Comprehensive Data for Modelling of architectural-informed and activation-driven contractions of the human M. tibialis anterior

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The M. tibialis anterior (TA) is an important contributor to successful locomotion and preserving an upright posture [1]. Its unique function as single-joint and sole ankle dorsiflexor as well as its superficial location allow for clearer determination of muscle properties and their influence on muscle contraction compared to other muscles of the human body [2]. However, information regarding the contractile and architectural properties of the TA remains scarce. Especially in regards to simulation there are, so far, no validated human 3D muscle models, which realistically predict muscle force generation, muscle deformation and changes in 3D muscle architecture during contraction. The aim of this study is to provide comprehensive data for modelling of architectural-informed and activation-driven models of the human TA.

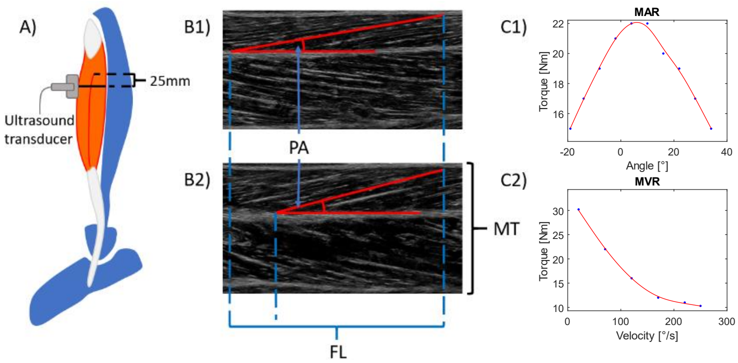

Figure 1: The ultrasound transducer is placed 25mm distal of the proximal end of the central aponeurosis of the TA (A). Clear differences in FL, PA and MT can be observed between relaxed (B1) and contracted (B2) conditions from ultrasound images. MAR (C1) and MVR (C2) are in accordance with results from studies with other skeletal muscles [3, 4].

Therefore, twenty-eight healthy and physically active males(n=13, a=26.6±4y, m=74.8±7.7kg, h=178.9±5.3cm) and females (n=15, a=24.6±3.3y, m=62.3±9.9kg, h=166±8.4cm) performed maximum voluntary isometric and isokinetic dorsiflexions in a dynamometer (ISOMED2000). Ankle joint angles were measured with a 3D high speed camera system (Baumer VLXT-Series). Information on the architectural changes (pennation angle and fascicle length) of the TA between relaxed and contracted state as well as during dynamic contraction was obtained with an ultrasound system (Aixplorer MACH30).

Based on this data the moment-angle-relationship (MAR)[3], moment-velocity-relationship (MVR)[4], contraction history-dependent effects (HDE)[5], isometric contraction behavior after stretch-shortening-cycle (SSC), muscle thickness (MT), pennation angle (PA), fascicle length (FL) of TA were characterized. MAR and MVR are in accordance with results of other studies on skeletal muscles [3, 4]. The physiological working range of the TA is on the ascending branch and the plateau of the MAR [6]. Changes in generated forces for the HDE are within the expected range for mammalian skeletal muscles [7]. The gender differences in muscles characteristics and muscle architecture parameters are discussed. The data serves as a basis for the development and validation of the first realistic human 3D muscle model to predict changes in 3D muscle architecture, shape and force during contraction. In further studies, the model should then be adapted to specific subject groups in order to take into account the influence of age or sport.

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