

ASSESSMENT OF MUSCLE VOLUME AND PHYSIOLOGICAL CROSS SECTIONAL AREA OF THE HUMAN TRICEPS SURAE MUSCLE IN VIVO

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The knowledge of muscle volume is essential to assess energy consumption and efficiency of a contracting muscle through modeling. Further, the muscle volume in combination with fascicle length and pennation angle can be used to approximate the physiological cross sectional area (PCSA). For in vivo measurement of muscle volume MRI is considered to be the most useful non-invasive imaging device [1]. Despite recent improvements in image processing a muscle reconstruction by MRI is still extensive. Until now no information is available whether the m. triceps surae (TS) volume or PCSA can be estimated from less extensive measurements. Therefore the aims of this study were to answer the questions whether it is possible (a) to predict muscle volume and PCSA of the entire TS by using only one specific muscle, and (b) to predict the individual muscle volumes within the TS by means of easily accessible parameters. Transverse MRI scans (4 mm contiguous slices) were acquired from the right calf of 13 male subjects (181 ± 4 cm, 76 ± 6 kg, 29 ± 6 years) in the neutral anatomical position. Each muscle was reconstructed using a B-Spline solid [2]. To determine the PCSA, fascicle length and pennation angle were examined by ultrasonography at the same joint angles. The m. gastrocnemius medialis (GM), m. gastrocnemius lateralis (GL) as well as the m. soleus (SO) volumes showed a linear relationship to the total TS muscle volume ($r^2 = 0.75$ to 0.86) and a intersubject variability $\leq 3\%$ (SD) in their relative portion of entire TS volume. The PCSA of the GM and SO showed a linear relationship ($r^2 = 0.73$ and 0.92) to the PCSA of the entire TS. The PCSA of the GL showed only a weak linearity ($r^2 = 0.32$). However, the variability across subjects of the proportional distribution within the TS was $\leq 4\%$ (SD) of TS PCSA. The most accurate prediction to assess the muscle volume or PCSA of the entire TS can be achieved using the GM or SO (muscle volume: RMS = 5 to 8%; PCSA: RMS = 6 to 12%). To predict the individual muscle volumes within the TS, the product of muscle length (ML) and maximum anatomical cross sectional area (ACSA) provides the best estimation (RMS = 4 to 7%). The regression between the product of ML and ACSA and muscle volume explained 82-95% of the variability across subjects in muscle volume. The location of ACSA in relation to the tibia length is well defined (SD $\approx 4\%$ of tibia length) for all three muscles. In addition the ACSAs of the GM and GL are located at the same tibia level. We can conclude that, only one MRI sequence (thickness ≈ 4 cm) for both gastrocnemii and one for the SO are required to identify the ACSAs of all three muscles. Muscle length can be determined by identifying the proximal and distal ends of the muscle with ultrasonography or MRI. Thus ML and ACSA are easily accessible in

comparison to a muscle reconstruction.

[1] Shellock FG (1989) Magn Imaging Q 5:243-261; [2] Ng-Thow-Hing V & Fiume E (2002) Proc. Graphics and Interface: 107-115

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