Bone repair in Thoroughbred racehorses
The effect of training and rest

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Injury to the bone underlying the cartilage in the fetlock joint is the most common cause of limb injury in Thoroughbred racehorses. Studies have found that up to 70 per cent of racehorses have some form of damage to the fetlock joint, and bone failure at this site may progress to fatal breakdown injuries. Although not all affected horses show signs of lameness, this type of injury impairs subsequent race performance.

Bone renewal at other skeletal sites is known to be affected by training but the fetlock joint has not been previously studied in detail.

The findings of this new research provide information to owners and trainers on appropriate training and rest period durations to help reduce the damage to bone exposed to high impact training.

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Acknowledgments

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Abbreviations

B.Ar/T.Ar  Bone area/total area
BSEM  Backscattered electron microscopy
E.Pm/T.Ar  Eroded perimeter/total area
MC3  Third metacarpal bone
SE  Standard error
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Executive Summary

What the report is about

This study examines subchondral bone turnover in the fetlock joint of racehorses both when in full race training and when resting from training. Bone turnover is critical for the repair of bone fatigue which occurs in all training race horses due to the extreme loads generated in the fetlock joint when galloping.

Who is the report targeted at?

This report is highly relevant to racehorse owners and trainers, veterinary surgeons who treat racehorses, and racing authorities.

Where are the relevant industries located in Australia?

The Australian domestic horse population is estimated to be approximately 1 million with high density areas in South East Queensland, Sydney and the Hunter Valley, Melbourne and central Victoria, Adelaide and Perth. Approximately 15% are used for Thoroughbred and Standardbred racing.

Australia has 374 race clubs located in metropolitan and regional centres of all states and territories. In 2010 there were 3668 trainers, 1004 jockeys and 31,773 horses racing for $427 million in prize money. There were 17,191 foals born in the 2010 breeding season; 4831 yearlings were sold at Auction sales in 2009/2010 for a total of $256 million; 1833 horses were exported to other countries; and $14,400 million was wagered on racing in the 2009/2010 financial year.

Background

Injury to the subchondral bone (bone underlying the cartilage) in the fetlock joint is the most common cause of limb injury in Thoroughbred racehorses. Up to 70% of Thoroughbred racehorses have bone bruising, or joint surface collapse of the cannon bone and condylar fractures which propagate from this joint surface are the most common cause of fatal breakdown injuries. These injuries are due to bone fatigue, damage that accumulates due to repeated high loading produced by high speed galloping. Bone is able to repair itself by focal bone resorption followed by new bone production, termed bone remodelling. This process is critical for the prevention of bone fatigue but little is known about how and when bone at this important site is repaired.

Bone can respond to the repeated high loads of race training by adaptation which slows damage accumulation, and repair which replaces damaged bone. The third metacarpal bone adapts to high speed exercise and training by marked increases in midshaft thickness and increased bone volume of its distal epiphysis. There is evidence that in horses in race training, repair of the third metacarpal bone is suppressed.

If these processes and their effect on injury development can be better understood then they may be modified or managed to help prevent injury. Changes in training techniques are known to influence how bone adapts and repairs so there is potential for developing training strategies that decrease the risk of injury.
Aims/objectives

By providing information on how to better manage horses to prevent a common injury this research will benefit racehorse owners and trainers, veterinary surgeons who care for racehorses, racing authorities as well as the racing industry as a whole.

Methods used

Third metacarpal bones from horses that died on Victorian racetracks or at the University of Melbourne Equine Centre were examined using backscattered scanning electron microscopy to investigate adaptation and repair processes and their role in bone injury. Bones from horses in race training were compared with those from horses resting from training.

Results/key findings

− Bone remodelling in horses in race training is suppressed when compared with horses resting from training
− Bone remodelling is more active towards the end of a training period than early in a training period
− Remodelling rates in horses in training are insufficient to remove fatigue damage that accumulates
− Maximal bone remodelling rates are achieved between four and ten weeks following commencement of a resting period

Implications for relevant stakeholders for:

These findings indicate that prolonged race training is undesirable as fatigue damage accumulates faster than it can be repaired, increasing the risk of joint injury and fracture. Therefore Thoroughbred racehorses should be regularly rested from training to allow bone repair. Although bone repair is likely to continue indefinitely, maximal repair occurs within the first 10 weeks of a rest period.

It is also important for trainers to understand that rest from training has the potential to result in highly porous subchondral bone which is at risk of injury. Horses returning to training from a rest period require time to fill these pores with bone.

Recommendations

− Further research is required to investigate means of increasing bone remodelling rates in horses during training and to determine training levels that minimise the risk of bone injury.
− Trainers should be educated to understand that bone within the lower limb joints has a limited fatigue life and that regular rest periods are required to allow repair.
Introduction

Injury to the bone underlying the cartilage (subchondral bone) in the fetlock joint is the most common cause of limb injury in Thoroughbred racehorses. Up to 70% of Thoroughbred racehorses have bone bruising, or joint surface collapse of the metacarpal bone, and condylar fractures, which propagate from this joint surface, are the most common cause of fatal breakdown injuries. These injuries are due to bone fatigue, damage that accumulates due to repeated high loading produced by high speed galloping. Bone is able to repair itself by focal bone resorption followed by new bone production, termed bone remodelling. This process is critical for the prevention of bone fatigue but little is known about how and when bone at this important site is repaired.

Bone can respond to the repeated high loads of race training by adaptation which slows damage accumulation, and repair which replaces damaged bone. The third metacarpal bone (MC3) adapts to high speed exercise and training by marked increases in midshaft thickness and increased bone volume fraction (BV/TV) of its distal epiphysis [1]. This improves its mechanical properties and is therefore likely to increase its resistance to injury [2].

Bone remodelling rates are influenced by both the loading environment and the presence of bone damage. We have previously shown that in horses in race training, remodelling of the third metacarpal bone is suppressed except at sites of bone injury [3; 4]. Suppression of remodelling is of concern because injury occurs when fatigue damage accumulates faster than it can be removed by remodelling. If the effect of training on the bone repair process can be better understood then modifications to management strategies may be help prevent injury.

In this project we broadened our examination of bone remodelling in the distal MC3 in horses in training and resting from training. We hypothesised that bone remodelling activity would be lower in intensely training horses. Additionally, we aimed to explore the relationship between remodelling activity and the time since a change in training status.
Objectives

Important questions that will be answered are:

1. Is bone remodelling inhibited in all horses that are in full training?
2. Do all horses have increased remodelling rates during rest periods?
3. How soon after discontinuing training is remodelling activated?
4. Is there a peak time in a rest period when porosity of the subchondral bone is greatest?
5. Is the degree of remodelling during a rest period dependent on the time the horse has been in training prior to resting?
Methodology

Left and right distal forelimbs were removed post-mortem from Thoroughbred horses that died or were euthanased in the period April 2007 to August 2012 and underwent post mortem examination at the University of Melbourne. Horses were assigned to two groups; (1) training: in a race training preparation; or (2) resting controls: horses that had previously had a race preparation but were not currently training. Training horses had been exercising for longer than four weeks and had progressed to intense exercise [fast canter or gallop] in the current training period.

Metacarpal (MC3) bones from 48 horses were collected; the sex distribution was the same for both groups, with 6 females and 18 males, 14 of which were castrated. The mean age (years) ± SE was higher in the training group (4.9 ± 0.4) than the resting group (3.7 ± 0.3). Of the training group, the cause of death was fracture (n=15), other musculoskeletal condition (n=3), acute abdomen (n=2) and other medical conditions (n=4). Of the resting group, the cause of death was fracture (n=2), other musculoskeletal condition (n=9), acute abdomen (n=7) and other medical conditions (n=6). None of the fractures were of the metacarpus.

The palmar-distal aspect of the MC3 was removed by cutting the bone at 55° to the frontal plane through the centre of rotation of the condyles and stored in 70% ethanol. Racing and training history were obtained from race records and telephone questioning of trainers, cross referenced with race records from an official database [Sirius]. Length of current training period was defined as the length of time (weeks) that a horse had been continuously training with no rest period of more than 4 weeks. Information regarding any lameness history and current or previous treatment including intra-articular cortisone and bisphosphonates was obtained from the trainer and the horse’s regular veterinarian.

The left or right MC3 was randomly selected using a random number generator. Sectins were then prepared for examination with electron microscopy. Two regions of interest (ROI) were examined: (1) the lateral parasagittal groove (PS); and (2) the lateral condylar subchondral bone (LC). Bone remodelling was quantified by measuring the eroded surface (surfaces that had recently been resorbed). The total volume of bone (B.Ar/T.Ar) was also measured. The number of microfractures per millimeter of articular surface was measured for each ROI.

Statistical analysis

A power study determined that 26 bones were required for each group in order to have a high probability of detecting a difference. Because there was a difference in age between the two groups, age was tested for confounding in all analyses. All values are reported as mean (± standard error, SE).
Results

Measures of eroded surface were lower in training than resting horses in both regions of interest with the greatest differences observed in the lateral condyle where eroded surface in resting horses was threefold that of training horses. This was associated with lower porosity in the subchondral bone in the training horses (figure 1), resulting in an increase in percentage bone area (B.Ar/T.Ar) within the lateral condyle.

One training horse had prominent subchondral bone porosity in the lateral condyle with many active eroded and mineralising surfaces. This horse had suffered bilateral humeral fractures during a training gallop. Despite being in training for 22 weeks, this horse had recently changed trainers and was reported to have been unable to race or trial for the previous 18 weeks due to musculoskeletal problems.

Figure 1

Electron microscopic images of subchondral bone from the lateral condyle of the distal metacarpus from six different horses. A. a horse that has been in training for 10 weeks, B. a horse that has been in training for 14 weeks, C a horse that has been in training for 22 weeks, D. a horse that has been resting for 1 week, E. a horse that has been resting for 4 weeks, F. a horse that has been resting for 9 weeks. There is greater porosity in the resting horses due to many eroded surfaces.
Figure 2

Eroded surface per unit area of bone (E.Pm/T.Ar mm⁻¹) in the lateral condyle of the distal metacarpal subchondral bone of horses in training (left) and horses rested from training (right) plotted against time in work or time resting. Eroded surface increased significantly with time in work but was higher in resting horses.

Eroded surfaces tended to be lower in horses examined early in a training period compared to those sampled later in both the parasagittal groove and the lateral condyle (figure 2).

Horses resting less than 5 weeks displayed large variation in eroded surface measures at both subchondral bone sites, which was not explained by the nature of their rest (box versus paddock) (figure 2).

Microfractures were more prevalent in the parasagittal groove than the lateral condyle for both training (1.9 ± 0.03 fractures/ millimetre bone surface versus 0.12 ±0.03) and resting horses (1.0 ±0.17 fractures/ millimetre bone surface vs. 0.08 ± 0.03) and there were more microfractures in the parasagittal groove of the training horses than the resting horses.
Implications

In this study it was demonstrated that Thoroughbred racehorses in training have lower remodelling rates in the subchondral bone of the fetlock joint compared to horses resting from training. This results in bone in training horses that is less porous than that of horses rested from training. Remodelling rates are slightly higher later in a training period than at the commencement of a training period but appear to be inadequate to prevent fatigue damage accumulation. This is consistent with the high prevalence of bone injury in the fetlock joint of Thoroughbred racehorses.

Post mortem studies of Thoroughbred racehorses in Hong Kong found 67% and 80% of horses had at least one grossly observable bone injury at the joint surface [5; 6]. A similar prevalence of joint injury is observed in Victorian Thoroughbred racehorses (C Whitton, unpublished data). Although not all affected horses exhibit clinical signs of lameness, injury to the subchondral bone of the fetlock joint does impair subsequent performance [7].

The findings indicate that prolonged training periods are undesirable for Thoroughbred racehorses as fatigue damage accumulates faster than it can be repaired increasing the risk of joint injury and fracture. Therefore these horses should be regularly rested from training to allow bone repair. Although bone repair is likely to continue indefinitely and was observed out to 16 weeks, maximal repair occurs within the first 10 weeks of a rest period. Based on the current data it is difficult to make exact recommendations on ideal training and resting period duration. However in combination with our previous study on condylar fractures [3] in horses over 3 years of age, limiting training periods to 18 weeks in duration and allowing two rest periods of at least 8 weeks per year would be prudent. This is unlikely to be the norm as a large proportion of horses in the current study were in training for longer than 18 weeks.

There was a large variation between horses in the response of subchondral bone to rest which was not explained by the period in training prior to the rest period, horse age and sex, or the type of rest the horse. Factors that may influence remodelling for which we had limited data were exercise the horses received when resting (both free exercise and forced exercise) and medication administered.

It is also important for trainers to understand that rest from training has the potential to result in highly porous bone underlying the joint cartilage. Porous bone is also at risk of injury [8] therefore horses returning to training from a rest period require time at lower exercise levels for these pores to fill with bone.
Recommendations

Further research is required to obtain a more detailed understanding of bone remodelling in horses in race training. In particular the effect of different training regimens on bone remodelling rates. Working with the horse’s intrinsic repair mechanisms is likely to make a substantial impact on joint injury rates which are currently too high.

The development of training strategies that increase bone remodelling rates in horses during training would reduce the impact of fatigue on bone exposed to high loading. It is unknown whether this is possible and the negative architectural effects of increased porosity produced by remodelling may outweigh the benefits. Alternatively increased frequency and duration of rest periods will maximise bone repair and therefore reduce injury.

Trainers should be educated to understand that bone within the lower limb joints has a limited fatigue life and that regular rest periods are required to allow repair.
References


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