Horserace Betting Levy Board
Parnell House
25 Wilton Road
London, SW1V 1LW

Tel: 020 7333 0043
Fax: 020 7333 0041
Web: www.hblb.org.uk
Email: equine.grants@hblb.org.uk

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Equine musculoskeletal sciences

Summary by Rob Pilsworth
HBLB's Veterinary Advisory Committee

Equine musculoskeletal sciences

The horse is a unique natural athlete. Its evolutionary development has led to a finely honed running machine capable of reaching and sustaining 35mph or more over fairly long distances. Although some animals are capable of faster speeds, such as the 'sprinter' predators like the cheetah, they can only sustain these speeds for a few hundred metres.

The horse in contrast is able to maintain a high cruising speed for the best part of a mile. To achieve this, the evolutionary strategy over countless generations of adaption has been to reduce the weight and size of the limb. Thus an original five digits has been reduced to a one digit weight bearing pillar.

Two of the original ‘fingers’ form the splint bone either side of the cannon bone but the rest have been lost altogether during evolution. Meanwhile, the muscle mass on the top of the horse has been increased to provide rapid and sustained propulsion, resulting in a body weight for most racing horses of between 450kg and 550kg. This has two important implications, firstly the half tonne weight of the horse moving at 35 – 40mph produces enormous stresses and strains within the limb and secondly, because of the evolutionary ‘fining down’ of the limb, these huge forces are borne by relatively small cross sectional areas of bone and tendon. During full gallop, the horse often has only one limb in contact with the ground at any one time and this limb will have concentrated the weight and momentum of the horse through no more than two or three square inches of weight-bearing surface area in the distal limb bones.

All of this unfortunately predisposes the horse to musculoskeletal injuries and much of the HBLB funding of research in recent years has been channelled into finding ways to avoid unnecessary injury and to 'flag up' horses at risk of injury before these injuries occur.

Studies in epidemiology

A starting point in investigating the occurrence of any disease or syndrome is for basic numbers on the occurrence and distribution of the disease pathology to be established. This work, know as epidemiology, is vital in pointing out differences between populations in terms of susceptibility to any illness or injury. It is often these differences which illuminate the cause of the injury itself.

One of the largest epidemiological studies funded by the HBLB was carried out by Professor Kenton Morgan and colleagues (PRJ 648 and 693) at the University of Liverpool. This study identified all limb fractures which led to the death of the horse which occurred below the hock or knee on UK racecourses. Using classical epidemiological methods of comparing cases of injury with controls (i.e. horses which had not sustained injury during the same period) the authors were able to identify a set of risk factors both at the level of the horse and at the level of the racecourse which were implicated in the development of these fractures.

Much useful data originated in this study. Flat racing on turf presented the least risk of fracture (0.4 fatal fractures per 1000 starts), whilst the highest level of risk was encountered in National Hunt flat racing (2.2 fatal fractures per 1000 starts).

This was an unexpected finding and the data from this study led to an immediate review of National Hunt flat racing, which resulted in alterations of distance involved. This has already borne fruit in reduced fracture incidence.

Other factors which came out of the study were that horses were at particular risk of fracture on the racecourse if they did not have gallop work included as part of their normal training, or that this was the first year in which they had been asked to race.

Both of these findings hint at the fact that it is important for horses to receive training at the speed at which they are going to be asked to race during their development in order for the bones to strengthen sufficiently to withstand that load.

Once a horse has survived its first year of racing, the risk of it developing a catastrophic injury diminishes significantly. Firm going, large fields, long race distances and short gaps between meetings at the same racecourse were also associated with increased fracture risk.

In addition to the statistical work, the limbs from the horses which had been destroyed were collected and subjected to detailed examination with both radiography (x-ray) and magnetic resonance imaging (MRI).

These techniques showed that much of the change necessary to produce a fracture had been building up over a long period of time prior to the break actually taking place.

Of particular interest were pre-existing areas of damage either side of the fetlock which are the origin points for the most common lower limb injury in the racehorse, the medial and lateral condylar fracture.

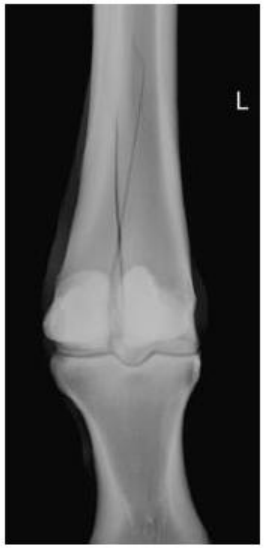


Fig 1. A Medial Condylar Fracture of the metacarpal bone (cannon bone). Note how the fracture line starts in the fetlock joint and courses up the bone

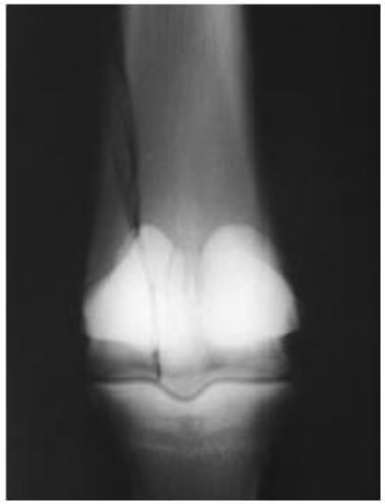


Fig 2. A Lateral Condylar Fracture of the third metacarpal bone (cannon bone). Note how the fracture line starts in the fetlock joint and courses in a diagonal manner to exit the bone on the lateral aspect of the cannon bone

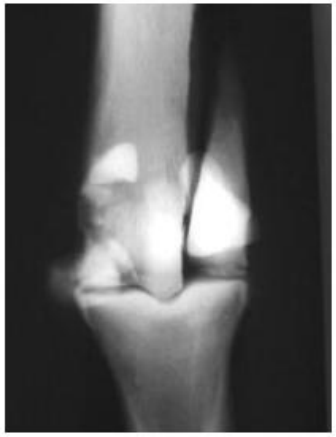


Fig 3. A severe lateral condylar fracture of the third metacarpal bone with a concurrent medial sesamoid bone fracture. The fracture is displaced in this case

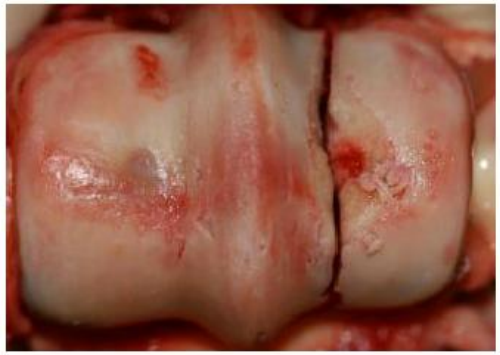


Fig 4. A post mortem picture of the joint surface of the cannon bone within the fetlock joint. There is a lateral condylar fracture which has occurred through the joint surface
(Pic courtesy of Dr C. Riggs)

These changes in the bone were not associated with the age of the horse or the number of times it had run, which makes it likely that certain horses have a predisposition to developing injury in this site which puts them at increased risk of fracture.

This has led on to further studies looking for ways of diagnosing these pre-existing predisposing changes so that at risk horses can be identified before they go on to develop a full limb fracture. The results of one such study can be found at Prj728.

As well as the epidemiological studies on injuries whilst actually racing several other groups have focused on the epidemiology of limb "injury" during training. Obviously horses only race approximately once every two or three weeks whereas they train on a daily basis and the factors involved in injury at home are just as important as those which cause injury on the racecourse.

These studies have been spear-headed by Professor James Wood and Dr Kristien Verheyen, initially when they were at the Animal Health Trust, Newmarket and more recently at the Universities of Cambridge and the Royal Veterinary College respectively.

The largest study was that carried out at the Animal Health Trust which recruited a large number of racehorse trainers involving over 1,000 horses and studied them over a two year period giving a total of nearly 13,000 horse months of training risk to study. Nearly 80% of these fractures occurring during training at home rather than racing.

One has to remember that the word fracture involves not only the classic ‘broken leg’ but also stress fractures of the tibia and pelvis which result in no displacement or discontinuity of the bone and merely present as areas of painful bone, which heals completely with time off.

Just as with the racecourse study it appeared that high-speed galloping exercise had a protective effect and horses were at more risk of fracture if they never exercised at full speed than the reverse.

In another study led by Professor Wood (PRJ 699) the focus moved exclusively to National Hunt horses in training with the emphasis on risk factors in bone, tendon and suspensory ligament injuries. Once again data from over 1,000 horses was collected over two racing seasons. The fracture incidence was very similar to the incidence found in the flat racing yards.

Studies of bone biology

Bone is a dynamic, vital living organ which is constantly adapting and changing in its size, strength, shape and architecture. This is dependent upon the requirements placed upon it by the body.

Professors Alan Boyde and Elwin Firth are pre-eminent workers in this field and were supported by the HBLB (PRJ 705) to carry out ultrastructron analysis by highly developed electron and confocal microscopy techniques looking at the area of bone so commonly injured in the racehorse at the end of the cannon bone.

These scientists compared changes found in this site in seven two year-old thoroughbreds which had trained on the racetrack against seven similarly aged horses which had never been trained but kept at pasture. What they found was that the bone density in the end of the cannon bone in trained horses increased by deposition of new bone on the pre existing internal surfaces.

They also found that defects of the mineralised cartilage (the area which acts as a buffer zone between the bone itself and the shiny joint surface) were often seen even in relatively untrained horses with depressions, grooves and areas of undermined cartilage being common.

Interestingly there was no difference between the trained and untrained horses in the stiffness of the mineralised cartilage or the subchondral bone even though the deeper bone had responded massively to training by deposition of new bone.

Changes were also observed in the parasagittal grooves, the area at which all condylar fractures begin in horses *before* they had entered training. It was not uncommon to find linear or ovoid radiolucencies in the articular cartilage and subchondral bone at exactly the site of condylar fracture formation in horses which had undergone no race training whatsoever.

This work is being further pursued with HBLB support in an on-going more extensive study by the researchers.

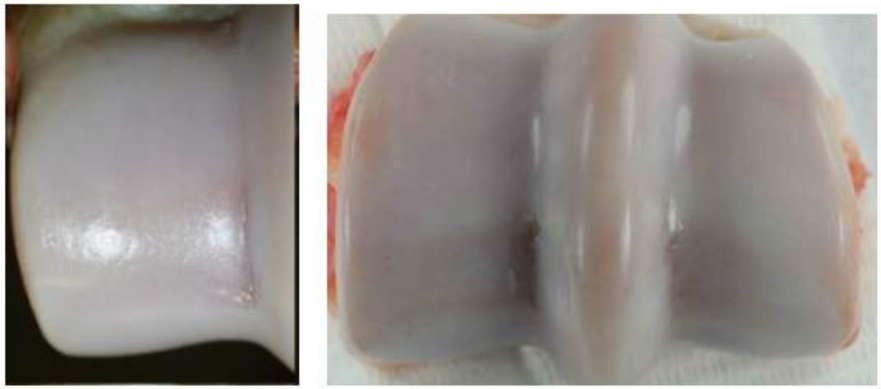
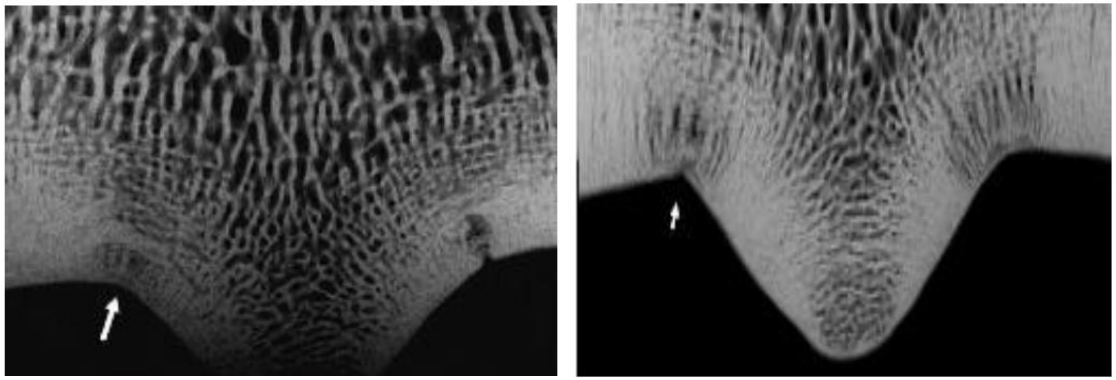


Fig 5. Examples of fissues (⇨) within the parasagittal groove of the third metacarpus/metatarus. Such grooves are frequently observed in horses at port mortem with no history of any joint disease, but may be associated with altered risk of sustaining a condylar fracture of the cannon bone



(From Firth, Doube and Boyde (2009) New Zealand Veterinary Journal, 57, 278-283)

Fig 6. Point-projection digital X-ray images of frontal sections through the condylar surface of the third metacarpus in two 17-month-old Thoroughbred horses prior to commencement of race training. There is obvious fissure formation in the left figure, and obvious radiolucencies in the right hand figure in the parasaggital grooves, which are present prior to race training commencing

Studies on tendon injuries

A strained tendon is probably the worst injury that can befall a racehorse in that the healed tendon is never the same again and will never be able to repair to pre-injury level.

Various surveys of National Hunt horses have shown approximately a third of these horses will sustain tendonitis in any one training season. The superficial digital flexor tendon is only a few centimetres in cross sectional area and yet has to withstand loading of 500kg horse landing after jumping a fence.

The Wood group which studied bone injury in the National Hunt racehorse also studied tendon injury (PRJ 699) and looked at the possibility of using regular ultrasonographic monitoring to identify horses which were heading towards a tendon injury before the injury actually happened.

Unfortunately they found that repeated serial ultrasound examinations were not able to detect any change prior to injury and were therefore useless in terms of flagging up horses at risk. Older horses were at greater risk of tendon injury than young horses.

Tendon biology

It is not fully understood why equine tendons heal so poorly and much work has been aimed at teasing apart the normal cellular processes of tendon biology in both health and disease in order to try to understand what factors limit the tendon's ability to heal.

Much of this work has been supported by the HBLB through the support of Professor Peter Clegg and his team at the University of Liverpool (PRJ 708). This research group examined the differences between an energy storing tendon such as the superficial digital flexor tendon, which is the tendon most commonly injured in the racehorse, to a tendon which takes little loading but is responsible for positioning the limb in normal locomotion, the common digital extensor tendon.

This tendon itself is rarely injured and therefore it was hoped differences between the two tendons could give some insight into the pathobiology of tendon injury. But the tendons show little difference in their content of non collagenous proteins and that the superficial flexor tendon, although containing more cells which could potentially turnover tendon matrix (the glue between the fibres), showed lower turnover of collagen than the non-weight bearing extensor tendon.

This seems paradoxical, in that the superficial digital flexor tendon at the back of the leg, which bears the majority of loading during fast exercise in the horse and is under enormous strain, appears to show lower levels of capability of collagen metabolism than its non-weight bearing 'spindly' counterpart on the front of the leg. It may be that this finding gives some indication as to why the superficial digital flexor tendon is so prone to injury.

Further work is in progress that will hopefully reveal whether this limited ability to produce and turn over collagen in the superficial flexor tendon predisposes it to injury and poor repair.

Another research strand focused on the junctions between the tendon cells themselves. Tendons exist as a large network of many different cells which are known to communicate with each other by certain chemical receptors at sites called the 'gap junctions'. Synthesis of new collagen by the tendon in response to injury is coordinated by intercellular communication between tendon cells at these junctions.

The study showed that the superficial flexor tendon appears to *lose* its ability to produce new collagen and to communicate via the gap junctions as the horse ages whereas, in contrast, the common digital extensor tendon continues throughout life to be able to produce collagen and for cells to communicate normally.

This has important implications for studies involving the early introduction of exercise in the growing horse as a method of protection of the tendon to the effect of excessive strain later in the horse's career.

Some work has already shown that treadmill exercise of foals during development increases the ability of their tendons to withstand load later in life. We have to accept that the stud farm environment and the preparation of yearlings for sale do not mimic free pasture exercise on large open areas of grassland which was the horse's evolutionary proving ground.

A separate research team under Dr Birch and Professor Goodship, first at the Royal Veterinary College in London and latterly at University College London, investigated this effect on the structure of tendons by early exercise with the support of the HBLB (PRJ 668 & 694).

These studies compared the superficial flexor tendon and the common digital extensor tendon in horses which had either undergone vigorous training or normal limited exercise during an 18 month programme.

This study showed that there was no deleterious effect of exercise and in fact when foals were exercised between 2 and 15 months of age the cross section of area of their tendons was increased, hinting that the tendon may be able to withstand the rigours of exercise more effectively later in life.

Tendon repair

Over the years many different treatment modalities have come and gone without any single one proving to be more effective than rest and controlled exercise alone. Recently there has been enormous interest in the possibility of introducing stem cells into the tendon to produce a more biologically successful repair than the immobile, inflexible 'scar' which is the normal end result of a tendon injury.

The HBLB has been active in its support of these investigations. For instance, PRJ 738 looked at whether stem cells actually survived after injection into the tendon and whether they would be distributed and incorporated into the tendon. Cells were appropriately labelled and then injected into injured tendons so that their progress could be tracked.

These studies showed that the mesenchymal stem cells are able to remain alive following injection into the tendon and could in fact integrate into healthy tendon. In another study PRJ721, no significant difference in the final strength of the healed tendon was demonstrable.

Studies on performance and wastage

One of the key elements in allocation of research funding within the equine industry is to make sure that the money is going to where the problems lie. To this end it is often useful to gather data on what problems most affect racehorses during their careers so that research efforts can be targeted effectively.

The HBLB supported a large study carried out by Professor Joanna Price (PRJ661 and 692) into the causes of lost training days in 182 thoroughbred yearlings as they went into flat race training at the end of 2001. The horses' daily exercise records were logged throughout the whole of the training period and any missing days had to be accounted for by specific problems or injuries.

These were categorised as lameness, medical problems, traumatic problems or unknown. The lameness and medical categories were then further subdivided.

Lameness was by far the most important condition causing horses to miss training and other medical conditions accounted for only 5% of untrained days in the two age groups.

It is nearly twenty years since a similar study was carried out and the sad fact is that the number of days lost to training through lameness has hardly altered in the intervening period. This "flags up" the importance of further research on why young racehorses go lame, and what we can do to intervene in a timely way to prevent this.

Studies on muscle

One of the most common conditions suffered by Thoroughbred racehorses is that of recurrent exertional rabdomyolysis (RER).

This disease, also known by the colloquial terms ‘set-fast’, ‘tying up’ and in the old days of working horses, ‘Monday morning disease’, is a complex condition which is not fully understood. Clinical presentation of RER is a horse which has exercised normally and then stiffens up, often to the point of being unable to walk forward, as it returns from exercise. The muscles develop a hard, board-like consistency and the horse shows all the symptoms of extreme anxiety and pain.

The management and feeding of horses affected with RER can significantly reduce the prevalence of the disease and therefore prevent episodes occurring, but only of course if the horse is known to be a likely candidate to be affected in the first place.

Previously, in order to determine whether or not a horse had the potential to suffer from RER, a biopsy of one of the deep muscles at the back of the thigh had to be obtained. This was a relatively invasive procedure requiring a fairly large skin incision and deep dissection into the belly of one of the muscles in order to obtain the sample.

In work supported by the HBLB (PRJ 727) Dr Richard Piercy and his team at the Royal Veterinary College developed a way of encouraging skin cells, which are very easy to collect, and through a minimally invasive procedure, transform themselves into muscles cells. They did this by identifying and cloning a transcription factor which encourages muscles differentiation and then introducing this factor into the skin cells in tissue culture using a virus vector to take it in.

Thus a tiny simple skin sample, obtained under local anaesthetic from the external surface of the horse, becomes muscle tissue from the same horse. This muscle tissue of course carries the same genetic code as the donor horse and so can then be tested by a variety of agents normally used to investigate whether or not the horse may be prone to be affected by RER.

Further work is ongoing to look at the differences between cells from horses known to be affected by RER and other horses known never to have had an episode. These differences will almost certainly increase our therapeutic and prophylactic abilities and measures towards this frustrating and painful disease.

Studies into gait analysis

Modern developments in video technology and computer manipulation of digital video images are allowing great leaps forward in our understanding of the biomechanics of locomotion. This type of work has allowed us to examine in detail single components of the equine limb and to see how they function as part of the athletic machine. One such project (PRJ 678) looked at the enormously important superficial digital flexor tendon which has already formed a major part of the discussions so far. This tendon originates from a muscle in the forearm of the horse called the superficial digital flexor muscle. Normally, in other animals, the *muscle* is the major part of the musculotendonous unit and has only a short tendon of insertion at the end.

However, in the horse, because of the extreme elongation of the limb in evolution as it became a lightweight galloping 'strut', the muscle occupies only approximately a third of the length of the musculotendonous unit, whilst two thirds of the length of the limb (from above the knee to beneath the fetlock joint) is purely composed of tendon. The research workers, headed by Professor Alan Wilson at the Royal Veterinary College were interested in how the musculotendonous unit works during locomotion. We know that the unit has to lengthen to allow the fetlock to sink and to propel the horse forward but does this lengthening and shortening of the unit occur through muscle contraction or through elastic stretching of the tendon itself?

This study, published first in the prestigious journal, *Nature*, showed that the musculotendonous unit acts as an energy storing 'spring' during locomotion and that the sole role of the muscle was to act in the same way as a shock absorber in a car, to dampen the vibrations produced by this stretching and recoil of the elastic spring, the tendon. This study adds even more weight to the argument that tendon repair will never be effective unless we are able to develop methods to produce an elastic structure following injury. This bears out our clinical wisdom the inelastic scar tissue currently produced as a result of tendon injury is not fit for purpose in propelling forward a supreme athlete such as the racehorse.

Summary

In terms of our understanding of the problems facing the racehorse this is to some extent a golden age. The genome of the horse has now been fully logged allowing close exploration of genetic links to certain orthopaedic diseases. Diagnostic imaging has leapt forward from simple x-rays of bone to a range of imaging techniques which allow us to see all of the structures of the limb, including bone and soft tissues in minute detail. High speed cinematography in association with video capture and analysis by computers is allowing us for the first time to look at the biomechanics of galloping exercise and measure differences in forces experienced by horse's limbs on different surfaces and at varying speeds.

As the *only* supplier of funding for UK research directed specifically at the thoroughbred racehorse, HBLB funding has been at the core of research aiming to help the racehorse cope with the effects of training and racing whilst minimising risk of injury. The studies described here have all in different ways contributed to this effort, and continued research funding is vital to support this effort.

To find out more about HBLB's research go to:

- HBLB's Advances in equine veterinary science and practice

http://onlinelibrary.wiley.com/journal/10.1001/%28ISSN%292042-3306/homepage/hblb_virtual_issue.htm