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RECONSTRUCTION OF THE HUMAN TRICEPS SURAE MUSCLE-TENDON UNIT BASED ON MRT IMAGES

Albracht, K., Baltzopoulos, V., Arampatzis, A.
Institute of Biomechanics and Orthopaedics; Institute for Biophysical & Clinical Research into Human Movement

Knowledge of the external (volume, shape) and internal (fascicle arrangement) characteristics of a muscle's architecture is required to assess in vivo muscle performance and provide a better understanding of muscle function through modelling. Available data on human muscle architecture is mostly based on cadaver tissue [1, 2], although recent imaging techniques as magnetic resonance (MR) imaging or ultrasonography allow obtaining such parameters in vivo. The triceps surae (TS) has often been modelled in spite of the little information available on its three-dimensional (3D) geometry throughout the entire volume in vivo. Therefore, the aims of this study were to reconstruct the 3D geometry of the TS including its internal architecture and to create a relevant database from in vivo measurements to be used in muscle modelling.

Transversal MR images (4mm contiguous slices) were acquired from the right calf of 10 male subjects (height 1.8 ± 0.4 m, weight 76 ± 6 kg, age 29 ± 6 years) in neutral anatomical position. Seven sets of MR images were needed to cover the entire TS. The boundaries of the three TS muscles were outlined manually for each slice. From these transversal contours a B-Spline muscle model of the MTU was created as proposed by Ng-Thow-Hing (2001). Tibia and Fibula were also digitised and served to define a reference coordinate system. Fascicle length and pennation angle of all three muscles were determined by ultrasonography.

Finally we obtained a geometrical reconstruction of the soleus (SO), the gastrocnemius medialis (GM) and lateralis (GL) providing a detailed 3D description of the TS geometry. The muscle volumes and MTU lengths were 466±54cm3 and 41.5±2.0cm for the SO, 284±45cm3 and 50.0±2.5cm for the GM, and 146±24cm3 and 47.6±2.4cm for the GL. The shapes of the GM and GL were similar whereas the SO shape was obviously different. This is indicated by the fact that the location of the of maximum cross section area in relation to muscle length differed across muscles (SO 62±4% GM 46±7% GL 49±4%). When normalised to the tibia length, muscle length or MTU length the variability of the retrieved parameters ranged from 5 to 10 % across subjects. Only a few parameters as the ratio between fascicle length and muscle length (SO 25% GM 17% GL 13%) showed a higher variability.

The observed non-uniformity of the external and internal architecture between the TS muscles may influence their predicted interactions and therefore underpins the importance of accurate assessment of this parameters for muscle modelling. All together, the reconstructions and the low inter-individual variability of the the parameters determined in the present study indicate that it is possible to assess the architectural characteristics of the TS and to create a scaleable muscle model.

References

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2. Wickiewicz TL et al (1983) Clin Orthop Relat Res 179:275-83
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