Changes in the Medial and Lateral Gastrocnemius Fiber Architecture with Age.

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Target Audience: MSK radiologists (focus on aging, sarcopenia), Image Processing Researchers (focus on fiber tracking).

Purpose: Age related changes in muscle fiber architecture (fiber lengths and pennation angles). Diffusion tensor imaging (DTI) allows the mapping of fiber architecture; this study investigates age related changes in fiber architecture of the medial and lateral gastrocnemius using DTI.

Methods: Five young (52 ± 7 years) and five senior (83 ± 3 years) Japanese women were recruited with informed consent; participants were free of internal or orthopedic disease. DWI were acquired on a 3 T GE scanner using a fat suppressed single shot EPI sequence without dual 180° pulses. Thirty-two non-collinear gradient directions with a b-factor of 400s/mm² were used; imaging parameters were (TE/ TR): 49 ms/4000 ms, 4averages. The FOV, slice thickness/gap, and matrix were 240 × 240 mm², 5 mm/0 mm, and 80 × 80 respectively. A custom built coil with a large field of view was used to image approximately 22 cm of the lower leg without moving the subject or coil; the intent was to cover the medial and lateral gastrocnemius muscles from their origin to insertion in a single acquisition. Diffusion weighted image volumes were corrected for eddy current, motion and susceptibility related artifacts, smoothed and masked with the muscle volume of interest: MG or LG. Fiber tracking was performed using DTIStudio (https://www.dtistudio.org/) on the (MG or LG) masked tensor volumes. The stopping criteria for the fiber tracking algorithm were: FA < 0.15 and an angle change > 20° between successive ROIs (1 pixel wide) were selected on coronal (reformatted) eigenvector images near the deep aponeurosis at distal and middle locations to extract fibers passing through these ROIs. Several fibers pass through each ROI due to the ‘brute-force’ nature of the fiber tracking algorithm. Fiber coordinates for each fiber were saved to calculate superficial and superficial pennation angles and fiber lengths. The surfaces corresponding to the deep and superficial aponeuroses were automatically identified from the masks. The pennation angle was calculated at the deep/superficial aponeuroses as follows: the closest point on the aponeurosis at distal and middle locations to extract fibers passing through these ROIs. Several automated checks were incorporated into this algorithm to ensure the integrity of the fibers including (i) exclusion of fibers that tracked entirely along the aponeurosis (ii) exclusion of fibers that terminated >3 voxels from the superficial aponeurosis, and (iii) trimming points on the fibers where the fibers ran parallel to the aponeurosis surfaces. Calculation of the angle of the superficial aponeurosis may contribute to these differences.

Results: Howev er, the differences were all smaller and the superficial aponeurors were: FA < 0.15 and an angle change > 20° between successive ROIs (1 pixel wide) were selected on coronal (reformatted) eigenvector images near the deep aponeurosis at distal and middle locations to extract fibers passing through these ROIs. Several fibers pass through each ROI due to the ‘brute-force’ nature of the fiber tracking algorithm. Fiber coordinates for each fiber were saved to calculate superficial and superficial pennation angles and fiber lengths. The surfaces corresponding to the deep and superficial aponeuroses were automatically identified from the masks. The pennation angle was calculated at the deep/superficial aponeuroses as follows: the closest point on the aponeurosis at distal and middle locations to extract fibers passing through these ROIs. Several automated checks were incorporated into this algorithm to ensure the integrity of the fibers including (i) exclusion of fibers that tracked entirely along the aponeurosis (ii) exclusion of fibers that terminated >3 voxels from the superficial aponeurosis, and (iii) trimming points on the fibers where the fibers ran parallel to the aponeurosis surfaces at either surface.

Discussion and Conclusions: Changes in the Medial and Lateral Gastrocnemius Fiber Architecture with Age. The fiber length changes with age agree with that obtained by ultrasound measurements [1]. The regional dependence of fiber lengths seen here is also anticipated as fibers get shorter as one goes from distal to proximal locations along the muscle. The age related differences in the ‘deep’ pennation angles agree with earlier findings of a decrease in pennation angle with age. However, in contrast to this, the ‘superficial’ pennation angles increased with age. The superficial angle can differ from the deep angle either due to fiber curvature or from the relative curvature of the aponeurosis surfaces. Calculation of the angle of the superficial fiber end with the distal aponeurosis should disambiguate these two situations. From an examination of these values (Table 1), it appears that in the older cohort, fiber curvature contributes to the ‘deep’ and ‘superficial’ angle differences while in the younger cohort, the relative curvature of the deep and superficial aponeurosis may contribute to these differences.