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Effect of Different Knee-Joint Positions on Passive Stiffness of Medial Gastrocnemius Muscle and Aponeuroses during Passive Ankle Motion

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Abstract : The human triceps surae (two bi-articular gastrocnemii and one mono-articular soleus) have aponeuroses in the posterior and anterior aspects of each muscle, where the anterior aponeuroses of the gastrocnemii adjoin the posterior aponeurosis of the soleus, possibly contributing to the intermuscular force transmission between gastrocnemii and soleus. Since the mechanical behavior of these aponeuroses at different knee- and ankle-joint positions remains unclear, the purpose of this study was to clarify this through observations of the localized changes in passive stiffness of the posterior aponeuroses, muscle belly and adjoining aponeuroses of the medial gastrocnemius (MG) induced by different knee and ankle angles. Eleven healthy young males (25 ± 2 yr, 176.7 ± 4.7 cm, 71.1 ± 11.1 kg) participated in this study. Each subject took either a prone position on an isokinetic dynamometer while the knee joint was fully extended (K180) or a kneeling position while the knee joint was 90° flexed (K90), in a randomized and counterbalanced order. The ankle joint was then passively moved through a 50° range of motion (ROM) by the dynamometer from 30° of plantar flexion (PF) to 20° of dorsiflexion (DF) at 2°/s and the ultrasound shear-wave velocity was measured to obtain shear moduli of the posterior aponeurosis, MG belly, and adjoining aponeuroses. The main findings were: 1) shear modulus in K180 was significantly higher ($p < 0.05$) than K90 for the posterior aponeurosis (across all ankle angles, 10.2 ± 5.7 kPa-59.4 ± 28.7 kPa vs. 5.4 ± 2.2 kPa-11.6 ± 4.1 kPa), MG belly (from PF10° to DF20°, 9.7 ± 2.2 kPa-53.6 ± 18.6 kPa vs. 8.0 ± 2.7 kPa-9.5 ± 3.7 kPa), and adjoining aponeuroses (across all ankle angles, 17.3 ± 7.8 kPa-80 ± 25.7 kPa vs. 12.2 ± 4.5 kPa-52.4 ± 23.0 kPa); 2) shear modulus of the posterior aponeuroses significantly increased ($p < 0.05$) from PF10° to PF20° in K180, while shear modulus of MG belly significantly increased ($p < 0.05$) from 0° to PF20° only in K180 and shear modulus of adjoining aponeuroses significantly increased ($p < 0.05$) across the whole ROM of ankle both in K180 and K90. These results suggest that different knee-joint positions can affect not only the bi-articular gastrocnemius but also influence the mechanical behavior of aponeuroses. In addition, compared to the gradual stiffening of the adjoining aponeuroses across the whole ROM of ankle, the posterior aponeurosis became slack in the plantar flexed positions and then was stiffened gradually as the knee was fully extended. This suggests distinct stiffening for the posterior and adjoining aponeuroses which is joint position-dependent.

Keywords : aponeurosis, plantar flexion and dorsiflexion, shear modulus, shear wave elastography
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