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In- vivo determination of 3D muscle architecture of the human triceps surae using free hand ultrasound

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Muscle fibre architecture is one of the main factors that determine muscle function. Muscle fascicles can follow complex 3D paths through a muscle, but, to date, no method is available for detecting these orientations non-invasively. Here, we present a method to image the 3D orientation of the muscle fascicles using B-mode ultrasound, a position tracking system and automated computer algorithms. Ultrasound data were collected from the triceps surae of a subject's right leg using ultrasound and external magnetic position tracking system. Images obtained from multiple scans of the muscles were analyzed for fascicle orientation in the image plane using automated methods: multi-scale vessel enhancement filtering (a technique used to enhance tube-like structures), followed by wavelet analysis to determine local fascicle orientations. The pixels in the 2D scan were transformed to voxels in 3D space and fascicle orientation at those pixels in the ultrasound image were converted to direction cosines at voxels in 3D space based on the position and orientation of transducer for a particular scan. Although each voxel potentially contains many estimates of fascicle orientation based on the different scans, the best orientation was determined by inspecting the coefficients for vesselness and convolution that were obtained from the different scans. This method results in a set of direction cosines for the local fascicle orientations at each voxel within the muscle. Our experimental data showed that the fascicle orientations changed in a systematic manner along the proximo-distal axis of the muscle. The proposed method can be used to quantify complex 3D muscle architecture within the skeletal muscle in man.