Short-duration exercise and confinement alters bone mineral content and shape in weanling horses

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ABSTRACT: The hypothesis that short-duration exercise may ameliorate the decrease in bone mass observed with confinement was investigated with 18 quarter horses (nine colts and nine fillies) weaned at 4 mo of age and placed into box stalls. After a 5-wk adjustment period, individuals were grouped by age and weight, and then divided randomly into three treatment groups: 1) group housed; 2) confined with no exercise; and 3) confined with exercise. The confined and exercised groups were housed in 3.7 m × 3.7 m box stalls for the 56-d duration of the trial. The exercised group was sprinted 82 m/d, 5 d/wk, in a fenced grass alleyway. The weanlings were led down an alleyway, turned loose in a small pen, and then released and allowed to run back down the alley. The group horses were housed together in a 992-m² drylot with free access to exercise. On d 0, 28, and 56, dorsopalmar and lateromedial radiographs of the left third metacarpal bone were taken to estimate changes in bone mineral content and cortical widths. Mean values of medial, lateral, and total radiographic bone aluminum equivalence increased over time (P < 0.05), whereas dorsal and palmar radiographic bone aluminum equivalence did not change significantly. Dorsal, medial, and total radiographic bone aluminum equivalence tended (P = 0.09) to differ by a treatment × day interaction, with values increasing over time only in the exercised group. Normalized medial and total radiographic bone aluminum equivalence tended (P < 0.1) to differ (P < 0.01) with treatment, with exercised horses having greater bone aluminum equivalence than confined horses. Dorsopalmar cortical width in exercised horses was greater than on d 56 (treatment × day; P = 0.07). The dorsopalmar medullary cavity decreased in exercised vs. group-housed horses (P = 0.027), whereas dorsal and medial cortical width tended to increase only in the exercised horses (treatment × day; P < 0.01). This study indicated that a short-duration exercise protocol might be effective in improving bone mass and therefore skeletal strength in horses.

Key Words: Bone, Confinement, Equine, Exercise, Growth

Introduction

Injuries to the skeletal system of the horse are a concern to the equine industry. Early training in young horses may be beneficial to the longevity of their careers. In Australia, horses receiving their first starts as 2-yr-olds had more starts and raced longer than those that began their racing careers at a later age (Bailey et al., 1999). The early training that these horses received in preparation to race as 2-yr-olds may have aided in modeling the skeleton for high-speed activity. Most studies show that the greatest skeletal adaptations occur in very young animals or humans (Loitz and Zernicke, 1992; Umemura et al., 1995; Iwamoto et al., 2000). Thus, if horses received exercise at an earlier age, well before traditional training began, greater benefits to the skeletal integrity of the horse may be seen.

Exercise bouts need not be of lengthy duration, provided an effective stimulus level on the bone is reached (Rubin and Lanyon, 1984; Inman et al., 1999). Four cycles per day of an externally applied force prevented bone loss in immobilized turkey ulnae (Lanyon, 1984) and five jumps per day increased bone mass and mechanical strength of rat femora and tibiae over sedentary controls (Umemura et al., 1997). Although no definitive magnitude of strain to cause bone adaptation has been described for all species, sprinting 50 m, 5 d/wk, for 6 wk enhanced bone geometry in immature calves (Hiney et al., 2004). No studies of the strain magnitude experienced in the metacarpal bone of immature calves have been performed, but galloping in horses creates high strain magnitudes in the third metacarpal bone (3,200 microstrains; Rubin, 1984). Thus, only a few cycles, corresponding to strides, should
be necessary to elicit an osteogenic response, especially in an immature animal. Therefore, a protocol similar to that of Hiney et al. (2004), featuring short bouts of sprinting exercise 5 d/wk, was implemented in an equine study to test if this species would respond in a similar manner.

Materials and Methods

Animals and Management

Eighteen quarter horses, nine colts and nine fillies, were weaned at approximately 4 mo of age. Horses were weaned by removal from their dams and placement into box stalls (3.7 m x 3.7 m). The foals remained in the stalls for 5 wk before the initiation of the study. Stress due to weaning temporarily decreases feed intake and thus slows growth (Knight and Tyszynski, 1985); therefore, this time period allowed the foals to adjust from the stress of weaning as well as to adapt to handling. Foals were fed alfalfa hay and a commercially available pelleted concentrate in a 50:50 ratio at 2 to 2.5% BW (Strategy Professional Formula GX, Purina Mills LLC, St. Louis, MO) to maintain body condition. The study was conducted in the summer, with the horses housed outside exposed to natural photoperiod, whereas the stalled horses received 16 h/d of artificial light. Individuals were stratified according to age, weight, and gender, and then randomly assigned to one of three treatments resulting in six horses per treatment: 1) confined without exercise (CF), 2) confined with exercise (EX), and 3) group housed (GR). The average weight of the horses was 226 ± 4 kg and the average age was 165 d.

The GR horses were housed together in a 992-m² drylot with free access to exercise. The CF horses remained in box stalls for the 8-wk duration of the project with no access to exercise, whereas the remaining EX horses received forced exercise 5 d/wk. The exercise protocol was moderate, requiring the horses to gallop 82 m over a turf surface. The EX horses were led from their stalls to the end of an 82-m grass alleyway and turned loose in a small pen. Horses were then released from the pen, galloped down the alleyway back toward the barn, and were caught in a small pen at the end of the alley. The speed of the horses averaged between 6 and 8 m/s accounting for acceleration and deceleration. Only on very infrequent occasions did the foals fail to gallop up the length of the alley when released. The horses were returned to their stalls, with the entire distance traveled being approximately 264 m, including the distance walked from the barn to the alleyway.

Behavior Observations

Observations of behavior were made over 24 h on d 0, 28, and 56 for all groups. Horses were kept under constant lighting and videotaped in either their box stalls or in the group drylot with an extended camcorder, which recorded 24 h on one tape. For all horses, four separate hours of each 24-h period were randomly chosen for each horse for observation, and then 15 min of each hour were analyzed. Behavior observations were limited to activities that would load the bone and therefore affect bone strength. Durations of behaviors were recorded and summed for each 15-min period. The total duration of the behaviors was recorded as a proportion, or percentage, of time for which all occurrences of the behavior lasted over the observation session. The total duration of behaviors was summed for each observation day and over all three days. These behaviors included bouts of standing, walking, lying down, and trotting. In addition to the behaviors recorded as cumulative intervals, the frequency or number of occurrences of shifting of stance from lying to standing, walking bouts, pawing, startling (reaction in response to a sudden and novel stimulus), and jumping were recorded for each 15-min period.

Sample Collection

Radiographs were taken at d 0, 28, and 56 to determine radiographic bone aluminum equivalence (RBAE) values, measures of optical density and a reflection of bone mineral content (Meakim et al., 1981). Only the left metacarpal bone (MCIII) was radiographed for determination of bone mineral content as other studies in mature horses have reported no difference in bone properties between forelimbs (Glade, 1993; Lawrence et al., 1994). Radiographs of the dorsal-palmar and medial-lateral views of MCIII were taken at a focal length of 77 cm and an exposure of 65 kVp (peak kilovoltage) (25 mA for 0.1 s). An aluminum stepwedge was attached to the radiographic cassette to standardize readings and to calculate RBAE values. Horses were also weighed on a livestock scale on d 0, 28, and 56.

Radiographic Bone Aluminum Equivalence

Optical density of the bone was assessed using radiographic photodensitometry to determine RBAE using a Bio-Rad (Hercules, CA) model GS 700 imaging densitometer (Bell et al., 2001). Radiographs were scanned 3 mm distal to the nutrient foramen of MCIII with Multi-Analyst software (Bio-Rad), a software package designed to translate digital images into numerical data. A linear regression was created by plotting the optical density of the scanned image of the aluminum penetrometer against the known thickness of the steps. Maximum optical density of each cortex was expressed in millimeters of aluminum for both cortices in each view of MCIII. Total RBAE was measured by taking the area under the curve of the bone scan and expressing it in relation to a known volume of aluminum calculated from the area of the scanned image of the stepwedge (Nielsen and Potter, 1997).

Cortical Widths

The dorsal-palmar radiographic view was used to measure the width of the medial and lateral cortices,
Exercise and confinement alters bone shape

Figure 1. Schematic illustration of a cross-section of bovine third and fourth metacarpal showing cortical measurements. B = outside major diameter (lateromedial bone diameter); b = inside major diameter (lateromedial medullary diameter); D = outside minor diameter (dorso-palmar bone diameter); d = inside minor diameter (dorso-palmar medullary diameter).

Figure 2. Schematic illustration of a cross-section of equine third metacarpal showing cortical measurements. DC = dorsal cortical width; PC = palmar cortical width; MC = medial cortical width; LC = lateral cortical width.

Figure 3. Schematic illustrations of cortical measurements created from Multi-Analyst software. a = bone diameter; b = medullary diameter; c and c' = individual cortical diameters.

the inner medullary diameter, and the outer cortical diameter (Figures 1 and 2). The beginning of the curve of the bone image, as developed by the Multi-Analyst software, to the highest point of the curve was measured for the width of each individual cortex, and the medullary diameter (or medullary cavity) was measured from the distance between the two peaks of the curve. The outer cortical diameter was measured as the entire distance of the curve (Figure 3). The similar procedure was used for the lateromedial view for determination of dorsal and palmar cortical widths, and the inner medullary diameter and outer cortical diameter across the dorsopalmar aspect of the bone.

Statistical Analysis

Statistical analysis of RBAE and cortical widths was performed using the MIXED procedure of the SAS (SAS Inst., Inc., Cary, NC) with a covariance test suitable for repeated measures. The covariance structure was first-order autoregressive, with horse within treatment used as the subject effect. The model tested for treatment, day, and the treatment × day interaction. When main effects were significant, post hoc comparisons were used to separate differences between means. Least squares means were separated by the Tukey’s method. Individual standard errors of the mean for each treatment are included in the tables and figures. To aid in visualizing changes over time within an individual, data were also normalized by subtracting d-0 values from all subsequent values. Behavior data were analyzed with a multinomial distribution, which predicted the probability of behavior occurrence between groups. Frequency behaviors, such as postural shifts, walking bouts and pawing, were analyzed using a Poisson distribution. For all analyses, P-values less than 0.05 were considered significant, whereas P-values less than 0.10 were discussed as trends.

Results

As horses were assigned to treatments according to weight, BW were similar at the initiation of the study (226, 226, and 227 ± 4 kg for EX, CF, and GR respectively) and remained similar throughout the study with final weights of 270, 269, and 263 ± 3 kg for EX, CF, and GR horses.
Radiographic Bone Aluminum Equivalence

Dorsal and palmar RBAE values did not differ according to time or treatment, but there was a trend for a treatment × day interaction (P = 0.09) in the dorsal cortex, with values increasing to d 56 only in the EX group (Table 1). The dorsal cortex of MCIII in the CF and GR animals remained essentially unchanged from the initiation of the trial. Although overall dorsal and palmar values did not increase over time, overall medial and lateral RBAE values increased significantly over the duration of the study (P = 0.001 and P = 0.001, respectively).

When treatment means were separated, the only increase in medial RBAE was in the EX group (treatment × day interaction; P = 0.055), similar to that seen in the dorsal RBAE data. Total RBAE also increased over time (P = 0.003) and, comparable to both dorsal and medial RBAE data, when means were separated, total RBAE values tended to increase only in the EX animals (P = 0.087). When total RBAE values were normalized, there was a significant effect (P = 0.020) of treatment, with values for EX horses increasing more (137 ± 44 mm Al) than those for either CF (38 ± 40) or GR horses (8 ± 25).

Cortical Widths

Dorsopalmar cortical diameter increased over time (P = 0.001; Table 2), with values on d 56 greater than either d 0 or d 28. In addition, there was a trend for EX to be greater than GR on d 56 (treatment × day; P = 0.07). Both CF and EX had greater dorsopalmar bone diameters on d 56 in comparison with d 28. When data were normalized by examining the changes in values from d 0, the treatment × day interaction was significant, as EX had increased by 2.3 mm (P = 0.07), CF had increased by 1.7 mm (P = 0.02), and GR did not change (P = 0.91). Overall, the medullary dorsopalmar diameters did not change over the duration of the trial, but treatment × day interactions were significant (P = 0.018). When data were normalized, the medullary cavity decreased in EX (−1.5 mm) compared with GR, which gained slightly (0.2 mm; P = 0.027). The change in medullary diameter of CF was not different from either EX or GR.

Dorsal cortical width averaged over all treatments did not change over time, but a trend for an increase did occur in EX (treatment × day; P = 0.01). When dorsal cortical width was normalized in relation to d 0, EX was greater than both CF and GR (P = 0.011). The average change in the EX was 2.0 mm vs. 0.2 mm in CF and −0.3 mm in the GR foals. Palmar cortical widths tended (P = 0.08) to increase over time but did not differ between treatments.

The lateromedial bone diameter increased over time (P = 0.001) but was not different between treatments (Table 3). Mean medial and lateral cortical widths increased over time (P = 0.003 and P = 0.036, respectively), and in the normalized medial widths, EX tended to gain more width in the medial cortex (2.1 mm) compared with GR (0.4 mm) (P = 0.09). Finally, the lateral cortex was not different by treatment.

Behavior

The percentage of observed time spent walking averaged over all days did not differ between treatments (2.3 and 2.8% for EX and CF, respectively), with the GR horses averaging slightly more walking at 5% of the observed time. The EX foals spent less time standing (64% of the observed time) compared with the CF (78%) and GR (84%; P = 0.004) foals. The EX foals spent a greater proportion of time (34%) lying down compared with CF (20%) or GR (12%; P = 0.001) foals. The incidence of pawing in the CF foals was greater (Table 4; P = 0.001) than in EX or GR. The frequency in shifting stance between standing and lying was greater in CF foals than in GR foals (P = 0.011). The number of walking bouts did not differ among treatments. As animals were never observed starting or jumping during the observation periods, these behaviors were not reported in the tables. The occurrence of trotting bouts was very infrequent. Thus, duration of trotting was very short.
Table 2. Mean dorsopalmar cortical diameters (mm) of the third metacarpal bone as affected by exercise, confinement, or group housing over the 56-d trial

<table>
<thead>
<tr>
<th>Variable</th>
<th>Exercised</th>
<th>Confined</th>
<th>Group</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>d 0⁰⁺⁺⁺⁺</td>
<td>d 28</td>
<td>d 56</td>
</tr>
<tr>
<td>Dorsopalmar o.d.b</td>
<td>27.0b</td>
<td>26.6d</td>
<td>29.3e</td>
</tr>
<tr>
<td>Dorsopalmar i.d.</td>
<td>15.1c</td>
<td>14.2d</td>
<td>13.5</td>
</tr>
<tr>
<td>Dorsal cortex</td>
<td>7.4d</td>
<td>8.1e</td>
<td>9.8</td>
</tr>
<tr>
<td>Palmar cortex</td>
<td>4.7c</td>
<td>4.9d</td>
<td>5.1</td>
</tr>
<tr>
<td></td>
<td>0.4, 0.4, and 0.5 mm for dorsopalmer o.d. on d 0, 28, and 56, respectively; 0.4, 0.3, and 0.3 mm for dorsopalmer i.d. on d 0, 28, and 56, respectively; 0.3, 0.3, and 0.4 mm for dorsal cortex diameter on d 0, 28, and 56, respectively; and 0.2 mm for palmer cortex diameter on each day.</td>
<td></td>
<td></td>
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<tr>
<td>bMeans pooled across treatments differed on d 0, 28, and 56 (P &lt; 0.05).</td>
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<td></td>
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<tr>
<td>cIndicates a trend for means to be greater in exercised horses than in group-housed horses on d 56 (P = 0.07).</td>
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<tr>
<td>d,eMeans within a cortical measurement and within a treatment with different superscripts indicate a trend (P &lt; 0.10) for treatment × day interactions.</td>
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Discussion

Many studies of weanling and yearling horses have shown an increase in RBAE values over time, with increasing mineralization of the skeleton occurring with maturation (Buckingham and Jeffcott, 1987; Raub et al., 1989; McCarthy and Jeffcott, 1992) and the majority of increase in mineral content of the young horse limited to the first year and a half of life (Nielsen et al., 1997; Hiney, 1998). In the current study, medial, lateral, and total RBAE values increased in all groups over 56 d, but dorsal or palmar RBAE values did not change.

The increase in RBAE may not have been due solely to increased density, but rather to the normal expansion of MCIII with growth. One of the difficulties in determining changes in mineralization with radiographic photodensitometry is that this technique does not specifically measure density. As the animal grows, bone increases in size; thus, the x-rays pass through a thicker (but not necessarily denser) tissue, thereby appearing denser on the film.

Because the largest recorded strains during galloping occur in the dorsal and medial cortex of MCIII (Gross et al., 1992), exercise typically causes greater mineralization to occur in the dorsal and medial cortex. Although overall medial and total RBAE values increased over time, only the EX group showed increased medial, dorsal, and total RBAE values, as shown by post hoc analysis. Although only trends, the short-term exercise seemed to cause more mineral deposition in those areas of the bone experiencing the most strain during galloping. Again, these changes may have been due to the formation of new bone rather than increased mineralization of preexisting bone.

One of the greatest adaptations created by exercise is in the geometry of bone. Therefore, a method of measuring widths from the radiographic image of the bone scanned into the Multi-Analyst software was used to analyze geometry. The main effects of growth in 56 d appear to be more related to the size and shape of the bone than to density. Whereas only EX group showed increases in dorsal, medial, and total RBAE, the CF and did not provide sufficient data for statistical analysis; therefore, these data were not reported.

Table 3. Mean lateromedial cortical diameters (mm), as affected by exercise, confinement, or group housing over the 56-d trial

<table>
<thead>
<tr>
<th>Variable</th>
<th>Exercised</th>
<th>Confined</th>
<th>Group</th>
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<tbody>
<tr>
<td></td>
<td>d 0</td>
<td>d 28</td>
<td>d 56</td>
</tr>
<tr>
<td>Lateromedial o.d.</td>
<td>35.0</td>
<td>35.9</td>
<td>38.3</td>
</tr>
<tr>
<td>Lateromedial i.d.</td>
<td>22.4</td>
<td>22.2</td>
<td>21.1</td>
</tr>
<tr>
<td>Medial cortex</td>
<td>7.0</td>
<td>8.1</td>
<td>9.1</td>
</tr>
<tr>
<td>Lateral cortex</td>
<td>6.8</td>
<td>7.1</td>
<td>7.4</td>
</tr>
<tr>
<td></td>
<td>0.7, 0.7, and 0.6 mm for lateromedial o.d. on d 0, 28, and 56, respectively; 0.7, 0.7, and 0.5 mm for lateromedial i.d. on d 0, 28, and 56, respectively; 0.3 mm for medial cortex diameter on each day; and 0.2, 0.3, and 0.3 mm for lateral cortex diameter on d 0, 28, and 56, respectively.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>bMeans pooled across treatments differed on d 0, 28, and 56 (P &lt; 0.05).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cMeans pooled across treatment for d 0 differed from d 28 and 56 (P &lt; 0.05).</td>
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<tr>
<td>dMeans pooled across treatments for d 0 differed from d 56 (P &lt; 0.05). Means for d 28 were not different from d 0 or 56 values.</td>
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and EX groups experienced increased dorsopalmar bone diameters, and all three treatments resulted in increased medial and lateral cortical widths and lateromedial bone diameter over the 56 d when data were averaged together. However, the tendency of the EX group to show an increase in mineral content was reflected in changes in width in the same aspects of the bone.

Changes in the shape of the bone may be the dominant loading adaptation that occurs during early life, and the changes in the shape of MCIII may be the best indicator of increased mechanical integrity. The total circumference of the bone (as estimated from measuring across the lateromedial and dorsopalmar widths of the bone) increased in all groups over the 56 d of the trial, indicating normal periosteal expansion with growth reported previously (Buckingham and Jeffcott, 1987). Periosteal expansion in the dorsopalmar direction was greater in EX in relation to GR, and normalized data showed both CF and EX to be greater than GR. Although no mechanical testing was performed in this study, others have shown that stiffness of equine bone increases with increased bone diameter (Hanson et al., 1995). As the moment of inertia varies with the fourth power of the outer diameter of the bone, the EX horses with greater bone diameter may potentially be at a mechanical advantage.

The size of the medullary cavity did not change with time, but endosteal expansion may not occur until later in skeletal development. Even so, in the normalized data, the EX group tended to have a smaller medullary cavity than did the GR group. Whether this was because of a contraction of the endosteal space due to exercise or an expansion of the endosteal space in GR horses is impossible to determine without the aid of histomorphometric studies.

Medial and lateral cortical widths increased significantly over time in all horses, but palmar cortical width only tended to increase. Normalized medial cortical width also showed a trend for an increase in EX vs. GR horses. Whereas dorsal cortical width averaged across all 18 horses did not change, the mean of the EX group tended to increase. Therefore, the exercise protocol seemed to be causing some adaptation of MCIII, but usually only in comparison to the GR horses. Why the GR horses would have shown less periosteal expansion than either of the box-stalled groups, especially as they underwent no less activity than that performed by the CF horses, is unclear.

Although the estimation of cortical widths from radiographic images is not as precise as data that can be obtained from modalities such as computed tomography, it at does provide an additional tool to monitor changes in bone that may not be related to density or mineral content changes. In the young animal, adaptation of the architecture of bone is the predominant response to exercise. Exercise increased the dorsal periosteal apposition rate in young Thoroughbreds (McCarthy and Jeffcott, 1991, 1992). Race training also increased dorsal, medial, and lateral cortical diameters, as well as dorsopalmar and lateromedial widths, and decreased the size of the medullary cavity, similar to the results here (Thomson et al., 2001). Thus, the data, while only showing trends for improvement in the EX, corresponds with alterations in bone geometry due to exercise previously reported in horses.

In addition, the foals receiving the short-term exercise responded in a manner comparable to calves performing a similar exercise program (Hiney et al., 2004). Running 50 min, 5 d/wk, resulted primarily in a change in bone shape of the fused third and fourth metacarpal bone. Exercise decreased the size of the medullary cavity and increased the dorsal cortical width compared with calves kept in confinement or those allowed free access to exercise, similar to the results in the horses. However, there were differences between calves and horses that suggest, while similar, these two species may not adapt to exercise in an identical manner. The exercised calves were not different in the dorsopalmar bone diameter whereas the exercised horses increased in dorsopalmar bone diameter. Conversely, the lateromedial diameter was smaller in the exercised calves compared with no change between groups in the equine study. The difference in adaptation of bone shape is most likely due to a dissimilar pattern of bone strain in the equine MCIII compared with the fused third and fourth metacarpal bone in the calves. Therefore, while useful to perform preliminary studies, the calf model may not be able to completely replace studies performed using horses.

Stalling the weanlings for 2 mo did not result in bone loss in CF and would not be expected in such rapidly growing animals; however, the CF horses were not at any disadvantage compared with the GR horses. The behavioral observations made of the horses aid in explaining the lack of differences in bone measures between the CF horses and GR horses allowed freedom of movement. The CF horses did not have lower RBAE or less favorable bone geometry compared with GR. Rather, the GR horses tended to have the lowest bone measurements, which was unexpected, and most treatment differences were seen between EX and GR. How-

**Table 4. Total number of occurrences of behaviors summed over all observations and days for each treatment group**

<table>
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<tr>
<th>Variable</th>
<th>Exercised</th>
<th>Confined</th>
<th>Group</th>
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<tbody>
<tr>
<td>Paw</td>
<td>13&lt;sup&gt;b&lt;/sup&gt;</td>
<td>96&lt;sup&gt;a&lt;/sup&gt;</td>
<td>28&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Walking bouts</td>
<td>315</td>
<td>410</td>
<td>288</td>
</tr>
<tr>
<td>Stance change</td>
<td>10&lt;sup&gt;b&lt;/sup&gt;</td>
<td>15&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4&lt;sup&gt;b&lt;/sup&gt;</td>
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<sup>a,b</sup>Treatment values that do not have common superscripts differ (P < 0.05).
ever, despite their greater opportunity for movement, the GR horses did not differ in the time spent performing activities that would significantly load the bone compared with CF.

The imposed confinement did seem to increase frustration in the CF horses as they pawed more than either EX or GR horses. Presumably this was due to the increase in motivation for locomotor behavior following a period of behavior deprivation, which can lead to a variety of abnormal behaviors or stereotypes in horses, including pacing weaving or pawing the stall floor (Dellmeier, 1989). In addition, the confined horses shifted their stance between laying and standing more frequently than either of the exercised groups. Even EX horses, which were out of the boxed stalls for only a very short time period (about 10 min), 5 d/wk, exhibited fewer frustrated behaviors. The amount of strain on the bone as a result of activities such as pawing is unknown. In addition, while infrequent, the CF animals were the only ones observed jumping or startling in their stalls. Both of these activities have been reported to result in very large strain magnitudes (Skerry and Lanyon, 1995; Konieczynski et al., 1998). These infrequent strains may play a significant role in the adaptation of bone and may explain why CF did not differ from GR.

Results of this study seem to indicate that very short periods of exercise increased bone mineral content and altered bone geometry of stalled weanling horses in comparison to those kept in small paddocks. Confinement of at least an 8-wk duration did not seem to cause any dramatic effects of disuse osteopenia; however, this is difficult to determine without pre-weaning RBae values. These results are similar to those found in a study of similar design conducted on young calves.

Implications

The results of this study indicate the potential value of implementing an exercise program in immature horses. By stimulating the skeleton at an early age to model for intense activity, these animals may be better adapted for training than those that begin training at a later age. The exercise protocol was easy to implement and was of minimal stress to the horses. Therefore, similar exercise protocols might be suggested to enhance skeletal strength before more traditional under-saddle training. Horses housed in pens may not have much strain placed on bone if the area provided is not adequate to encourage activity. The group housing used in this study was too small and lacking in stimuli to encourage much activity. Therefore, it is recommended to increase the space available when a specific exercise program is not used. Currently, more research needs to be performed regarding the long-term benefits of such an exercise program and the frequency with which they should be employed.

Literature Cited


