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Changes in diaphyseal and epiphyseal bone parameters in thoroughbred horses after withdrawal from training

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Introduction

Competition horses sustain athletic injury, which is a significant cause of compromise to animal welfare and cost to equine industries across the world. Some injuries can be treated and have a good prognosis for retention of athletic function, but other injuries are either impossible to treat or reduce or terminate the capability of athletic performance at pre-injury level. The specific pathogenesis of many athletic injuries remains unknown, but many are associated with the repetitive cyclic trauma of training and competition. The most significant career-threatening injuries are to bone, cartilage or tendon. Musculoskeletal tissue development in foals has not received great attention, despite the provocative stage of chondro-osseous development at the time of normal birth. Therefore, we became interested in studying factors which could possibly lead to prevention of athletic injury in later life of the horse.

The Global Equine Research Alliance undertook an initial study between 2000-2003, which consisted of imposition of exercise at a very early age, determination that such exercise was not clinically harmful to musculoskeletal tissues, and study of the responses of the tissues when horses were exposed to training and racing as two-year-olds and again as three year olds.

As training stimulus increases, bone mass and bone density are known to increase in horses[1]. But there has been little study of the changes that occur after training is interrupted, despite the assumption that withdrawal from training (sometimes referred to as "spelling") causes loss of bone mass, and epidemiological evidence of spelling being a risk factor for fracture after training is resumed[2]. This abstract reports on that part of our large study which dealt with the extent of changes in bone parameters at three time points: before training began, when training ceased, and several months after a period of pasture exercise following the athletic training. Other, detailed, accounts of the whole study are reported in other publications being prepared.

Materials and methods

Nineteen horses were born and raised at pasture, and were allowed free exercise in 4 hectare paddocks. From 10 days of age to 18 months of age, half of the horses were exposed to a conditioning regimen in addition to the free exercise at pasture. The conditioned group received the additional exercise in the form of 1,030 m forced exercise at the trot and canter on a grass/sand training track 5 days/week. The distance and the average velocity of the base and sprint components of the exercise regimen were recorded for each horse.

The horses were then trained as two-year-olds at a commercial training centre by a qualified trainer. Training was undertaken in the early morning, six days per week, and training distance and velocities were recorded for each horse[3]. After withdrawal from training, the horses were confined in 4 hectare paddocks.

Data of the bone parameters were thus available before (Pre2) and after (Post2) 242±10.2 (SEM) days of training, and 147±25 days after the training had ceased (Pre3), using

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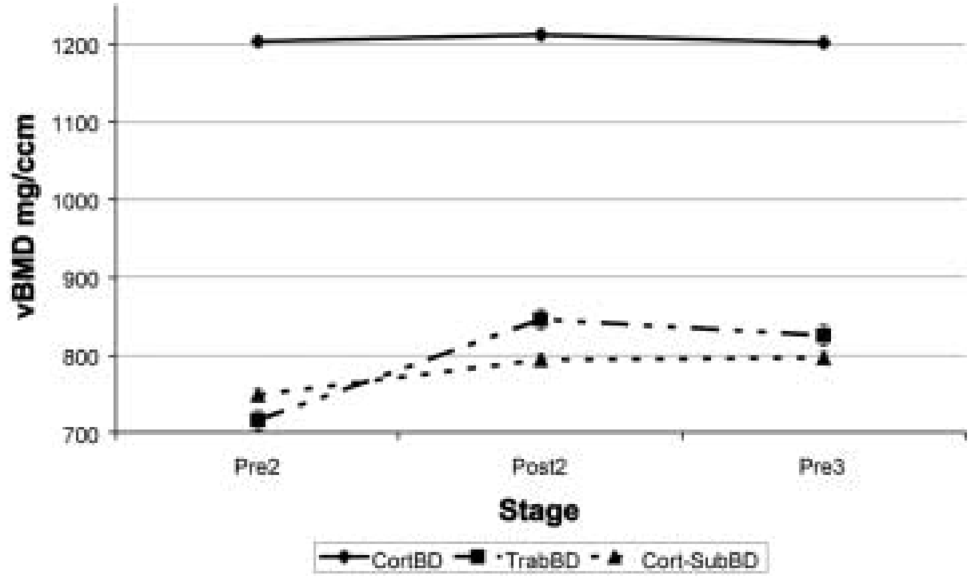

Figure 1. Mean cortical bone mineral density of the diaphysis, and trabecular and cortical-subcortical density of the epiphysis of the third metacarpal bone of 19 two-year-old horses scanned at three stages: before entering training (Pre2), after 8 months training (Post2), and 5 months after training had ceased (Pre3). $_v$BMD= volumetric bone mineral density; CortBD= cortical $_v$BMD; TrabBD= trabecular $_v$BMD of inner 45% of epiphysis; Cort-SubcortBD= $_v$BMD of outer 55% of epiphysis.

peripheral quantitative computed tomography (XCT 2000, Stratec, Pforzheim, Germany) of the third metacarpal (Mc3) diaphysis and epiphysis, with the horse under general anaesthesia. The mean values for mineral content, bone area, volumetric bone mineral density ($_v$BMD), periosteal and endosteal circumferences, and the stress/strain index (SSI), calculated by the manufacturer's software, were determined in the Mc3 diaphysis at a distance from the metacarpo-phalangeal joint (MCPJ) space equivalent to 45% of the length of Mc3. In the Mc3 epiphysis at a site 7 mm from the MCPJ space, BMD was determined in the inner 45% of the cross-sectional image of the epiphysis, and of the so-called cortical-subcortical bone in the outer 55% of the epiphysis.

Equivalent parameters at the three scanning times were compared with a General Linear Model. Previous conditioning history (conditioned or control) was treated as a fixed effect, horse identification was a random effect and bodyweight at the time of scanning was a covariate. Data are presented as mean+SEM.

Results

Workload

By weeks 11 and 12 after beginning training, the mean workload undertaken by the previously conditioned group was greater than that by the control group (p=0.05). By the end of training (Post2) there was no significant difference in the cumulative workload between the preconditioned and control groups. The mean velocity of the canter throughout training was relatively constant at 8.58±0.02 m/s (SEM); velocity of the gallop was variable (range 11.00-17.84, mean 14.87±0.10 m/s). The workload in this first season of training produced little evidence of injury in the horses. By Post2, 13 of the 19 horses had completed competitive sprinting events, consisting of racing and/or trials (eligibility to race).

Bone parameters

Diaphysis

Before training started (Pre2) there was a trend for the diaphysis to be larger and bone mass and area to be greater in the previously conditioned group than the control group (822.98±16.78 mg/mm vs. 789.77±20.55 mg/mm and 685.08±14.45 mm^2 vs. 656.16±17.70 mm^2, respectively) and more resistant to deformation (SSI of 6159.81±209.67 mm^3 vs. 5769.97±256.79 mm^3). None of the differences was significant however, and thus at each stage, data from the previously conditioned and control horses were pooled and compared longitudinally over time (n=19).

After two-year-old training (Post2) there were significant increases over the Pre2 values for area (662.28±11.17 mm^2 vs. 701.13±11.08 mm^2), mineral content (797.17±13.28 mg/mm vs. 849.90±13.18 mg/mm), $_v$BMD (1203.86±3.11 mg/cm^3 vs. 1212.54±3.08 mg/cm^3), periosteal circumference (105.30±1.02 mm vs. 108.21±1.02 mm), and SSI (5856.30±170.46 mm^3 vs. 6429.78±169.09 mm^3) (p=0.023-0.052). There was a non-significant increase in endosteal circumference.

In the 145±10 days after training ceased (Pre3), there were non-significant increases in the area (719.11±11.71 mm^2), content (864.28±13.93 mg/mm), periosteal circumference (108.92±1.08 mm) and SSI (6558.23±178.75); $_v$BMD decreased significantly to 1202.11±3.26 mg/cm^3 (-9.99±13.42) (p=0.02).

Epiphysis

Prior to the start of the 2-year-old training program there were no significant differences in the parameters at the 7 mm epiphysis site between the preconditioned and control horses. Pooled parameters from these two groups were analysed and compared longitudinally over time.

The total area of the epiphysis at the 7 mm level was not statistically significantly different between Pre2, Post2 and Pre3 stages (1699.41±24.21 mm^2, 1730.69±24.16 mm^2 and 1724.49±25.46 mm^2, respectively; p=0.368). The group mean mineral content increased from 1246.17±19.53 mg/mm to 1412.38±19.49 mg/mm (p=0.001) between Pre2 and Post2. $_v$BMD increased from 734.29±9.035 mg/cm^3 to 817.34±9.01 mg/cm^3 (p=0.001).

In the central 45% of the epiphysis, the trabecular density increased by 18.5% (p=0.001) from the Pre2 to the Post2 stage. The fall in density (2.5% of the Post2 value) by Pre3 was not significantly different (p=0.27).

In the outer 55% of the epiphysis, the cortical-subcortical density increased by 6.7% (p=0.001) between Pre2 and Post2, but had the same value (796.2 mg/cm^3) at Pre3.

Discussion

The increase in $_v$BMD is consistent with previous findings. The reduction in cortical density after spelling was due to the differing rates of increase in mineral content and area. Resistance to deformation (SSI) increased during spelling, due to increase in size of the diaphysis, consistent with the continuing but slow growth of horses at this age. In Thoroughbreds that have been trained at this level of workload (which was less intensive than some horses trained by some commercial trainers), SSI of the Mc3 diaphysis appears not to be compromised by the slight but significant fall in cortical $_v$BMD. However, we report data from only one site, and other factors such as local severe cumulative microdamage at other sites could presumably result in reduced SSI with spelling. However, most fractures begin at the articular surface and propagate into metaphysis and diaphysis, which is the reason for obtaining data on the response of the epiphysis of Mc3 to withdrawal from training.

Thoroughbreds train for only a few minutes per day, over distances of approximately 3,000 m. Our horses did in fact train for 3-5 minutes per day, and mean peak velocity was 17.8 m/s. We did not measure activity when the horses were at pasture in the spelling interval between Post2 and Pre3, for technical and resource constraint reasons. The forces applied to the skeleton during spelling would be expected to be less, and applied less often, than peak forces applied during training and racing, but we have no data to support this opinion. Thus it is impossible to estimate if and how the activity at pasture contributed to attenuating bone loss.

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