In vivo determination of the force-length relationship of the soleus and gastrocnemii muscles

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Summary

The in vivo force-fascicle-length relationship (F-L-R) of the monoarticular soleus (SOL) and biarticular gastrocnemii (GM/GL) were determined in 14 participants using a combination of dynamometry, ultrasound imaging and motion capture. Participants performed multiple maximal isometric voluntary contractions (MVCs) in a flexed and extended knee position. We found that the optimal lengths were different from the lengths at which triceps surae (TS) force is maximal, due to a different contribution of SOL between the two knee angle positions. In conclusion, the F-L-R of SOL, GM, GL and their optimal lengths cannot be assessed in one knee joint position without consideration of the SOL contribution.

Introduction

Synergistic muscles have been shown to have different force production characteristics [1]. Determining the F-L-R of the synergistic TS muscles in vivo would help to understand the functional diversity between these muscles during everyday activities. Previous studies have assumed that the optimal lengths (L_0) of the TS muscles are aligned with the lengths at which TS force is maximal in extended knee position (KE) [2,3]. Our aim was to determine the active F-L-R of the monoarticular SOL and biarticular GM/GL muscles in vivo and test the hypothesis that the L_0 of the three muscles are not aligned with the length at which the TS force is maximal in KE.

Methods

Fourteen physically active participants (8F/6M) performed MVCs at 10 different ankle angles on a dynamometer in flexed knee position (KF) to assess the active F-L-R of SOL. The force acting on the Achilles tendon (AT) was calculated from the active ankle joint moment and the instantaneous tendon lever arm, and SOL fascicle length were measured by ultrasound. By applying a 2nd order polynomial to the discrete force and fascicle length data we determine the SOL F-L-R. The 10 MVCs were repeated in KE position to determine the active TS force and fascicle length of SOL, GM and GL at the 10 different ankle angles (Figure 1). The GM/GL F-L-R was determined by subtracting the SOL contribution and applying a 2nd order polynomial to the discrete force and fascicle length data. The SOL contribution was assessed by mapping the SOL fascicle lengths measured during KE onto the SOL F-L-R.

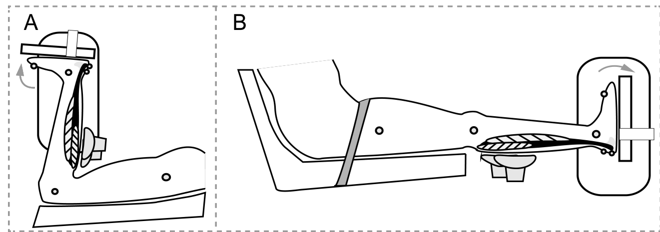

Figure 1. Experimental setup, dynamometry and ultrasound imaging in flexed knee (A) and extended knee position (B).

Results and Discussion

The L_0 were SOL: 46.8± 8.7 mm, GM: 42.0±7.4 mm and GL: 58.8±13.3 mm, and were significantly different ($p<0.05$) from the L_0 at which the TS force is maximal in KE (Figure 2). The SOL length during the MVCs in the same ankle angle range in KE was significantly shorter ($p<0.05$) compared to KF, indicating a different SOL contribution between the two knee joint positions.

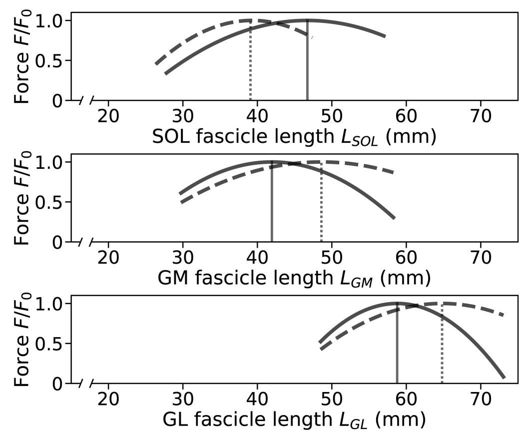

Figure 2. Normalized F-L-R and L_0 of SOL, GM and GL muscles (solid curves) and normalized F-L-R and L_0 using only the extended knee position (dashed curves).

Conclusions

The findings show that L_0 of SOL, GM and GL muscles cannot be assessed in KE position only, confirming our hypothesis. The different SOL fascicle lengths in the same ankle angle range between the KF and KE positions during the MVCs indicate a different contribution of the SOL to the AT forces between the two knee joint positions and imply important effects on the F-L-R assessment of the GM/GL muscles.

References

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