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Management and Training of Horses to Prevent Fractures and Improve Bone Strength

By Brian D. Nielsen, PhD, PAS, Dpl. ACAN

Preventing skeletal injury is critical for horse owners, particularly owners of performance horses. Three aspects are important in a discussion of skeletal injury; first, the pain resulting from injuries represents a welfare issue for the horse. A second issue pertains to public perception, since horses occasionally become injured or, even worse, die in front of large crowds during races, cross-country events, and other sports using horses. The third issue relates to the economic aspect of injuries. Injured horses typically have to be removed from training. Competition is then delayed and potential income is lost. This issue of *Large Animal Veterinary Rounds* discusses the prevention of injury in order to diminish negative effects on the horse, as well as on public perception and economics.

Bone deposition

While some injuries are likely inevitable, new research demonstrates that prevention is possible if several previously accepted practices are changed. Many skeletal injuries can be avoided simply by understanding how bone responds to mechanical loading, and the forces experienced during training and competition. Bone is a dynamic structure and constantly changes in response to varying forces through two primary mechanisms.

• The first mechanism is bone modeling; this appears to occur only in juvenile bone, ceasing once longitudinal bone growth is finished. Through bone modeling, new mineral is either added or taken away. Bone can become longer, thicker, and heavier, resulting in changes in the shape and architecture of the skeleton.

• Bone remodeling is the second mechanism. This process removes old or damaged bone and replaces it with new mineral. Bone remodeling occurs throughout life, but typically, does not result in a net change in the quantity of mineral present.

Given that bone modeling occurs only in the juvenile skeleton, the greatest opportunity to create bone that can withstand the rigors of training is during this growth period. Generally, that opportunity is lost once an animal matures. Contrary to traditional thinking, current research demonstrates not only the advantages of training a horse at a young age, but also the problems associated with failing to do so during this critical period. Furthermore, limiting the ability of a horse to exercise on its own can also predispose a horse to a weakened skeleton.

Stalling of horses is a common practice; however, in recent years evidence has accumulated revealing the detrimental effects of stalling without offering the horse sprinting opportunities. Nielsen et al[1] reported a decline in the mineral content of the third metacarpal bone of 2-year-old Quarter Horses entering race training (Figure 1). The relatively rapid decline in mineral content and, very likely, in associated strength during the first 2 months of training was surprising. However, a review of the management of these horses gives some indication of the cause. Prior to the

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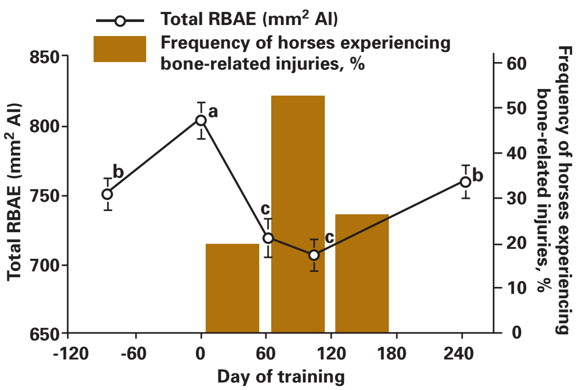
Figure 1: Bone density as measured by radiographic aluminum equivalence (RBAE) and periods during which bone-related injuries occurred[1]



RBAE = radiographic bone aluminum equivalence

^{abc} Days lacking a common superscript differ (P<0.05)

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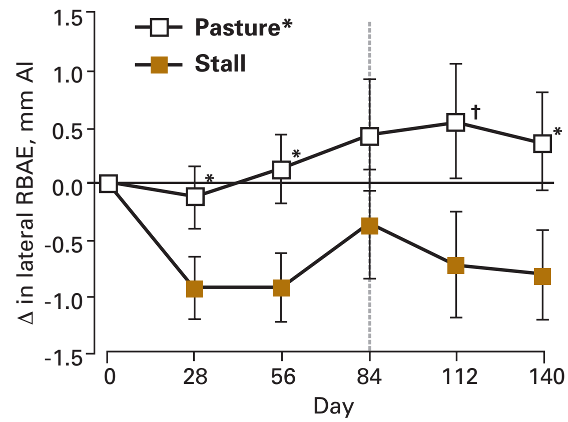
Figure 2: Changes in bone density as measured by lateral radiographic bone aluminum equivalence (mm Al) versus day of project[2]



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* In legend indicates pasture different than stalled (P<0.05)

* In graph indicates pasture different than stalled at given day (P<0.05)

† In graph indicates pasture different than stalled at given day (P<0.1)

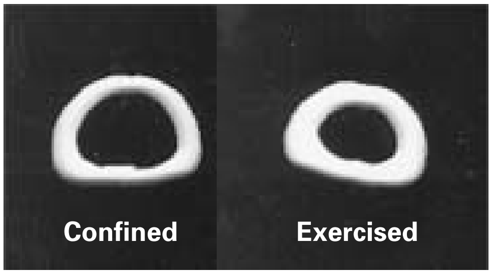
initiation of training, the mineral content of the third metacarpal bone was increasing. This is expected, since yearling horses are still growing. When the horses began training, they were also removed from pasture and placed in stalls. During the first couple of months, the horses were trained in the traditional manner; they were only walked, trotted, and slowly cantered in the manner typically called "long, slow distance" to develop a fitness foundation. Only after the horses had been in training for about 2.5 months were they first asked for speed. This corresponds to the time in training when most bone-related injuries occur. This is not surprising because with a lowered mineral content from relative inactivity, the bones are more susceptible to injury. Shortly after increasing the speed of exercise, the mineral content of the third metacarpal bone began to rise.

In order to verify that removal from pasture and placement into stalls truly caused the decrease in mineral content, Hoekstra et al[2] took a group of long yearlings (average age, 18.5 months) that had been raised on pasture and randomly put half into stalls and half on pasture. By day 28, horses placed in stalls had lost a dramatic amount of mineral from the metacarpal bones (Figure 2). Despite walking the horses for 1 hour/day on a mechanical horse walker, the mineral loss still occurred. After 3 months, the horses were started under saddle and were ridden at the walk, trot, and slow canter for an additional 2 months, but the mineral content of the metacarpal bones never increased and remained lower than at the start of the study. The results clearly demonstrated that stalling young horses was detrimental to bone strength. However, the question remained as to how much time horses need to spend on pasture to prevent bone mineral losses.

A study by Bell et al[3] examined the issue by dividing weanlings into three groups: maintained on pasture, kept in stalls, or kept in stalls for twelve hours and turned out on pasture for 12 hours. Both the partially- and completely-pastured groups had improved bone formation compared to stalled horses. This is consistent with studies in other species demonstrating that only a minimum number of bone-loading cycles (similar to strides) is necessary to prevent disuse osteoporosis.[4,5] To prevent bone loss, the duration of turnout on pasture probably only needs to be sufficient to allow a few fast-paced strides. Additionally, there are other advantages to maintaining horses on pasture, eg, offering social interaction[6] as well as increasing the ease in starting under saddle.[7] This was examined in conjunction with the Hoekstra et al study[2] examining bone loss when horses were removed from pasture and placed into stalls. Horses in stalls for three months prior to training were more difficult to train than those maintained on pasture,[7] as evidenced by exhibiting more unwanted behaviours such as bucking, jumping, and resisting rein pressure. Additionally, although on the first day of training there was no difference in the length of time spent working with the horses in the two treatment groups, by the seventh day, pastured horses needed only about half the groundwork time before being ridden than did the stalled horses. Overall, training time for pastured horses was 75% of the time needed for stalled horses to reach the same training goals.

The benefits of exercise on bone appear to occur very quickly. This is because bone responds more readily to the amount of force placed upon it rather than how many times the force is applied. An increase in speed results in increased force on the leg and causes the bone to bend. The bone responds to this strain and tries to maintain a balance by allowing the bone a limited degree of bend. This response is

Figure 3: Example of cross sectional image of fused third and fourth metacarpal bone from confined and exercised calves[8]



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logical from an evolutionary standpoint. If a horse runs faster than it has in recent runs, the bone will bend more. The increase in strain is recognized and the body responds by adding mineral in order to reduce the amount of strain. In contrast, if a horse does not run and hence, the bone does not bend, the body senses the decrease in strain and removes the mineral perceived as unnecessary. As a result, a balance is struck between having enough mineral present to withstand regularly encountered forces, but not so much as to be energetically inefficient.

Exercise requirements for bone deposition

While the exact number of strides at a speed needed to promote bone deposition has not been fully determined, some ideas are available. One study used Holstein bull calves as a model for young horses and divided the calves into three groups.[8] One group was group-housed with other calves and allowed free access to exercise. The two other groups were kept in tie-stalls that allowed standing and lying down, but prevented exercise. One of the stalled groups was led from their stalls 5 days per week and the calves were sprinted down a concrete alleyway for 50 meters before being caught and led back to their stalls. After 6 weeks, the differences between the forced exercise group and the other 2 groups were remarkable. In examining the cross sectional area of the third and fourth metacarpal bones, it was clear that the forced exercise group had thicker bones than the non-exercised groups (Figure 3). Furthermore, there was a trend for an increase in the force required to fracture bones in the sprinted group compared with the other two groups. Considering the calves were only made to run 50 meters per day emphasizes that only minimal strides at higher speeds are needed to maintain, and even increase, bone mass.

A similar study was conducted with weanling horses, except that the exercised group was sprinted 80 meters per day on a grass alleyway.[9] Similar to the calf study, exercised horses had greater mineral content in the metacarpal bones than stalled and group-housed horses. Aside from demonstrating that minimal strides at a sprint can improve bone formation, both the horse and calf studies revealed that group housing by itself is not sufficient to maximize bone strength. In both situations, behavioural data provided clues as to why this was the case. Group-housed animals were relatively inactive, supporting the contention that if animals do not run, the benefits from being on pasture or housed in groups are minimized. Therefore, techniques to encourage running in horses kept on pasture should be considered. Groups of 2 or 3 animals are less likely to run than larger groups. Due to allelomimetic (mimicry) behaviour, if one horse begins to run, others will usually follow suit. With a small group of horses, there is less likelihood of horses spontaneously choosing to run compared to larger groups. Likewise, young horses are more likely to spontaneously run as compared to mature horses. As a result, keeping a single young horse with a group of geriatric horses will likely produce less favourable results than keeping a young horse with similarly aged horses.

As important as it is to place load upon the skeleton in order to maintain strength, it must be cautioned that the phrase "if a little is good, a lot must be better" does not apply to skeletal physiology. While a few strides at fast speed are necessary to maintain and strengthen bone, too many strides at high speed can easily overwhelm the skeleton, particularly, if the skeleton has not been previously conditioned to handle that rate of speed. Bone accumulates damage when it is repeatedly bent under large forces (such as running at a high rate of speed). This may lead to fractures, although bone has the capacity to repair itself if the rate of healing is not overwhelmed.

Recognizing these factors, it is easy to explain why young racehorses have such a high injury rate – reportedly reaching upwards of 70%.[10] Under traditional management and training practices, high injury rates are almost inevitable. Prior to the onset of training, horses that have been through the yearling sale process are often stalled for 2 to 3 months, in order to guarantee "saleable" condition. During this period, the horses are usually only walked or, sometimes, trotted. As a result, the bones of young horses respond to the reduced strain load on the skeleton and lose strength. Following the sale, horses are kept in stalls while being started under saddle. The first 2 to 3 months of training usually consist of walking, trotting, and galloping (racetrack terminology for cantering). Unless horses are given regular pasture turnout time during these periods, it would be expected that the skeleton would weaken below the levels found in the horse prior to the preparation for the sale. Another problem is that during the early conditioning period, other physiological systems (eg, the cardiovascular and muscular systems) gain fitness and the horses become mentally ready to progress in training. The result is that horses appear and act fit according to trainers; therefore, the trainers begin to introduce speed into the training program. This addition of speed is occurring when the bone is dramatically weaker than it was 3 to 6 months earlier. If speed were gradually introduced, bone would increase in strength and no problems would ensue. Unfortunately, speed is generally introduced rather rapidly, since the horses appear to be capable of handling the work. Before long, damage accumulates and is often sufficient to result in fractures of the fatigued bone – either as microfractures in the early stages or in complete fractures – if not caught in time.

Nutrition

A discussion about preventing fractures would not be complete without discussing nutrition. Only the adequacy of energy requirements can be easily evaluated, usually by simply scoring the body condition of the horse using the standard 9 point scale.[11] A moderate body condition score (BCS) of around 5 appears to be the most desirable for athletic horses, as revealed by the evidence in studies involving endurance horses[12] and racehorses.[13,14] At a BCS of 5, the ribs will not be visible, but can easily be felt. A horse much below a BCS of 5 will not have sufficient energy reserves to perform adequately. When a horse has a BCS much greater than 5, they will have greater difficulty in dissipating heat. Additionally, horses will tire sooner because they carry extra weight associated with fat stores and the extra weight further increases the load on the legs, multiplying the risk of injury.

It is difficult to assess whether the requirements for other nutrients are being met without being excessive. This requires calculating the quantity of nutrients (eg, protein and minerals) and comparing it to the animal's requirements. In many cases, the extra nutrients required for exercise are met by increased feed consumption to meet the increased energy demands associated with work. However, several studies emphasize an increased need for dietary calcium, compared to recommendations of the 1989 National Research Council report,[15] especially during early periods of training when bone turnover and formation are increased.[16,17] Fortunately, if a good quality hay and a balanced, commercially-prepared concentrate are used in feeding, the increased calcium demand will usually be met. Problems may be seen when raw grains (ie, straight corn or oats) are fed. These are naturally high in phosphorus and low in calcium and, by not providing sufficient calcium, may limit bone development. Interestingly, a 10-year study in humans revealed that calcium intake over that period was not associated with bone gain or bone strength.[18] Instead, only exercise during adolescence was significantly associated with increased bone mineral density and bone bending strength. This underscores the importance of exercise in young horses to maximize bone strength. However, if sufficient exercise is provided, extra dietary calcium will likely be utilized to improve bone strength. Thus, proper nutrition is important, but proper exercise appears to play an even more important role in preventing skeletal injury to horses.

Summary

Prevention of training-related fatigue fractures is important and can be easily accomplished by understanding a few key ideas. They are:

- **"Use it or lose it!"** Since bone responds to the load placed upon it, if a horse is not allowed or forced to take any strides at full speed, it should be assumed that its skeleton is not as strong as it could be. For show and pleasure horses, this is usually not an issue; however, for a horse that is expected to compete at a high rate of speed, this can be extremely detrimental.
- **"Pasture turnout time will help prevent mineral loss."** However, it does not guarantee strong bones. If a horse runs at full speed, even if for just a few strides daily, it should be sufficient to prevent mineral loss. If horses do not voluntarily run at full speed during turnout times, some form of encouragement may be needed. This could entail simply turning them out with pasture-mates; it could also mean forced exercise may be required. It is recognized that horses will occasionally injure themselves during turnout time, prompting some to choose to keep their horses stalled when not being ridden or handled. Generally, horses accustomed to having continuous or daily turnout times are much less likely to receive injuries while in pasture than horses with only rare opportunities for turnout.
- **"More is not better."** Bone responds to the magnitude of strain and not to the number of cycles. In other words, bone responds to the amount of the force applied and not to the number of times the force is applied. Until bone is adapted to new forces placed upon it, taking too many strides at a fast speed will injure rather than strengthen the bone. Thus, especially in the early stages of training, fast strides should be kept to a minimum, but they need to be part of the overall training program.
- **"It takes much longer to replace lost bone than it does to lose it."** Within just a few days of receiving insufficient stimuli in the form of mechanical loading, mineral loss from bone begins. Unfortunately, replacement of lost bone is a much slower process. This can play a role in causing injuries after a horse has been disabled for such problems as respiratory diseases. It is often tempting to work a horse too hard after it has recovered, since they will not have lost a great deal of cardiovascular fitness. Regrettably, the same cannot be said for skeletal fitness. If there is a quick return to the same intensity of training that the horse was performing before an illness, injuries often arise.

• **"Young bone has a much greater ability to adapt to exercise than does mature bone."** Many individuals in the horse community operate under the belief that it is better to wait until a horse has matured before beginning training. Research during the past decade has clearly proven that this belief is false. In order to maximize bone strength, it is important to subject the juvenile skeleton to forces that will allow a change in architecture and an increase in mineral content. If strenuous exercise is delayed until the horse has become skeletally mature, the horse will lack the ability to respond rapidly to the forces placed upon it. Likewise, the juvenile skeleton is probably more susceptible to weakening when insufficient loads are placed upon it than is the mature skeleton.

While research is further elucidating specifics on how much exercise is needed to maintain skeletal integrity, many skeletal injuries can be prevented by keeping these principals in mind when advising on management and training programs.

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Abstracts of Interest

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

HINEY KM, NIELSEN BD, ROSENSTEIN D.
EAST LANSING, MICHIGAN

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 x 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-m^2 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 x 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 x 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 x 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.

J Anim Sci 2004;82(9):2313-20.

Behavioral and physiological responses of horses to initial training: the comparison between pastured versus stalled horses

RIVERA E, BENJAMIN S, NIELSEN B, SHELLE J, ZANELLA AJ.
EAST LANSING, MI

Horses kept in stalls are deprived of opportunities for social interactions, and the performance of natural behaviors is limited. Inadequate environmental conditions may compro-

mise behavioral development. Initial training is a complex process and it is likely that the responses of horses may be affected by housing conditions. Sixteen 2-year-old Arabian horses were kept on pasture (P) (n=8) or in individual stalls (S) (n=8). Twelve horses (six P and six S) were subjected to a standardized training procedure, carried out by two trainers in a round pen, and 4 horses (two P and two S) were introduced to the round pen but were not trained (C; control). On sample collection day 0, 7, 21 and 28, behavior observations were carried out, blood samples were drawn and heart rates were monitored. Total training time for the stalled horses was significantly higher than total time for the pastured horses (S: 26.4±1.5 min; P: 19.7±1.1; *P*=0.032). The stalled group required more time to habituate to the activities occurring from the start of training to mounting (S: 11.4±0.96; P: 7.3±0.75 min; *P*=0.007). Frequency of unwanted behavior was higher in the stalled horses (S: 8.0±2.0; P: 2.2±1.0; *P*=0.020). Pastured horses tended to have higher basal heart rates on day 0 (S: 74.7±4.8; P: 81.8±5.3 bpm; *P*=0.0771). While the physiological data failed to identify differences between housing groups, the behavioral data suggest that pasture-kept horses adapt more easily to training than stalled horses.

Appl Anim Behav Sci 2002;78(2-4): 235-252.

Comparison of bone mineral content and biochemical markers of bone metabolism in stall- vs. pasture-reared horses.

Hoekstra KE, Nielsen BD, Orth MW, Rosenstein DS, Schott HC 2nd, Shelle JE.
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Sixteen Arabian yearlings were assigned randomly to 2 groups, confined to stall and pastured, to investigate the effects of confinement vs. pasture-rearing on bone mineral content and biochemical markers of bone metabolism over a 140 day period. Following an 84 day pretraining period, 6 horses from each group were selected randomly to complete a 56 day training period. Serum osteocalcin concentrations were determined from blood samples collected every 14 days. Urinary deoxypyridinoline concentrations and mineral content of the third metacarpus, as determined by lateral and medial radiographic bone aluminum equivalency (RBAE), were determined every 28 days from 24 h urine samples and radiographs of the left forelimb, respectively. In comparison with starting values, lateral RBAE was lower in the confined horses at Day 28 and remained lower throughout most of the project, while pastured horses had increasing lateral RBAE. Horses kept in stalls had lower medial RBAE at Day 28 than pasture-reared horses. Medial RBAE tended to remain lower in confined horses than in pastured horses throughout most of the project. The onset of training failed to negate the loss of mineral. Serum osteocalcin concentrations were lower and urinary deoxypyridinoline concentrations were higher in the confined horses at Days 14 and 28, respectively, compared with the pastured horses, and subsequently returned to baseline. These results suggest that housing yearling/2-year-old horses in stalls may be associated with a loss of bone mineral content in comparison with horses maintained on pasture.

Equine Vet J Suppl 1999;30:601-4.

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Tel.: (306) 966-7267 or (306) 966-4124
Email: anne.ruholl@usask.ca

13-16 July 2005
2005 Annual Convention,
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Victoria Conference Centre, Victoria, British Columbia
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22-24 September 2005
American Association of Bovine Practitioners Annual Meeting
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