Effect of changes in achilles tendon path on the corrected for joint rotation elongation of the gastrocnemius medialis tendon and aponeurosis

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Introduction
It is well known that it is extremely difficult to completely prevent any joint rotation during an "isometric" maximal plantarflexion effort (Magnusson et al. 2001; Muramatsu et al 2001). In order to avoid an overestimation of tendon elongation, this joint rotation needs to be accounted for (Magnusson et al. 2001; Muramatsu et al 2001). The assumption made in this method is that for the same ankle joint rotation, the displacement of the digitised point at the aponeurosis relative to a skin marker in the inactive situation is the same as the length changes of the Achilles tendon path from the origin to the skin marker during the contraction. However, the tendon and aponeurosis are not rigid structures and theoretically the displacement of the digitised point at the aponeurosis should be smaller than the changes in length of the curved path of the Achilles tendon during the contraction. Thus theoretically after the above correction the calculated elongation would still overestimate the actual elongation of the tendon and aponeurosis. Contrary to this, recently Maganaris (2005) reported that the suggested correction underestimates the actual elongation of the tendon by 35%. Therefore the aim of this study was to examine the influence of the changes in the curved path of the Achilles tendon on the corrected for joint rotation elongation of the gastrocnemius medialis (GM) tendon and aponeurosis.

Methods
Nine subjects (age: 29.4 ± 5.7 years, body mass: 78.8 ± 6.8 kg, body height: 178 ± 4 cm) participated in the study. The subjects performed maximal voluntary isometric plantarflexion contractions (MVC, ankle angle 85°, knee fully extended) in the prone position on a Biodex-dynamometer. The kinematics of the right leg were recorded using the vicon system (8 cameras 120 Hz) to calculate the resultant moment at the ankle joint. A 7.5 MHz linear array ultrasound probe (Aloka SSD 4000) was used to visualize the distal tendon and aponeurosis of the GM muscle-tendon unit. Small reflective markers (multimarkers) having a diameter of 2.5 mm each, were attached to the skin every two cm from the tuberositas calcanei to the skin marker on the muscle belly (Fig. 1). The path formed by the series of markers along the skin approximates the Achilles tendon path. This curved path was reconstructed by interpolating the 3d coordinates of the markers using cubic splines. The elongation of the GM tendon and aponeurosis was calculated (a) as the difference of the measured and the passive (due to joint rotation) displacement of the tendon and aponeurosis (passive tendon displacement correction method) and (b) as the difference of the measured displacement and the length changes of the reconstructed Achilles tendon path (tendon path consideration method). The elongation of the GM tendon and aponeurosis calculated with the tendon path consideration method was defined as the actual elongation of the tendon and aponeurosis. The differences in elongation and strain between these two methods were checked using the T-test for two dependent samples (α=0.05).

Results
The maximal ankle joint rotation during the "isometric" MVC was 13.0 ± 3.7° at a maximum resultant plantarflexion moment of 143.3 ± 30.8 Nm. The elongation and strain of the tendon and aponeurosis calculated by the passive tendon displacement correction method (elongation: 20.4 ± 3.8 mm, strain: 6.5 ± 1.7%) showed significantly (p<0.05) higher values compared to the tendon path consideration method (elongation: 19.2 ± 5.7 mm, strain: 6.2 ± 1.7%). The absolute differences in the examined elongation between both methods were 1.2 ± 0.4 mm. These differences were due to the higher changes in length of the reconstructed curved path compared to the changes in the passive displacement of the digitised point at the aponeurosis (Fig. 2).

Discussion/Conclusion
Without any correction for ankle joint rotation, the measured elongation clearly overestimates the actual elongation of the GM tendon and aponeurosis. After the passive displacement correction the calculated elongation still overestimates the actual elongation of the GM tendon and aponeurosis. However this overestimation has a negligible effect on the examined in vivo strain (~0.3%) of the tendon and aponeurosis.

References