Axial Speed of Sound and Injured Tendon's Mechanical Properties

Claudio Vergari

USC INRA-ENVA.957 de Biomécanique et Pathologie Locomotrice du Cheval
cvergari@vet-alfort.fr

Injuries of the superficial digital flexor tendon (SDFT) are a common problem in racing horses. Lesions are often accompanied by hypertrophy of the affected area and a decrease in tendon elastic modulus. Ultrasonography is the preferred technique to evaluate the early stage of tendon injuries, as echogenicity of the lesion is initially decreased. However, mean echogenicity of healing lesions progressively increases up to levels close to normal, although the tendon's mechanical properties have not yet recovered. Tendon axial quantitative ultrasound, initially designed for non-invasive measurement of tendon force, is a good candidate to follow up tendon lesions, since the theory of ultrasound wave propagation predicts that the speed of sound (SOS) depends on the medium's elastic properties (given that certain hypotheses on the propagating medium and structure are met). The objective of this preliminary study was to evaluate the potential of axial quantitative ultrasound to follow up tendon lesions.

The SDFT axial SOS (defined as the velocity of the first arriving signal, FAS, with signals at 1 MHz) was measured in vivo in the metacarpal area of the right limb of 12 horses (French Trotters, 2-4 years old, 428 ± 40 Kg average body mass), during 6 series of straight line walk on an asphalt pavement. Measurements were performed before (SOS_N) and about 4 months after (SOS_I) the bilateral surgical induction of a core lesion in the tendon (as approved by an ethical committee). The horses were then euthanized; each right SDFT was isolated (keeping the distal insertion on the middle phalanx intact) and tested in tension until failure, in order to measure the maximal tendon's instantaneous elastic modulus (E) and the true stress at tendon failure.

Average SOS_N was 2179 ± 31 m/s (mean ± SD) while SOS_I was found significantly lower ($p < 0.001$), at 2065 ± 67 m/s. Average true stress at tendon failure was 80 ± 10 MPa, while average E was 1.04 ± 0.18 GPa. While neither SOS_N nor SOS_I were correlated to E, a statistically significant correlation (Spearman's $\rho = 0.70$, $p = 0.025$) was found between SOS normalized value (SOS_I/SOS_N) and E. No correlation was found with true stress or strain at tendon failure.

The limits of the present study are due to the difficulties of comparing data which were acquired in vivo and in vitro. For instance, it was arbitrarily assumed that the maximal SOS measured at walk corresponded to the maximal E measured in vitro. These preliminary results still have to be confronted to the clinical and ultrasonographical evaluation of the injured tendons, and should be confirmed by testing more tendons. However, the correlation between tendon's Young's modulus and normalized SOS suggest that quantitative axial ultrasound is indeed a promising candidate to follow up tendon lesions.

Keywords: Biomechanics, tendon, speed of sound, quantitative ultrasound