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Stress fractures in the racehorse

Comparing injury, rehabilitation and management with British military personnel

'Tis the season to be extra vigilant for the signs of stress fracture in our racehorses. In spring, when training ramps up and the flat season begins, the incidence of stress fractures increases, largely due to lack of skeletal adaptation.

Given that stress fractures were first described in the scientific literature in 1855 by Breithaupt, a Prussian military physician, who identified the "march fracture" in the metatarsal bones of feet in soldiers, it is perhaps appropriate to take a timely look at the military for what we can learn about these bony injuries and their management.

Stress fractures represent end-stage cumulative damage and comprise the vast majority of fractures sustained by racehorses, human athletes and military recruits. They typically involve predilection sites, incomplete cracks, pre-existing pathology, and highly consistent shape and form.


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Racehorses and soldiers are similarly at risk from stress fractures induced by training

BACKGROUND TO STRESS FRACTURE

Categorisation of fractures

Fractures can be broadly categorised according to their origin and development into monotonic, insufficiency, or fatigue fracture, with the latter two collectively referred to as stress fractures. Insufficiency fracture, which involves abnormal bone such as that found in cancer or osteoporosis, is rare in horses. Fatigue fracture occurs as a result of an abnormal amount of stress applied to normal bone and is therefore the more correct term to use when talking about racehorses, although stress fracture is the more widely used term in the industry.

Bone strain continuum

Stress fracture lies at the far end of a continuum of bone response to stress. It starts with bone strain which is subclinical yet detectable on bone scan, and passes through stress reaction which is focally tender and more obvious on bone scan, then progresses to stress fracture once a line is distinguishable on diagnostic imaging. Of course fractures can result from a one-off accident involving momentary overload from extraordinarily high forces such as a kick, collision or fall, but such "monotonic" fractures are less common.

Bone physiology and pathology

Bone's structural and material properties change in response to exercise through modelling and remodelling processes as the physical forces encountered alter its architecture to accommodate the loads experienced. Modelling means adding new bone, whereas remodelling refers to resorption and replacement of existing bone. The triggers that influence bone (re)modelling come from ground reaction forces and muscular forces involved in creating and attenuating load. While muscle contraction contributes to bone stress by altering the mechanical environment, it is still considered more protective than causative due to its energy absorption and the facilitation of controlled loading.

When functional requirements direct bone to model and remodel to alter its shape and internal architecture, resorption and replacement of damaged bone are involved, during which continued repetitive loading can subject bone to stress reactions as the repair process struggles to keep pace with micro-damage. There is a vulnerable window in the remodelling process which can lead to weakening of bone, hence the paradox that biological repair of bone is actually contributory to stress fracture development.

However, there are some protective effects of remodelling on fatigue life of bone, which is a term used to describe the number of load cycles to failure. Research using human bone has suggested that isolated microcracks are not necessarily precursors to fatigue failure, but may be agents of stress redistribution and fatigue life improvement. The fatigue life of the equine cannon bone may be extended by remodelling through the creation of barriers to microdamage propagation. Osteons, which are the basic unit of structure of compact bone, are created in the remodelling process that promote toughness and inhibit crack propagation because recently formed osteons appear to be relatively deformable, creating a compliance effect.

SIGNS OF STRESS FRACTURE

Stress fractures can be challenging to diagnose in the racehorse, especially those affecting the proximal limb where it is difficult to localise the site of pain through palpation and regional anaesthesia. Some horses with hindlimb fractures exhibit periods of recurrent low-grade lameness before diagnosis and in cases involving the wing of the ilium (pelvis), overt lameness can resolve after just a few days of rest. Signs and symptoms associated with stress fracture in humans are insidious onset localised bony pain that worsens with activity, resting pain (an inconsistent finding), localised swelling, pain on direct palpation, and distal impact pain.

Fig 1a **Radiograph of a fractured tibia in a racehorse**

Fig 1b **Fractured tibia boiled out**

Fig 1c **Close up of boiled out fractured tibia**

An x-ray of a catastrophic tibial fracture in a racehorse (a), which would necessitate euthanasia. This type of fracture is often the end stage of a long process of intense bone remodelling as a result of changes in loading, which leave tell-tale signs of changes such as disorganised new bone growth on the surface of the bone (Figures 1b and c). The ideal is to detect these changes early, certainly in time to prevent the development of a complete displaced fracture

COMPARATIVE PREDILECTION SITES

In the racehorse stress fractures occur in consistent locations that for anatomical and biomechanical reasons seem susceptible to accumulated wear and tear. They include the third metacarpal and metatarsal (cannon) bones, the ilium, tibia (see Figures 1a-c), proximal phalanx (pastern) and the back. According to Defence Primary Health Care (DPHC) British soldiers have four common stress fracture sites: shaft of tibia, metatarsals (foot bones), neck of femur (thigh bone), and shaft of femur. The variations in predilection sites between species and within military personnel clearly reflect the contrasting locomotory forces between bipeds and quadrupeds and the demands of different occupations.

INCIDENCE

DPHC regard the overall reported incidence of bony injuries across the Tri-Services as low. At the Infantry Training Centre in Catterick the Combat Infantryman's Course (CIC), widely considered the most physically demanding of all British Army initial military training courses, recruits undergo a structured and graduated physical fitness programme and typically expend in excess of 5000 kcal of energy per day. Data from the CIC involving 170 stress fractures in 2012/13 showed that a recruit had a 4.5% chance of sustaining a stress fracture during the 26-week long course, with the tibia being the most common site. However, the chance of stress fracture was influenced by the division joined. For example, the Pegasus Company (P Coy) course for the Parachute Regiment is more physically demanding and recruits had a 13.6% stress fracture incidence rate in the same period. Another recent study of Royal Marine (RM) recruits that formed part of the Surgeon General's Bone Health Project reported the prevalence of stress fracture as typically between 4-7%. The 32-week RM training is renowned as being one of the longest and most arduous initial military training programmes in the world, hence in contrast to other military programmes, the most common site of stress fracture is the metatarsal, not the tibia.

In comparison, studies have shown that racehorses in training have just over a 1% chance of sustaining a stress fracture in a 30-day period; so in a yard of 100 horses, that's just over 1 per month. Extrapolating this statistic into something comparable with the 4.5% incidence rate found on the 26-week CIC, that's around 6 stress fractures in a yard of 100 horses in 6 months (26 weeks), or 6%. While the various stress fracture statistics of military recruits and racehorses cannot be directly compared because of the non-uniform exposure times and the difference between incidence and prevalence, they do appear to be roughly in the same ball park.

RISK FACTORS IN RACEHORSES

Exercise

Fatigue damage in bone occurs over a period of days or weeks and is often precipitated by a recent change in activity, in particular an increase in training. Recent epidemiological studies in racehorses have identified a number of exercise-related risk factors for stress fractures that include failure to integrate gallop speeds into training regimens, cumulative distance trained, racing and training surfaces, and return to training after significant periods of rest.

Not all training regimens stimulate the development of an adequately robust skeleton that can endure the forces thrust upon it during competitive performance where it is truly pushed to its limits; and this may explain the higher fracture rates seen in racing compared to training. Training at slower speeds for prolonged intervals is likely to induce a modelling response that does not prepare bone to withstand loads experienced under racing conditions. An appropriate modelling response with minimal risk of stress fracture can be stimulated by reducing the proportion of low-speed work and boosting the frequency of short interval high-speed work as indicated by a number of studies in racehorses.

One large-scale epidemiological study published in the last decade and involving around 1,200 flat racehorses in the UK, revealed that accumulation of canter exercise in previously untrained bone increased risk of fracture, whereas accumulation of high-speed gallop exercise had a protective effect. However, the researchers advised caution when increasing distances at gallop and canter in too-short time periods (greater than 6km at gallop and 44km at canter in a 30-day period), because the same study highlighted an association between this and increased fracture risk.

Lay-offs

Prolonged lay-offs and periods of rest from racing of more than a month have been associated with an increased risk of fracture in a number of studies. Some degree of disuse osteoporosis may develop in these horses whereby insufficient bone mass for their athletic occupation means an increased susceptibility to microdamage accumulation, stress fracture and the possibility of a complete fracture.

Track surfaces

Track surfaces for training and racing have been reported to affect distal limb fracture incidence. The use of sand gallops in training was shown to increase the risk of fatal distal limb fracture on UK racecourses. In a number of North American epidemiological studies, dirt racing has been implicated in higher injury rates (including fractures) than turf racing.

Age and sex

Epidemiological studies of racehorses in the UK indicate that training and racing as two-year-olds may confer a long-term reduction in the risk of fracture compared to horses that start at age three or four. Overall, fillies appear at higher risk of fracture than male racehorses, in particular those affecting the pelvis.

RISK FACTORS IN MILITARY PERSONNEL

Risk factors for stress fracture are divided into extrinsic and intrinsic factors by DPHC. Some examples of extrinsic factors include harder training surfaces and the training regimen. The latter encompasses mileage; number of training cycles; inadequate rest periods and training with fatigued muscles; running pace; and hill running (particularly downhill). Intrinsic factors include sex (females are significantly more susceptible to bony injury), age (risk increases after 20 years of age), and smoking. Anatomy is an important intrinsic factor; for example, external rotation of the lower limb (toes turned outward), femoral anteversion (toes turned inward), leg length discrepancy, genu varum (bow legged) and genu valgrum (knock knee), narrow tibia, and reduced muscle bulk (small calf girth).

MANAGEMENT OF STRESS FRACTURES IN MILITARY PERSONNEL

DPHC guidelines for initial management recommend MRI when a stress fracture is highly suspected as the Army has found a high rate of false negative x-ray results even up to three months from the time of initial presentation. Other important factors are the removal from training and protection from activities that could progress the injury, addressing other predisposing risk factors (e.g. diet, smoking, overweight), pain management by the avoidance of the aggravating activity (may include wearing of military footwear), and simple analgesia. Non-steroidal anti-inflammatory drugs are contra-indicated as they have an inhibitory effect on fracture healing and have been shown to increase time taken to return to training.

For the purposes of rehabilitation, stress fractures are stratified according to high or low risk of non-union. Fractures with high risk of non-union occur in zones of tension or have a poor blood supply and are managed in alignment with the directions of the orthopaedic team.

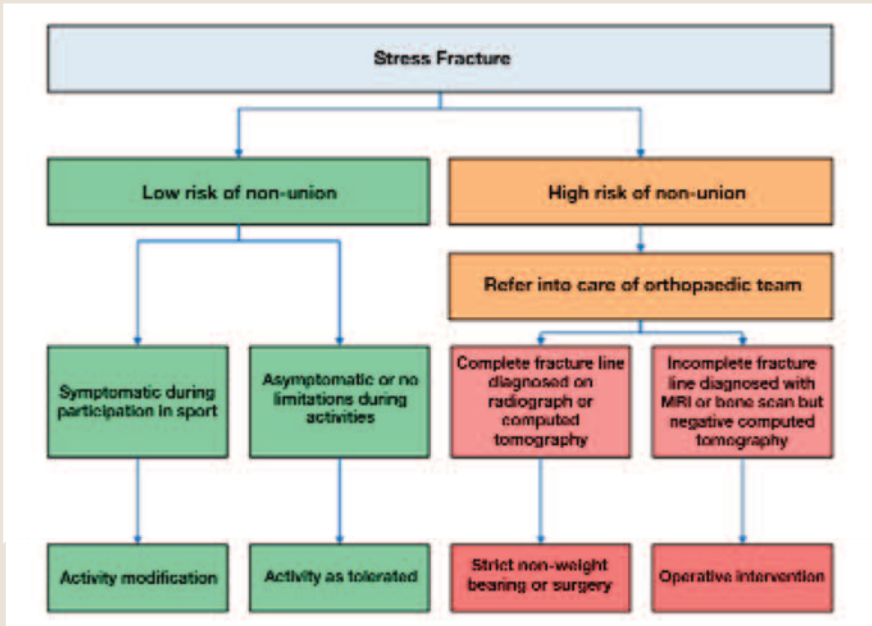

Fig 2 Management algorithm for stress fractures

COURTESY OF DEFENCE PRIMARY HEALTH CARE

EARLY MOBILISATION AND GRADUATED EXERCISE PROGRAMMES

For fractures with low risk of non-union, the general principle employed is to slowly increase impact loading once ambulation and day-to-day activity are pain-free. The rate of resumption of activity is very much dependent on the individual and is modified to suit the symptoms. Reassessment of the injury is ideally made at three-weekly intervals with a return to the start of the interval period if pain is still present at the time of reassessment. So the progression of the rehabilitation programme is only graduated in the absence of pain. Rehabilitation programmes are jointly coordinated by the physiotherapist and the medical officer and closely follow the Best Practice Guidance document provided by the Directorate of Defence Rehabilitation based at Headley Court.

The approach of early mobilisation via controlled exercise used by the Army as an integral part of stress fracture management (see Figure 2) is modelled on the rehabilitation of human athletes and has also been adopted by equine vets over the past decade or so. Termed “relative rest” it typically involves removal of the aggravating activity and activity modification such as a reduction in training volume followed by a graduated return to normal training.

SUMMARY

In conclusion, stress fractures are mainly the result of high mileage and repetitive load experienced in training, therefore racehorses and military personnel are two populations particularly at risk. The high forces thrust upon the equine skeleton under racing conditions must be taken into account in designing training regimens since the loads experienced increase linearly with speed. Long, slow miles in training need to be complemented with short interval high-speed work that will induce a modelling response in bone appropriate to withstand the forces generated at racing speeds. For horses with a stress fracture rest is not always best. Early, controlled mobilisation as advised by your vet may be the best medicine. This of course depends on accurate diagnosis, safety of the fracture and stage of healing. Some stress fractures, particularly in the distal limb, require surgical fixation and thereafter careful, graduated loading according to the surgeon's protocols.

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