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To move or too late. How Exercise Influences the Injury Resistance of the Equine Musculoskeletal System? (28-Jun-2004)

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Born to Move

The horse evolved over a period of more than 50 million years from a five-toed forest dweller to a single-toed inhabitant of open plains that relied on its ability to flee at high speed for its survival. This was possible because during this long period the horse's musculoskeletal system was gradually modified, increasing strongly locomotor performance. It was this phenomenal locomotor system that made man domesticate this species about 5,000 years ago (Dunlop and Williams 1996) and that enabled the horse to play such an important role in the history of mankind in the fields of warfare, agriculture and transport. Although the horse lost all these traditional roles in these areas in recent history, the species did not become marginalised. Far from that, the species is, at least in the Western world, more popular than ever because of its role as a sports and leisure animal. In fact, it is again its ability to move that saves the species from extinction, be it in another sense nowadays than in earlier times.

When Movement Falters

Given the importance of the locomotor system for equine performance, it may be not surprising that ailments of the musculoskeletal system account for the major part of wastage in most equestrian activities (Rossdale et al. 1985, Williams et al. 2001). Of these ailments, osteoarthritis (OA) is by far the most important single disease in mature animals (Todhunter 1992). Osteoarthritis is a major problem in human health care as well, which is mainly caused by the incapacity of heavily damaged mature articular cartilage to regenerate satisfactorily. This inherent problem of articular cartilage has been recognised since long, already in 1743 the English physician William hunter wrote: "*If we consult the standard chirurgical writers from Hippocrates down to the present age, we shall find, that an ulcerated cartilage is universally allowed to be a very troublesome disease; that it admits of a cure with more difficulty than a carious bone; and that, when destroyed, it is never recovered*" (Hunter 1743). We have not been able yet to solve this problem in the more than 250 years that have passed since these words were written, but modern research has taught us that the reason of this insufficient repair lies in the extremely long turnover times of the collagen network in articular cartilage. Turnover times for mature cartilage have been estimated between 120 (dog) and 350 (man) years (Maroudas 1980, Maroudas et al. 1992), indicating the extremely low metabolic rate (and hence repair capacity) of the adult individual. In the young animal these figures are of course much different, as in these there is active growth and continuously ongoing remodelling.

So far, no satisfactory remedy for OA has been found. This means for mankind that many people with end stage OA end up having artificial joints implanted. For the equine species it frequently means an untimely end to an athletic career, or even to life if no other use of the animal can be made. Although there are a number of promising new techniques, including gene therapy, resurfacing of cartilage using several bioengineering techniques, and the use of stem cells, none of these has yet given the final answer to the problem in human medicine. For the horse these new modalities are further away still and they may remain cost-prohibitive for a long time. Therefore, the only real option seems to be prevention.

Research in Motion

In the last decade much research has been performed on the fundamental aspects of equine joint physiology and pathology. Brama et al. (2000a) described a distinct topographical heterogeneity in a large a number of biochemical parameters that appeared to match with biomechanical loading as experienced by the joint during athletic performance (Brama et al. 2001). Data from sheep, in which a comparable topographical heterogeneity was found in proteoglycan content of articular cartilage from mature animals but not in newborn lambs (Little and Ghosh 1997), led to research into the biochemical composition of joints from neonatal and juvenile horses. From this research emerged the concept that the foal was born with a biochemically "blank" joint. This means that the biochemical composition of the extracellular matrix at birth is similar at all sites of the joint, and that this matrix adapts during the juvenile period to the site-specific biomechanical challenges imposed by locomotion and athletic performance, by developing the topographical heterogeneity that is typical for the mature individual (Brama et al. 2002). It lay at hand to suppose that the stimulus for this development was biomechanical loading, which in the horse is equivalent to exercise.

Evidence for this hypothesis came from three longitudinal studies that all had exercise as a variable and that all were performed in rather large groups of horses. In the first study, indicated with the acronym EXOC, 43 Warmblood foals were divided into 3 exercise groups at age one week. One group (n=14) was kept (with the mare) in a 3x3 m box stall for the first 5 months of life, the second group (n=14) was kept in the same type of box stalls, but was also subjected to an exercise regimen of a number of gallop sprints during approximately one half hour per day, the third group (n=15) was kept at pasture for 24 hours per day. After 5 months 24 animals (8 from each group) were sacrificed for post mortem analyses, the remaining 19 were housed together and kept in a loose house with access to a paddock until the age of 11 months. Then they were sacrificed too in order to see if any effects that had been induced by the different exercise regimens were reversible or not after a period of (moderate) exercise. The second study (the so-called GEXA-trial) was a variant on the first one in the sense that here two groups of 16 Thoroughbred foals were raised under different exercise conditions from one week of age until 18 months. One group stayed at pasture 24 hours per day, the other group was also at pasture, but was subjected to an additional exercise regimen that consisted of daily cantering several times round a 500 m track. At age 18 months, 6 of each group were sacrificed for post mortem analyses and the remaining 20 were trained and raced under conditions as close to real-life conditions as possible, until the age of 3 years. The last of these trials, the JUMPEX-trial, was a little different in set-up in that it focused on jumping technique and performance. Here, 40 warmblood foals were divided into two groups at age 6 months. One of these groups was raised conventionally (i.e. pasture or loose house, according to the season, until age 3 years, then breaking and full start of specific jumping training at age 4 years), the other half received specific (free) jumping training from the age of 6 months until the age of 3 years from which moment on they were treated in a similar fashion as the other horses. These horses were followed until they were 5 years old.

A Great Move Forward

From the studies mentioned above, and from other, related, studies in other species, it became clear that the general hypothesis of biochemical shaping of the joint through biomechanical loading could be confirmed. In fact, it appeared that for the extracellular matrix of articular cartilage a kind of Wolff’s law appeared to apply according to which composition (and to a certain extent structure) followed loading. There was, however, an extremely important difference with this law. Whereas bone retains its remodelling capacity throughout life, in articular cartilage the collagen network, once formed, cannot change anymore because of the extremely low metabolism and resulting high turnover times alluded to earlier. This means that the shaping of the collagen network during the so-called process of "functional adaptation" (Brama et al. 2000b) is a once in a lifetime process. It was indeed proven in the EXOC-trial that certain post-translational modifications of collagen, and also overall collagen content, not only did not develop the normal topographical heterogeneity in the continuously box-rested foals, but failed to do so as well after the animals were released from their confinement (van Weeren et al. 2000). Failure to develop topographical heterogeneity means failure to adapt to the specific biomechanical challenges. This cannot be interpreted but as a decrease in tissue quality and hence an increase in the proneness to injury. These findings stress the tremendous importance of exercise in the early phase of life for a proper development of the musculoskeletal tissues. Also in human medicine the importance of the juvenile period for the development and conditioning of the locomotor system has been signalled, based on different experiments using different techniques and different animals but leading to the same conclusion. Exercise in children is becoming a topic of large interest in the prevention of osteoarthritis (Helminen et al. 2000).

The next Moves

With the process of functional adaptation now firmly established as a crucial biological phenomenon during the development of the horse (and other species including man), new questions arise. Will any type of exercise have the same beneficial effect and can we give too much? Can we influence this process in a positive sense, i.e. can we condition the extracellular matrix of cartilage in such a way through specific exercise regimens that tissue quality improves and hence injury resistance increases? Can we indeed prove that the functional adaptation in a biochemical sense is accompanied by concomitant changes in biomechanical parameters, as one should expect? Does training at foal age produce more than better-prepared musculoskeletal tissues; does it also have effect on specific skills that relate to later athletic performance?

From the EXOC study it became clear that the combination of box-rest with high intensity exercise had a clear detrimental effect. This effect could not only be demonstrated in cartilage, but in tendons and even in bone as well (Barneveld and van Weeren 1999). It was concluded from that study that exercise was beneficial and necessary for a correct development of the locomotor system, but that it should be dosed carefully in very young animals. Preliminary data from the GEXA-trial indicate that even a relatively light amount of exercise on top of free pasture exercise has effects on the biochemical composition of the extracellular matrix. Collagen cross-link levels were higher, especially in the top layer of the cartilage, in animals that received additional exercise (van Weeren et al. 2004). In a biomechanical study based on material from several of the studies mentioned above Brommer et al. (2004) showed that indeed a process of "biomechanical functional adaptation" could be demonstrated. The JUMPEX-study showed that specific training for jumping at young age had no permanent effects (Santamaría et al. 2004), but also that very carefully increasing the exercise level leads to an exceptionally low injury rate, even in an intensive training programme.

Perennially on the Move

Movement is not only the main product of the live horse; it is also a prerequisite for the horse's life. In the early phase of life movement, i.e. exercise, proves to be much more important than once thought for the generation of a strong and healthy musculoskeletal system. The new data also put some orthopaedic developmental disorders into another perspective (van Weeren and Brama 2003). So far the principles are clear, but much knowledge is lacking about the most appropriate types and amounts of exercise. Here, there is an important task for everybody interested in equine research. Even if no detailed exercise programmes can yet be given there is no doubt, however, that exercise at young age is crucial in the equine species. If movement is too little, it may soon be too late. This need for early exercise may be in conflict with some (commercially driven) developments and concepts in horse husbandry in the Western world. It should, however, be made clear that 50 million years of evolution cannot be negated by whatever man-made consideration. Knowledge of the specific biology and physiology of the horse and the respectful treatment of the species based on this knowledge will not only be beneficial to the horse, but in the end serve the long-term interest of the breeder or owner as well.

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