Automated Skeletal Muscle Architecture Analysis in Dynamic Ultrasound Imaging

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Background, Motivation and Objective

Ultrasound (US) Imaging is a fundamental procedure in the assessment of skeletal muscle architecture. Muscle Thickness (MT) and Fascicles Pennation Angle (FPA) are descriptors of the muscle functionality and are measured to track training and rehabilitation outcomes. Conversely, US imaging during exercise is still a largely neglected field for practical reasons. Thanks to the recent introduction of US probe fixation systems, skeletal muscles could be imaged with US in dynamic conditions. In this study, we investigated MT and FPA measurements during walking using US. However, a substantial effort is required for manual measurements, which results to be time-consuming and prone of errors. To overcome these limitations, we propose an algorithm for automated US muscle architecture analysis in dynamic conditions.

Methods

8 healthy subjects (age: 24.5 ± 1.9 y, BMI: 22.8 ± 3.0 kg/m^2) are asked to walk at 4 km/h on a treadmill (LifeFitness, USA). US videos of the medial gastrocnemius muscle are recorded at 20 Hz with a MyLab70 ultrasound device equipped with a linear LA523 transducer (Esaote, The Netherlands) and fixated on the calf using a Probefix Dynamic (USONO, Eindhoven, The Netherlands). Dynamic US images are analysed with an automated algorithm for the continuous MT and PA measurements. Results are compared with manual measurements performed by an expert operator (Figure 1, Panel A - B).

Results, Discussion and Conclusions

Experiments were successful in all subjects, providing US data and muscle parameters for sequences of 10 seconds. The percentage of incorrect automatic muscle segmentation is below 0.1%. The averaged MT is 15.4 ± 0.2 mm, ranging during gate between 9.6 - 21.5 mm. The average FPA is 13.1 ± 2.0°, ranging between 4.6 - 18.2°. Preliminary results of the manual validation show that the differences between the automatic and manual measurements are below 0.1 mm for MT and 2.5° for FPA respectively (Figure 1, Panel C). Automated analysis takes less than 0.8 second per image, compared to the 1.5 minutes of the manual annotation. The proposed method shows that continuous automated US skeletal muscle architecture analysis during exercise is feasible and has the potential of being robust and accurate, finding application in clinical practice and sports science.

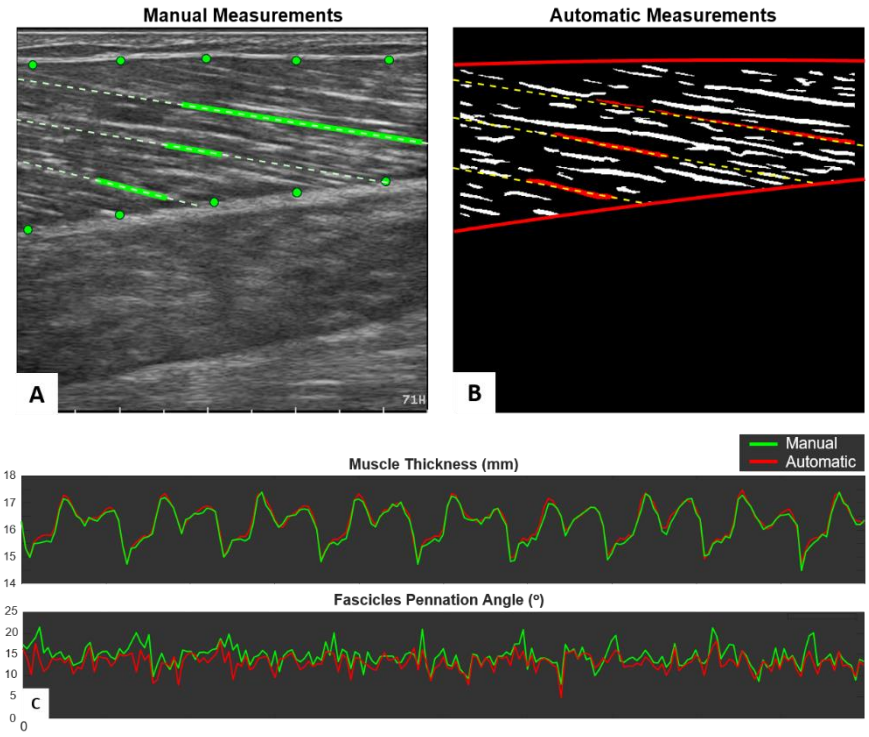

Figure 1.
Panel A: Example of manual Muscle Thickness measurements in five points and Pennation Angle along three representative Fascicles of the Medial Gastrocnemius muscle.

Panel B: Example of automatic Muscle Thickness and Pennation Angles on the corresponding three Fascicles.

Panel C: Manual vs Automatic Muscle Thickness and Pennation Angle along 10 seconds acquisition interval.