facilitate supervision of horses, individual feeding, and grooming, but obviously limit the scope for unrestricted movement and social interaction in horses. Box-stall housing can also affect the musculoskeletal system in growing horses (Hoekstra *et al.*, 1999). Restricted ability for movement, e.g. living indoors in box stalls, has been shown to negatively affect bone quality in growing horses compared with growing horses kept on pasture, irrespective of training (Hoekstra *et al.*, 1999). Loose housing systems are not common for sport horses, possibly due to fear of injury but also concerns among trainers that a lack of rest in such systems delays recovery and affects competition performance negatively.

In humans, intense exercise can result in delayed-onset muscle soreness (DOMS), reduced range of motion in the affected limb, and release of muscle enzymes (Peake *et al.*, 2017). These symptoms commonly occur 1-3 days post-exercise in humans (Peake *et al.*, 2017), but in horses little is known about the DOMS process. In humans, the most effective means of alleviating pain from DOMS is exercise (Cheung *et al.*, 2003), so it is likely that a housing system that enables physical activity would positively affect the wellbeing of horses and, in particular, recovery of musculoskeletal condition.

It is well known that physical activity is crucial for normal joint function in humans, and this is also likely to apply to horses. However, it is also known that intense and repeated exercise can lead to increased synovial effusion in joints (Te Moller and Van Weeren, 2017). Effusions in the joint area is associated with inflammation and pain. Joint-related lameness is a common problem in sport horses (Bertuglia *et al.*, 2016; Vigre *et al.*, 2002; Wallin *et al.* 2000), and post-exercise 'swelling' of the fetlock area is a common condition among sport horses. In horses kept in conventional box-stall competition stables, a common post-exercise 'therapeutic' practice is to try to reduce the swelling and improve recovery of distal limbs with bandages, liniment, massage or cold water, using a water hose. In humans, the importance of post exercise active movement has been emphasised both directly post-exercise and during recovery (Cheung *et al.*, 2003) and one can therefore hypothesise that a lack of physical activity post-exercise could delay recovery in horses.

The aim of this study was to examine musculoskeletal condition after competition-like exercise and determine whether recovery of musculoskeletal condition was affected by housing system. Two different systems were compared: loose housing, where physical activity was possible for 24 h/day, and control housing, where activity in groups was possible only for 4-5 h/day. Musculoskeletal condition was evaluated by measuring muscle enzyme activities (aspartate aminotransferase (AST) and creatine kinase (CK)), back muscle response on pressure algometry (mechanical nociceptive threshold (MNT)), flexion joint range of motion, movement asymmetry and the circumference and diameter of fetlock joint region swelling. The hypothesis was that a loose housing system provides better conditions for musculoskeletal recovery than control housing.

2. Materials and methods

The Umeå local ethics committee approved this study, and it was performed in compliance with European Union directives on animal experiments (2010/63/EU; EC, 2010) and the laws (Swedish Constitution, 1988:534) and regulations (Swedish Board of Agriculture Constitution, 2012:26) governing experiments on live animals in Sweden.

Horses and management

Eight adult Standardbred geldings (mean age 11 years, range 9-13 years) were used. The horses were considered sound and fit for training by an experienced trainer during the study. All horses were used to both housing systems before this study started. Rectal temperature was measured every day at 07:00 h to ensure that no horse showed signs of infection by elevated rectal temperature. All horses had participated in competition races and had average earnings of 146,553 SEK (range 26,500-495,798 SEK). Mean bodyweight at the beginning of the trial was 509 kg (range 410-562 kg). The horses had been trained since the age of two according to training programs used by Swedish trotting trainers (Ringmark, 2014).

Experimental design

The horses were randomly allocated to two groups of four and kept in the control housing system (CH) or loose housing system (LH) for 21 days, followed by a 3-day transition period and then a complete change-over to the other treatment. All horses performed two similar exercise tests (ET), on day 7 (ET1) and day 14 (ET2), in each treatment (Figure 1). On day 3, 11, and 18 of each treatment, the horses were exercised (5,000 m warm-up, 3,000 m at a speed of 11.1 m/s) on a racetrack.

The horses in treatment CH were housed individually indoors in 3×3 m boxes with wood shavings as bedding and were let out into a hard surface (grit/sand/mud) paddock (2,000 m^2) together with the other horses in their group for 4-5 h every day. The control housing system was designed to be similar to the most common housing system used in Sweden (box stall and some hours/day in an outdoor paddock) (Jordbruksverket, 2016).The horses in treatment LH were kept together in a group housing

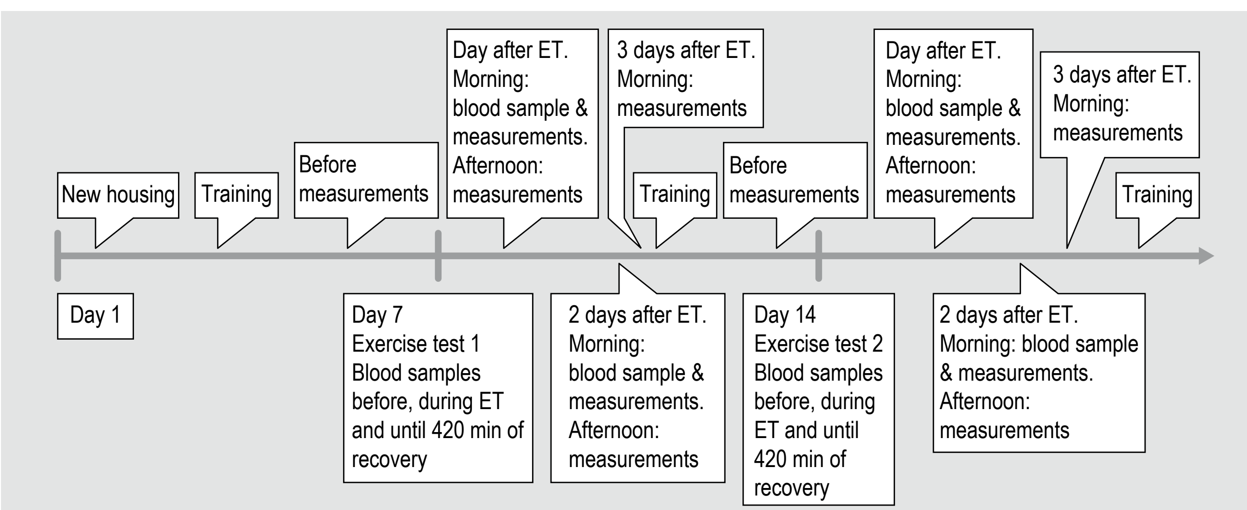

Figure 1. Experimental plan for both experimental periods. ET = exercise test.

area that consisted of a hard surface (grit/sand/paved) paddock (3,200 m^2) with a shelter with rubber matting and automatic feeding stations.

Exercise test

On the day of the ET, the horses were transported 50 km to an official racetrack (Östersund´s racetrack, Sweden; 1000 m oval, banked, gravel racetrack). The horses performed the ET in groups of four, two from each treatment. The same driver drove the same horse in a harness race sulky on all test occasions and the horses raced in the same group at the same time on all occasions. The ET started with a warm-up consisting of 4,000 m slow trot (6.3-6.7 m/s) and 500 m trot (10 m/s). After warm-up, the horses walked the track for 10 min. Then the horses trotted 2,140 m in the same race field position at 11.8-12.2 m/s for the first 1,640 m and as fast as they could (free positioning) for the last 500 m. This was followed by a cool-down of 1000 m slow trot (6.3-6.7 m/s). The ET resulted in peak max heart rates of 221-224 bpm and plasma lactate concentrations of 20.6-20.8 mmol/l as previously reported in Connysson *et al.* (2019).

Approximately 1 h after crossing the finish line in the ET, the horses were transported back home, and 3 h after the exercise tests they were put back in their housing system. The drivers ranked willingness to perform of all horses, using the following options; very dull, dull, alert, very alert.

Measurements, sampling, and analysis

During ET days, blood samples were collected via a catheter inserted in the jugular vein. A local cutaneous anaesthetic (Tapin (lidocaine 25 mg/g/prilocaine 25 mg/g), Orifarm Generics, Stockholm, Sweden) was administered before the catheter placement approximately 1 h before first blood sampling. Blood samples were collected in 6 ml lithium-heparinized tubes (102 IU) and kept on ice until centrifuging (10 min, 920×*g*, 18 °C), after which the plasma was frozen (-20 °C). Blood samples were collected at rest in the stable (Rest), at the racetrack 1 min after the finish line (FL), and after 10, 180, 240, 300, 360, and 420 min of recovery (R10, R180, R240, R300, R360, and R420). At 20 and 44 h after the ET (R20h and R44h), blood samples were collected by venipuncture from the jugular vein. Plasma AST and CK concentrations were analysed using an automated clinical chemistry analyser (Abbott Architect c4000, Abbott Park, IL, USA) with commercial reagents from Abbott (reference range AST 2-13 ukat/l and CK 2-12 ukat/l).

In the morning on the day before ET and three days after ET (morning and afternoon on the first two days, morning on the last day), swelling in the hind fetlock region was assessed by measuring circumference of the fetlock joint region with a measuring tape and the diameter with a slide calliper, both fitted with a dynamometer as previously described in (Bergh *et al.*, 2018). Measuring points were standardised by clipping a mark in the horse's coat at the same height as the injection site for the palmar fetlock joint pouch. MNT in back muscles was measured with an algometer (Somedic, Hörby, Sweden) at two locations: 5 cm lateral of TH17-18 and L3-4 respectively, and these measurement points were also marked by clipping the coat. Flexion joint range of motion in right hook (*tarsocrural* joint) and carpus was measured with a goniometer as previously described in (Adair *et al.,* 2016; Liljebrink and Bergh, 2010). All these measurements were performed three times at every site by the same person, blinded to the reading every time, while the readings and recordings were made by another person. Means for every measurement site were then calculated and used in further analysis.

On the same occasions, movement asymmetry in a straight-line trot in hand on a hard surface was recorded with a sensor-based system, Lameness Locator (Equinosis, Columbia, MO, USA), as described by Keegan *et al.* (2011). Uni-axial accelerometers were attached to the poll and pelvis, and a gyroscope dorsally to the right pastern. Data were used if there were at least 25 steps in trot recorded. If not, a new measurement was performed. Data were processed with the software package for the gait analysis system. Outliers for head movement were manually removed (up to maximum 10% of the strides). Differences in minimum head (HDmin) and pelvis (PDmin) height during left and right stance phases, and differences in maximum head (HDmax) and pelvis (PDmax) height after left and right stance phases, were calculated for each stride. The vector sum (VS) of HDmin and HDmax was calculated ($VS=\sqrt{(HDmin^2+HDmax^2)}$) for head movement asymmetry, and the sum (PDsum) of PDmin and PDmax absolute values for pelvis movement asymmetry (Keegan *et al.*, 2011).

Recovery blood samples and other morning recovery measurements (pressure algometry, flexion joint range of motion, movement asymmetry and the circumference and diameter of fetlock joint region) were done in the morning before the CH horses were turned out in the paddock and the afternoon measurements (pressure algometry, flexion joint range of motion, movement asymmetry and the circumference and diameter of fetlock joint region) were done 2-3 h after coming in from the paddock. Locomotion activity during housing was recorded using inertial measurement units (X-IMU, x-io technologies, Bristol, UK)

Statistical analysis

Analysis of variance was performed with the MIXED procedure in SAS (version 9.4; SAS Institute Inc., Cary, NC, USA), using an autoregressive (AR(1)) structure. Plasma sample results were pooled into race (FL and R10), short-term recovery (R180-R420), and long-term recovery (R22h and R44h). All four MNT measurements were pooled to one value. Right and left hind fetlock measurements of circumference and diameter were pooled to one hind fetlock measurement of circumference and one of diameter for each sampling occasion. Movement asymmetry head, movement asymmetry pelvis, circumference of fetlock joint region, diameter of fetlock joint region, joint range of motion hook, joint range of motion in right carpus, and MNT measurements were pooled into before and recovery until morning 3 (morning and afternoon on the first two days after ET, morning day 3 after ET). The statistical analysis was performed with a statistical model including fixed effects of housing, sample, and the interaction between these. The model for an observed variable of horse i in housing j, sample k, was:

$$Y_{ijk} = \mu + \eta_i + \pi_j + \gamma_k + (\pi\gamma)_{ik} + e_{ijk}$$

where μ is the overall mean, η_i is the effect of horse, π_j is the effect of housing, γ_k is the effect of sample, $(\pi\gamma)_{ik}$ is the effect of the interaction between housing and sample, and e_{ijk} is the random error. The random part included horse, horse × housing, and period. Observations within each horse × period × housing combination were modelled as repeated measurements.

Post-hoc comparisons were adjusted for multiplicity using the Bonferroni method. Values are presented as least square means with the pooled standard error of the mean (SEM). Differences were considered statistically significant at $P<0.05$.

3. Results

One of the horses was excluded due to a hoof crack, although that horse showed no clinical signs of lameness. During the race, the drivers ranked three horses as more alert, two horses as lazier, and two horses with same ranking when comparing CH to LH treatments.

Overall (all samples during one treatment compared with all samples during the other treatment) circumference and diameter of hind fetlock region were significantly lower in LH horses than CH horses (circumference 26.3 and 26.7 cm, respectively, SEM = 0.4 (P=0.045); diameter 4.9 and 5.1 cm, respectively, SEM 0.9 (P=0.017)). There were no overall effects of LH compared with CH on plasma concentrations of CK (2.0 vs 2.0 ukat/l, SEM = 0.2) or AST (4.5 vs 4.9 ukat/l, SEM = 0.3). There were also no overall effects of LH compared with CH on front limb VS (11.5 vs 13.0 mm, SEM = 2.1), sum hind limb (6.0 vs 6.0 mm, SEM = 0.7), hook joint range of motion (50.1 vs 50.4 degrees, SEM = 1.0), carpus joint range of motion (25.2 vs 24.7 degrees SEM 1.7) or MNT (278 vs 282 kPa, SEM = 30).

Response to the race (finish line and 10 min after finish line) and short-term recovery (3-7 h)

Plasma CK and AST concentrations were greater during the race compared with Rest values, but there were no differences between housing systems (Table 1). The different housing systems did not significantly affect plasma CK, or AST concentrations during 3-7 h recovery (Table 1). Plasma CK concentrations exceeded the Rest values during short-term recovery (Table 1). There was a tendency (LH: P=0.081, CH: P=0.078) for higher plasma AST concentrations during short-term recovery compared with rest (Table 1).

Long-term recovery (20-68 h)

Housing system had no significant effect on plasma CK activities or AST activities during 20-44 h of recovery (Table 1). The circumference and diameter of hind fetlock joint region were larger in CH horses than LH horses during recovery (Table 2). Diameter of hind fetlock joint region was greater during recovery than before race values in CH horses (Table 2). However, VS head, pelvis symmetry, joint range of motion in carpus, and MNT were not affected by the race (before compared with the days after) (Table 2).

4. Discussion

The results in this study show that most recovery parameters of musculoskeletal condition was not altered by the different housing systems tested. However, an enlargement (‘swelling’) of the hind fetlock region (increased circumference and diameter) was observed post-exercise) in CH but not in LH, although the numerical differences were small. Since the present study did not examine the origin of the swelling of the distal limb the clinical importance of this swelling remains to be evaluated. However, it is a common practice in racing stables with box-housed horses to put bandages and liniment on the distal parts of the legs (from carpus/hook to pastern) to prevent or reduce swelling. The information on effects of bandages and liniment on effusions is limited. In one study, wool bandages were shown to stop fluid flow through lymph vessels (Fedele *et al.*, 2006). The results indicate that LH prevent the swelling occurring in CH. This is probably due to increased voluntary movement, and thereby increased circulation, in LH horses compared with CH horses. Voluntary movement activity has been shown to be lower in stabled or partly stabled horses compared with horses housed in loose systems (Chaplin and Gretgrix, 2010). In the control housing system used in the present study, horses were kept in a box for 19-20 h/day and in a paddock for 4-5 h/day. An attempt to measure locomotion activity was made in the present study, resulting in full data from only one individual (due to technical problems with the IMU:s

Table 1. Plasma concentrations during recovery of creatine kinase (CK) and aspartate amino transferase (AST) in Standardbred horses kept in loose housing (LH) or control housing (CH).

Variable	Sample[a]	LH	CH	SEM	*P*-value
Plasma CK (ukat/l)					
	Rest	1.6	1.6	0.2	1.000
	Race	2.8[b]	2.8[b]	0.2	1.000
	Short-term recovery	2.1[b]	2.1[b]	0.1	1.000
	Long-term recovery	1.7	1.5	0.2	1.000
Plasma AST (ukat/l)					
	Rest	4.1	4.5	0.3	1.000
	Race	5.1[b]	5.6[b]	0.3	1.000
	Short-term recovery	4.5[c]	4.8[c]	0.3	1.000
	Long-term recovery	4.5[c]	4.7	0.3	1.000

[a] Race = finish line and 10 min of recovery; short-term recovery = 3-7 h recovery; long-term recovery = 20-44 h of recovery; SEM = standard error of the mean.
[b] Significantly different ($P<0.05$) from Rest values in the same housing system.
[c] Tendency for significant difference ($P\leq 0.09$) from Rest values in the same housing system.

Table 2. Movement asymmetry head, movement asymmetry pelvis, circumference of fetlock joint region, diameter of fetlock joint region, joint range of motion hook, joint range of motion in right carpus, and mechanical nociceptive threshold (MNT) in horses housed in loose housing (LH) or in control housing (CH).[a]

Variable	Sample	LH	CH	SEM	*P*-value
Movement asymmetry head, VS (mm)					
	Before exercise	13.1	12.7	2.6	1.000
	Long-term recovery	11.2	13.0	2.0	0.841
Movement asymmetry pelvis, PDsum (mm)					
	Before exercise	6.3	5.8	1.1	0.585
	Long-term recovery	5.2	6.7	0.7	1.000
Circumference of fetlock joint region (mm)					
	Before exercise	262	264	4	0.773
	Long-term recovery	263[b]	267	4	0.025
Diameter of fetlock joint region (mm)					
	Before exercise	47.9	49.8	1.0	0.235
	Long-term recovery	48.7[b]	51.7[c]	0.9	<0.001
Flexion joint range of motion right hook (degrees)					
	Before exercise	49	51	1	0.559
	Long-term recovery	50	50	1	1.000
Flexion joint range of motion in right carpus (degrees)					
	Before exercise	26	25	2	1.000
	Long-term recovery	25	25	2	1.000
Mechanical nociceptive threshold (kPa)					
	Before exercise	294	278	32	0.931
	Long-term recovery	276	284	29	1.000

[a] Long-term recovery = 20-68 h recovery; SEM = standard error of the mean; VS = vector sum; PDsum = sum of PDmin and PDmax absolute values for pelvis movement asymmetry.
[b] Significant treatment effect.
[c] Significantly different ($P<0.05$) from before exercise.

not indicating if recording data or not). In that individual, the activity (from 21:30 to 07:30 h) was, as expected, higher in the LH system (250%).

Even if the ET in this study resulted in peak max heart rates (221-224 bpm), and plasma lactate concentrations (20.6-20.8 mmol/l, Connysson *et al.*, 2019) similar to those reported in competition races (Ronéus *et al.*, 1999) the horses in this study did not show signs of muscle damage or muscle soreness. Although AST- and CK-activity were elevated after the ET, both values at rest and race values were lower than reported previously after a real race in Standardbred trotters (Kristensen *et al.*, 2014; Pösö *et al.*, 1983), indicating comparatively limited muscle damage. The lack of muscle enzyme activity response to ET might be an effect of the low-starch diet in the present study. Low-starch diets have been shown to decrease muscle enzyme response to exercise in athletic horses with recurrent exertional rhabdomyolysis (MacLeay *et al.*, 1999; McKenzie *et al.*, 2003) as well as in healthy athletic horses (MacLeay *el al.*, 1999). Post-race muscle enzyme values reported in earlier studies (Kristensen *et al.*, 2014; Pösö *et al.*, 1983) were probably measured on horses on a high-starch diet, although diet is not reported in those studies. The use of high starch diets has been the standard way to feed athletic horses (Jansson and Harris, 2013). Combined with the lack of post-exercise response in MNT in the back, this indicates that the ET in the present study did not cause any measurable DOMS in the area evaluated. Pressure algometry has been shown to be a useful tool for quantifying muscle response changes in horses with suspected sacroiliac dysfunction (Varcoe-Cocks *et al.*, 2006), but there is a lack of data on use of the method in athletic horses. In this study, MNT was applied to the area of *longissimus dorsi* and it is possible that the response would have been different if a muscle more active during fast trot would have been evaluated.

Joint range of motion of carpus or hook was not affected by the ET. A reduced range of motion in affected limbs have been observed in humans with severe DOMS (Peake *et al.*, 2017). In studies on DOMS in humans, effects of active recovery have been observed only during a short period after exhaustive exercise (Dupuy *et al.*, 2018) and in rugby players for example, 7 min of low intensity exercise directly post-competition improved CK clearance (Gill *et al.*, 2006). Effects of active recovery in the immediate post exercise period on lactate removal (both in humans and in horses) has also been studied and improved removal is generally observed. However, lactate removal has, in humans, been suggested to not be a valid indicator on recovery quality (Barnett, 2006). The absence of data of validated methods that could measure DOMS in athletic horses shows the need for more studies.

Motion asymmetry in the horses was not significantly affected by ET or housing system. However, on some occasions individual horses were over the symmetry threshold for lameness applied by the Lameness Locator system, even though these horses were considered sound by the trainer throughout the study. Earlier studies on riding horses in training have also reported that horses considered free of lameness by the owner can show movement asymmetries (Kallerud *et al.*, 2021; Rhodin *et al.*, 2017). The asymmetry values obtained in the present study were similar to those reported previously in Standardbred geldings in training (Ringmark *et al.*, 2016).

In conclusion, a loose housing system did not alter the recovery of musculoskeletal condition compared to control housing other than preventing enlargement ('swelling') of the diameter and circumference around distal joints. The importance of swelling around distal joints for long-term orthopaedic health needs further investigation.

Conflict of interest

The authors declare no conflict of interest.

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