NEW AUTOMATED ALGORITHM FOR MUSCLE ARCHITECTURE EXTRACTION FROM B-MODE ULTRASOUND IMAGES

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Introduction

Human muscle architecture has a critical impact on muscle contraction mechanics and is usually determined by ultrasound imaging of the connective tissues surrounding the fascicles [1]. Since manual measurements of fascicle length (FL), pennation angle (PA) and muscle thickness (MT) are time-consuming and technically demanding, especially during locomotor activities, several automatic tracking algorithms have been developed to extract FL, PA and MT from ultrasound images. However, due to the nature of the ultrasound data, which is characterized by low contrast, noise and speckle, there is much room for improvement both in terms of the accuracy of the results and the level of automation. The purpose of this study is to present preliminary validation results of a new algorithm developed to provide a robust estimation of muscle structure changes during movements.

Methods

Ultrasound images of the medial gastrocnemius during treadmill walking were recruited from ten gait cycles, each performed by a different young man [1]. Muscle architecture parameters were calculated on each 1% of each gait cycle by: a) manual digitization, b) the TimTrack algorithm [2] and c) the proposed algorithm. The proposed method involved three steps. First, the superficial and deep aponeuroses were detected by advanced image processing, getting and sorting objects according to their area or contour size, combining objects in pairs in order to automatically detect aponeuroses and processing the contours of the aponeuroses objects to return the corresponding curves. Secondly, the algorithm calculated orthogonal lines to the middle line of the muscle (in parallel to both aponeuroses) that intersected both aponeuroses into 5 points equally distributed along the muscle. MT was the average length of the line segments defined by their intersections with both aponeuroses. In the last step, fascicle orientation was estimated by an advanced image processing algorithm that included image decomposition, Laplacian pyramids and Gabor filters. For each fascicle object a line was fitted and FL was calculated between the fascicle's intersections with the two aponeuroses. Finally, PA was calculated as the angle between the fascicle line and the tangent to the deep aponeurosis at the intersection points. Root mean squared error (RMSE) was calculated between manual and algorithmic measurements.

Results

The average (±SD) RMSE for the new algorithm was 3.2±1.1 mm for FL, 1.1±0.5 mm for MT and 1.5±0.4 deg for PA. The corresponding values for TimTrack were 6.25±1.8 mm for FL, 0.4±0.2 mm for MT and 4.4±1.7 deg for PA. Average waveforms of muscle architecture parameters across all gait cycles are shown in Fig 1.

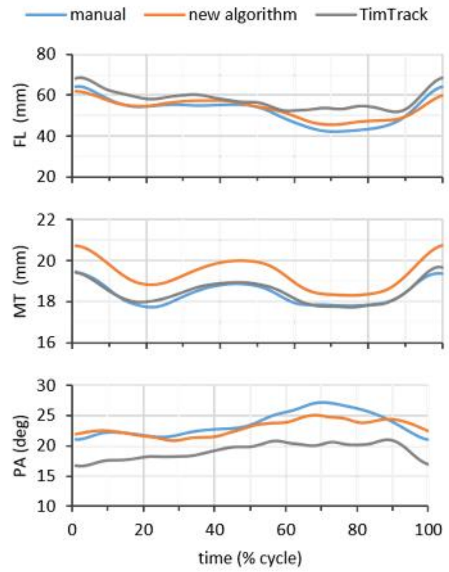

Figure 1: Fascicle length, muscle thickness and pennation angles from the proposed and Timtrack algorithm.

Discussion

The new algorithm showed excellent performance in tracking FL and PA of gastrocnemius medialis during human walking when compared to manual procedures and TimTrack. Regarding MT, TimTrack was closer to manual measurement. However, due to its systematic nature, the larger error of the new algorithm may be due to differences in the assumptions made to calculate MT.

References

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