STRAIN AND ELONGATION OF THE GASTROCNEMIUS MUSCLE TENDON AND APONEUROSIS DURING MAXIMAL PLANTAR FLEXION EFFORT

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INTRODUCTION

Regarding the strain and elongation distribution along the tendon and aponeurosis, the literature is reporting different findings (Maganaris and Paul, 2000; Muramatsu et al., 2001). The differences in the reports and especially those from *in vivo* experiments on human tendons and aponeuroses may rise from methodological differences between the studies. For instance, no *in vivo* study was found examining the elongation of the human tendon and aponeurosis simultaneously in the same trial. Examining the elongation during the same trial can be an important methodological issue, since the elongation of the tendon and of the aponeurosis are history-dependent mechanical properties affected by the creep effect. Therefore the purpose of this study was to examine *in vivo* the elongation and strain of the human gastrocnemius muscle tendon and aponeurosis simultaneously in the same trial during maximal voluntary plantar flexion efforts.

METHODS

Twelve subjects (weight: 76.86 ±6.94 kg, height: 185 ±6 cm) participated in the study. The subjects performed maximal voluntary isometric plantar flexion contractions on a Biodex-dynamometer. The kinematics of the leg were recorded using the vicon system (8 cameras 120 Hz) to calculate the resultant moment at the ankle joint. To determine the center of pressure under the foot, a flexible pressure distribution insole from pedar-system was used. Bipolar surface electrodes with an interelectrode distance of 2 cm were used to measure the EMG-activity of the antagonist tibialis anterior during the maximal voluntary plantar flexion. Two ultrasound probes were used to visualise the distal (myotendinous junction region) and the proximal (~8cm proximal to identified myotendinous junction) part of the distal aponeuroses of the gastrocnemius medialis. The elongation of the tendon and the aponeurosis were identified and analysed at 0, 15, 30, 45, 60, 80 and 100% of the maximum ankle joint moment of each trial. The differences in elongation and strain between the tendon and the aponeurosis were checked using the T-test for two dependent samples.

RESULTS AND DISCUSSION

The main findings of the present study were: (a) during maximal isometric plantarflexion efforts, the absolute elongation of the gastrocnemius muscle tendon was different to that of the aponeurosis (Fig. 1), (b) at all studied load levels, the strain of the gastrocnemius tendon did not differ from the strain of the aponeurosis (Fig. 2), (c) during the "isometric" plantarflexion the ankle angle exhibited significant changes, and (d) the non-rigidity of the dynamometer arm-foot system and the coactivity of the tibialis anterior have a significant influence on the moment exerted at the ankle joint, the influence of the non rigidity being twice as high compared to the influence of coactivity.

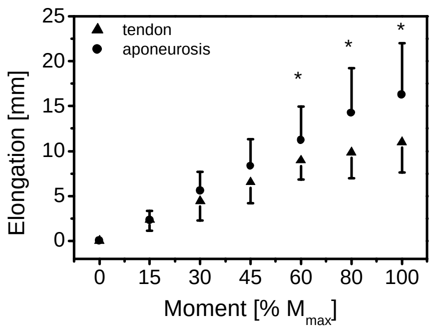

Figure 1: Elongation of the tendon and the aponeurosis in relation to the ankle moment (mean ±SD, n=12)

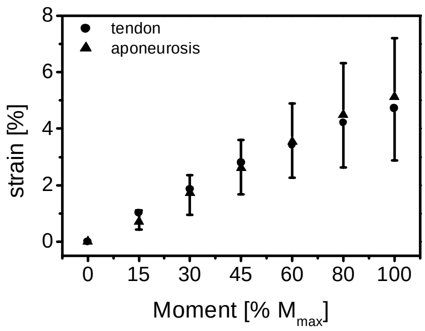

Figure 2: Strain of the tendon and the aponeurosis in relation to the ankle moment (mean ±SD, n=12)

SUMMARY

The main methodological drawbacks for *in vivo* estimation of the strain of tendon and aponeuroses using ultrasound are: ankle joint rotation, non rigidity of the dynamometer arm-foot system, coactivity of the antagonist muscles, changes of the tendon moment arm, creep effect and two dimensional measurement of the displacement of the tendon and aponeurosis. The experimental design of the present study takes into account the first three points. The next two points should not have any influence on the results since the elongation of the tendon and aponeurosis were examined simultaneously. The last point could not be addressed here. A two-dimensional analysis of curved surfaces causes projection errors. We conclude that the strains of the human gastrocnemius muscle tendon and aponeurosis, as estimated *in vivo* using two-dimensional ultrasound, do not differ from each other. The elongation of the aponeurosis is significantly greater compared to that of the tendon and in consequence the choice of the analysed cross-point on the ultrasound image influences the estimation of the stiffness (compliance) of the tendon and the aponeurosis.

REFERENCES

Maganaris and Paul (2000). *J. Exp. Biol.* **203**, 751-756.
Muramatsu, et al. (2001). *J. Appl. Phys.* **90,** 1671-1678