Exercise and limb pathology in young racehorses

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Intention of the study

To determine changes occurring during early life in the tissues of bones and joints of racehorses, to investigate if alterations in the tissues predisposing to injury might already be present before training, and to quantify how much tissues change with training and withdrawal from training.

Changing structure in the condylar fracture site. After showing changes in the exact site of condylar fracture initiation in horses before training, imaging of tissues from foals, weanlings, yearlings, two year olds after early training, and three year olds after racing showed that the very first evidence of abnormality in the cartilage and in the bone occurs before 5 months of age. Further CT examination of whole bones is being undertaken presently.

Microcomposition of bone and cartilage tissues. Vibrational spectroscopy on samples of bone has probed the relationship between the chemical microstructure and morphological properties of bone. This is to test how the mineral or collagen chemical composition of bone changes during growth, and if the condylar fracture site (see above) is different from that in other tissues. Principal component analysis has shown clear differences between horses and between ages, in spectroscopic parameters in the sagittal groove; complex mathematical analyses are being undertaken presently.

Strengthening bones of young horses before training begins. In horses that had received conditioning exercise from early in life, the bone shaft of the distal limb bones was bigger and stronger, and the increased bone strength was retained through the 2 and 3-year-old racing years, compared with horses in which extra exercise has not been imposed from an early age. The use of early exercise may reduce the onset of sore shins, and possibly other orthopaedic problems, in horses in training. The effect appears not to be confined only to the lower limb bones, since in a separate study, clear changes were also evident in the radius and tibia.

Enlarging the size of the joint in the young horse. Increasing joint size by imposition of exercise to make the organ stronger is said to be impossible (in contrast to the bone shaft), and has been shown in only one study (in people). Our data on joint enlargement showed that in 3-year-old racing Thoroughbreds (if they had had conditioning exercise as a foal from a very young age) the metacarpo-phalangeal joint was larger, and the bone density lower, than in horses that had not been exercised from an early age. These findings may have implications in the onset of impact-related disease, and if proven, may represent a further benefit of exercise from early in life.

Quantifying the response of the metaphysis. Most fractures involve the metaphysic, because the cortical shell there is thin, and bone turnover is higher than in the shaft. Perhaps the complex structure and dynamic 1ehavior of the metaphysis could be induced to change (positively), reducing likelihood of fracture. A method to quantify the structure and changes in the bone fractions of the metaphysic has been developed. This "metaphyseal index" allows the amounts of the two types of bone to be determined, and shows quite wide variation between foals at 5 months of age and in 2-year-old horses.

References

Firth EC, Doube M, Boyde A. (2009). Changes in mineralised tissue at the site of origin of condylar fracture are present before athletic training Thoroughbred horses. New Zealand Veterinary Journal 55, 278-283.

Kawcak CE, McIlwraith CW, Firth EC. (2010). Effects of early exercise on metacarpo-phalangeal joints in horses. American Journal of Veterinary Research 71, 405-410.

Nicholson CL, Firth EC. (2010) Assessment of bone response to conditioning exercise in the radius and tibia of young Thoroughbred horses using pQCT. Journal of Musculoskeletal and Neuronal Interactions 10(3), 199-206.

van Weeren PR, Firth EC, Brama PAJ. (2010).To move or to perish: the importance of exercise during musculoskeletal development in the horse: Pferdeheilkunde 26(4), 581-587.

Doube M, Firth EC, Boyde A, Bushby AJ. (2010). Combined nanoindentation testing and scanning electron microscopy of bone and articular calcified cartilage in an equine fracture predilection site. European Cells and Materials 19, 242-251.

Firth EC, Rogers CW, van Weeren PR, Barneveld A, Kawcak CE, McIlwraith CW, Goodship AE, Smith RKW. (2011). Responses in proximal phalangeal, third metacarpal and third carpal bone of thoroughbred foals exposed to exercise early in life. The Veterinary Journal accepted

Firth EC, Rogers CW, van Weeren PR, Barneveld A, McIlwraith CW, Kawcak CE, Goodship AE, Smith RKW. (2011) The effect of previous conditioning exercise on diaphyseal and metaphyseal bone responses to imposition and withdrawal of training in young Thoroughbred horses. The Veterinary Journal accepted

Rosa B, Firth EC, Blair HT, Vickers M, Morel P, Cockrem J. (2010) Short-term voluntary exercise in the rat causes bone modeling without initiating a physiologic stress response. American Journal of Physiology - Endocrinology and Metabolism in press 2010.

Kim ME, Kawcak CE, McIlwraith CW, Firth EC, McArdle BH, Broom ND (2009). Influence of early conditioning exercise on the development of gross cartilage defects and cartilage matrix swelling behaviour in the equine midcarpal joint. American Journal of Veterinary Research 70:589-598.

Firth EC. Fetal ossification and normal joint development. In: Equine Reproduction, Chapter 47, 2nd edition, Editors McKinnon. AO, Squires EL, Vaala WE and Varner DD (in press 2010). Textbook chapter.

Using exercise to improve bone growth and development in the young horse. Industry Story, submitted to NZRB September 2010.

Firth EC, Rogers CW, van Weeren PR, Barneveld A, McIlwraith CW, Kawcak CE, Goodship AE, , Smith RKW (2010). The effects of early exercise from a young age in Thoroughbred Horses. Invited address, 18th International Conference of racing Analysts and Veterinarians, Queenstown, March 8-12.

Research Outputs
(Abstracts, Presentations, Papers, Industry Stories)

Rosa B, Firth EC, Blair HT, Vickers M, Morel P. (2011). Moderate voluntary exercise in pregnant rats positively influences fetal growth without initiating a maternal physiological stress response. American Journal of Physiology Am J Physiol Regulatory Integrative and Comparative Physiology 300:R1134-R1141.

Firth EC, Rogers CW, van Weeren PR, Barneveld A, McIlwraith CW, Kawcak CE, Goodship AE, Smith RKW. (2010). The effect of previous conditioning exercise on diaphyseal and metaphyseal bone responses to imposition and withdrawal of training in young Thoroughbred horses. The Veterinary Journal, in press

Kim ME, Kawcak CE, McIlwraith CW, Firth EC, Broom ND (2010). Early exercise and lesion development in the equine midcarpal joint: a detailed structural and histomorphometric study. American Journal of Veterinary Research, in press.

Firth EC, Rogers CW, van Weeren PR, Barneveld A, Kawcak CE, McIlwraith CW, Goodship AE, Smith RKW. (2010). Responses in proximal phalangeal, third metacarpal and third carpal bone of thoroughbred foals exposed to exercise early in life. The Veterinary Journal, in press.
http://dx.doi.org/10.1016/j.tvjl.2010.11.016

Rosa B, Firth EC, Blair HT, Vickers M, Morel P, Cockrem J. (2010). Short-term voluntary exercise in the rat causes bone modeling without initiating a physiologic stress response. American Journal of Physiology - Endocrinology and Metabolism 299: R1037-R1043.

Kawcak CE, McIlwraith CW, Firth EC. (2010). Effects of early exercise on metacarpo-phalangeal joints in horses. American Journal of Veterinary Research 71: 405-410.

Doube M. Firth EC, Bushby AJ, Boyde A. (2010). Combined nanoindentation testing and qBSE SEM imaging of equine bone and articular calcified cartilage in a fracture predilection site. European Cells and Materials 19: 242-251.

van Weeren PR, Firth EC, Brama PAJ. (2010). To move or to perish: the importance of exercise during musculoskeletal development in the horse: Pferdeheilkunde 26(4):581-587.

Nicholson CL, Firth EC. (2010). Assessment of bone response to conditioning exercise in the radius and tibia of young Thoroughbred horses using pQCT. Journal of Musculoskeletal and Neuronal Interactions 10: 199-206.

Brama PAJ, Hyttinen MM, Holopainen J, van Weeren PR , Firth EC, Helminen HJ. (2009). The effect of loading on the organisation of the collagen fibril network in juvenile equine articular cartilage. Journal of Orthopedic Research 27: 1226-34.

Brama PAJ, Holopainen J, van Weeren PR, Firth EC, Helminen HJ, Hyttinen MM. (2009). Influence of exercise and joint topography on depth-related spatial distribution of proteoglycan and collagen content in immature equine articular cartilage. Equine Veterinary Journal 41:557-563.

Kim ME, Kawcak CE, Firth EC, Broom ND. (2009). Influence of early conditioning exercise on the development of gross cartilage defects and cartilage matrix swelling behaviour in the equine mid-carpal joint. American Journal of Veterinary Research 70:589-598.

Boyde A, Firth EC. (2008) High Resolution Microscopic Survey of Third Metacarpal Articular Calcified Cartilage and Subchondral Bone in the Juvenile Horse: Possible Implications in Chondro-Osseous Disease. Microscopy Research and Technique, 71(6), 477-488.

Brama PAJ, Firth EC, van Weeren PR, Tuukkanen J, Holopainen J Helminen HJ, Hyttinen MM. (2009). The influence of intensity and changes of physical activity on bone mineral density of immature equine subchondral bone. Equine Veterinary Journal 41:564-571

Firth EC, Doube M, Boyde A. (2009). Changes in mineralised tissue at the site of origin of condylar fracture are present before athletic training Thoroughbred horses. New Zealand Veterinary Journal 55, 278-283.

Hyttinen MM, Holopainen J, van Weeren PR, Firth EC, Helminen HJ, Brama PAJ. (2009). Changes in collagen fibril network organization and proteoglycan distribution in equine articular cartilage during maturation and growth. Journal of Anatomy, 215, 584-591.

Rogers CW, Firth EC, McIlwraith CW, Barneveld A, Goodship AE, Kawcak CE, Smith RKW, van Weeren PR (2008). Evaluation of a new strategy to modulate skeletal development in the equine athlete by imposing track-based exercise during growth: the effects on 2-year-old and 3-year-old racing careers Equine Veterinary Journal 40: 119-127.

Rogers CW, Firth EC, McIlwraith CW, Barneveld A, Goodship AE, Kawcak CE, Smith RKW, and van Weeren PR. (2008) Evaluation of a new strategy to modulate skeletal development in the equine athlete by imposing track-based exercise during growth Equine Veterinary Journal 40: 111-118.

van Weeren PR, Firth EC, Brommer H, Rogers CW, DeGroot J, Brama PAJ. (2008) Early exercise advances the maturation of articular cartilage extracellular matrix in the horse. Equine Veterinary Journal 40: 128-135.

van Weeren PR, Firth EC (2008). Future tools for early diagnosis and monitoring of musculoskeletal injury: biomarkers and computer tomography. Veterinary Clinics of North America 24(1): 153-175.

Ferguson VL, Bushby AJ, Firth EC, Howell, P, Boyde A. (2008). Exercise does not affect stiffness of third metacarpal condylar subarticular calcified tissues in 2 year old Thoroughbred racehorses European Cells and Materials 16:40-47.

Doube M. Firth EC, Boyde A (2007). Variations in articular calcified cartilage by site and exercise in the equine distal metacarpal condyle. Osteoarthritis and Cartilage 15(11) 1283-1292.

Doube M. Firth EC, Boyde A (2006) Site- and exercise-related variations in equine articular calcified cartilage thickness, mineralization density and linear accretion. Journal of Anatomy, 20