Horse Species Symposium: Exercise physiology of the horse

426 The effect of oxidative stress during exercise in the horse.
Carey A. Williams*, *Rutgers, The State University of New Jersey, New Brunswick, NJ.*

Oxidative stress is an imbalance of the oxidant to antioxidant ratio in the body. In the following presentation, I will highlight studies from my laboratory along with other pertinent studies of oxidative stress in exercising horses. An increase in oxidative stress and changes in anti-oxidant status has been shown during endurance, intense exercise, and eventing competition in horses. Antioxidants are vitamins, minerals, and protein that must be synthesized in the body or obtained from the diet. Therefore, exercise level and diet are both factors that play a role in influencing the oxidative stress and antioxidant status of the equine athlete. Along with exercise intensity, duration and diet, age and conditioning program also have affected oxidative stress in the horse. The "free radical theory of aging" states that long-term effects of the degenerative changes associated with aging may create oxidative stress. However, in old horses (22 ± 2 yr), the amount of lipid peroxidation and blood antioxidant concentrations were similar to those found in mature but younger (12 ± 2 yr) horses. Same as older horses that may require dietary intervention to help combat oxidative stress so might young growing exercising horses. Studies have shown that yearlings (18 ± 2.4 mo) did not begin their exercise training with higher levels of oxidative stress in muscle or blood than mature mares (13 ± 2.1 yr). Prior to exercise conditioning, yearlings had lower lipid peroxidation and higher antioxidants than mature mares. Conditioning reduced oxidative stress and improved antioxidant status in mares, while few effects were seen in yearlings. This suggests that age alone was the biggest defense against oxidative stress after exercise. Other studies during competition (endurance, jumping, eventing, and racing) have investigated the influence on oxidative stress with varying results. These results will be expanded upon during the presentation. Even though there have been many studies examining the levels of lipid peroxidation, antioxidant status and other related metabolites in the horse during exercise, we still have a long way to go before we fully understand the large variation in results both with and without antioxidant supplementation.

Key Words: equine, antioxidant, oxidative stress

427 Effects of aging on mitochondrial function in skeletal muscle of Quarter Horses.
Chengcheng Li*[1], Sarah H. White[2], Lori K. Warren[1], and Stephanie E. Wohlgemuth[1], [1]*Department of Animal Sciences, University of Florida, Gainesville, FL,* [2]*College of Health Sciences, University of Kentucky, Lexington, KY.*

Abstract. Research in human and rodents has shown an age-associated decline in physical function, aerobic capacity and skeletal muscle mitochondrial function, which in humans begins around the age of 50 yr. On the other hand, many horses can still actively work or compete beyond 20 yr of age, an age equivalent to a 65-year-old human. The purpose of the present study was to determine the age-related changes in fiber type composition and mitochondrial function in equine skeletal muscle. Muscle biopsies of right gluteus medius and triceps brachii from young (1.8 ± 0.1 yr; n = 24) and aged (20 ± 5 yr; n = 10) Quarter Horses were compared. High-resolution respirometry was performed on freshly sampled and subsequently permeabilized muscle fibers. Remaining tissue was frozen in liquid nitrogen and stored at −80°C for measurement of fiber type composition and enzyme activities. Statistical differences were analyzed using one-way ANOVA and Holm-Sidak post hoc analysis (Sigmaplot 12.0). We found that aged horses had a higher percentage of oxidative type I myosin heavy chain (MHC) isoform in both gluteus ($P < 0.001$) and triceps ($P = 0.024$) compared with young horses. The proportion of glycolytic type IIX MHC isoform tended to decrease with advancing age, particularly in triceps ($P = 0.061$). The proportion of intermediate fiber type IIA MHC isoform was not affected by age. Age had no effect on mitochondrial respiration in gluteus; but *triceps* from aged compared with young horses had greater leak respiration ($P = 0.038$), electron transport system capacity ($P = 0.032$), and a tendency for a lower respiratory control ratio ($P = 0.076$). Cytochrome *c* oxidase activity in both triceps ($P < 0.001$) and gluteus ($P < 0.001$) was lower in aged compared with young horses. Using citrate synthase activity as a marker, mitochondrial density increased by 26.8% in the gluteus of aged horses ($P = 0.034$), but was unaffected by age in the triceps ($P = 0.183$). Our data suggest that aging resulted in an increased percentage of oxidative type I fibers, increased mitochondrial density, and impaired mitochondrial function in Quarter Horse skeletal muscle.

Key Words: myosin heavy chain isoform, cytochrome c oxidase, high-resolution respirometry

428 Bones and muscles in endurance horses—Physiology, pathology, and clinical issues.
Katja F. Duesterdieck-Zellmer*, *Oregon State University, Corvallis, OR.*

Adaptation of muscle or bone to endurance exercise in the horse is of great interest, as specific training and nutrition regimens may maximize performance and prevent injury. Medical manipulation of muscle or bone, while ethically questionable, may also impact the fitness of these tissues. The speed in endurance competitions has increased in recent years, as has the incidence of fractures in endurance horses. The bones of endurance horses experience repetitive loading, resulting in microdamage, which can be repaired or may accumulate into stress fractures that can be catastrophic. This phenomenon is well known in flat-racing horses, but has received less attention in endurance horses. Apparently, front limb fractures are more common than hind limb fractures and most fractures occur in the metacarpal/metatarsal or proximal phalangeal regions in endurance horses, most of which were metatarsal/metacarpal condylar fractures. Information about specific training regimens directed towards prevention of certain bony injuries is available only for flat-racing horses, indicating a need for research in this field to benefit endurance horses. Additionally, bisphosphonate medications that have the potential to significantly affect bony remodeling have been recently approved for use in equines in many countries. While there is no information on specific effects of bisphosphonates on the skeleton in endurance horses, they may be less safe for them, compared with other equine athletes. Genetics determine the predominant muscle fiber types, total fiber number and relative size of fast and slow twitch fibers in horses, favoring certain breeds over others to be successful endurance athletes. Elite endurance horses have a high ratio of type I (slow twitch) and IIA (fast-oxidative glycolytic) muscle fibers and endurance training stimulates transition from fast twitch (type IIX) to slower twitch fibers (type IIA and I). Endurance training also causes hypertrophy of type I and IIA fiber types, resulting in increased aerobic and decreased anaerobic capacity of the muscle. On a cellular level, these changes are induced by quantitative and qualitative alterations in gene expression of both regulatory and structural genes.

Key Words: horse, muscle, bone

429 Biomechanics of the exercising horse. Hilary Clayton*[1,2],
[1]*Sport Horse Science LLC, Mason, MI,* [2]*Michigan State University, East Lansing, MI.*

Horses have long been used for athletic pursuits due to their superb physiological and biomechanical abilities. This talk explores structural and functional specializations of the equine limbs in relation to athletic performance. During locomotion the limbs cycle back and forth relative to the trunk moving primarily in the sagittal plane. Protraction and retraction are facilitated by morphological adaptations that reduce limb mass, especially in the distal limb, and allow a more proximal location of the moment of inertia. The joint angulations and muscle architecture of the hind limbs facilitate the generation of forward and upward propulsion of the center of mass, whereas the more strut-like forelimbs control speed and direction of movement. During a stride each limb has stance and swing phases. During swing the limb is rapidly protracted and then there is a final period of retraction that reduces hoof velocity relative to the ground at impact. During the first 50 ms after hoof contact with the ground, the hoof is rapidly decelerated and brought to rest with the effects of deceleration being mitigated if the hoof can slide a little forward and sink downward into the footing. The forces associated with hoof impact are damped within the hoof and distal limb so their effects are progressively attenuated in the more proximal parts of the limb. Vibrations associated with impact are damped by the digital flexor tendons. During the stance phase the limb is loaded by the mass of the horse (and rider). It is during this phase of the stride that stretching and recoil of elastic tendons makes a significant contribution to the exchange between kinetic and potential energy in the gaits that have a suspension phase. In the terminal part of the stance phase, tension applied to the third phalanx by the deep digital flexor tendon eventually exceeds the counteracting ground reaction force causing the heels to lift. During locomotion dynamic balance is maintained by the interactions between momentum that carries the horse forward, gravity that pulls the body downwards, and the propulsive forces from the limbs. As each limb contacts the ground it ‘catches’ the body, raises it and provides propulsion to maintain the forward progression.