Effect of metatarsophalangeal joint positions on maximal voluntary isometric ankle plantar flexion torque

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Summary

We investigated the effect of the metatarsophalangeal (MTP) joint positions on the ankle plantar flexion torque (τ_{ankle}) at maximal isometric voluntary contraction. Sixteen males performed maximal voluntary isometric ankle plantar flexion with MTP joint at 0°, 15°, 30°, and 45° extension. The results demonstrated that τ_{ankle} and the forces applied under the toe were greater in 15° MTP joint extension than in the other positions. The findings suggest that changes in MTP joint positions affect τ_{ankle} via the force-length relationship of toe flexors, with 15° extension being the optimal position.

Introduction

The joint position at which the maximal torque is generated indicates the optimal position for the muscles to function [1]. It is known that τ_{ankle} varies with knee and ankle joint positions and is maximized with the knee extended and ankle 0°–20° dorsiflexed position [e.g., 2], reflecting the force-length relationship of the triceps surae muscle. However, even after the surgical excision of the Achilles tendon, τ_{ankle} reached up to 38% of the sound limb [3], indicating that τ_{ankle} is attributed to the force generated by toe flexors in addition to the triceps surae. Moreover, it has been reported that toe flexion torque (indicative of the toe flexor forces) increases with MTP joint 25°–45° extension [4]. Thus, it is suggested that τ_{ankle} changes with MTP joint position via the force-length relationship of the toe flexor muscles. The purpose of this study was to investigate the effect of MTP joint positions on τ_{ankle}.

Methods

Sixteen healthy young males (21.7 ± 1.6 years; mean ± SD) participated. Participants were placed in a supine, knee fully extended, and ankle neutral position, and their dominant foot was fixed to a custom-made myometer. Participants were requested to perform maximal voluntary isometric ankle plantar flexion with MTP joint set at 0°, 15°, 30°, and 45° extension in a randomized and counterbalanced order.

The MTP joint extension changes the direction of the applied forces under the toe (Figure 1A). Thus, the forces applied under the toe (F_{toe}) and proximal foot (F_{prox}; ball of the foot to the heel) regions were separately recorded using an insole-type plantar pressure sensor (Pedar-X, Novel) attached to the footplate of the myometer. We calculated τ_{ankle} from plantar pressure data using the following equation:

$$\tau_{ankle} = F_{foot} \times L = (F_{cos} + F_{prox}) \times (COP - COR)$$

where F_{foot} is the resultant force of F_{cos} (i.e., cosine component of F_{toe}) and F_{prox}, and L is the horizontal distance between the center of pressure (COP), which is matched to the point of action of F_{foot}, and the center of rotation (COR) of the footplate.

Results and Discussion

The τ_{ankle} and F_{cos} were significantly greater in MTP joint 15° extended position than in the other joint positions ($p < 0.05$), while no significant change was found in F_{prox} (Figure 1B–D). The results indicate that the changes in τ_{ankle} across MTP joint positions are derived from the changes in the toe flexor forces. The optimal MTP joint position for τ_{ankle} (i.e., 15° extension) differed from that for the toe flexion (25°–45° extension) [4]. In the case of τ_{ankle}, increased toe flexor forces with MTP joint extension would be counterbalanced by the cosine effect (F_{cos} decreases as MTP joint angle increases).
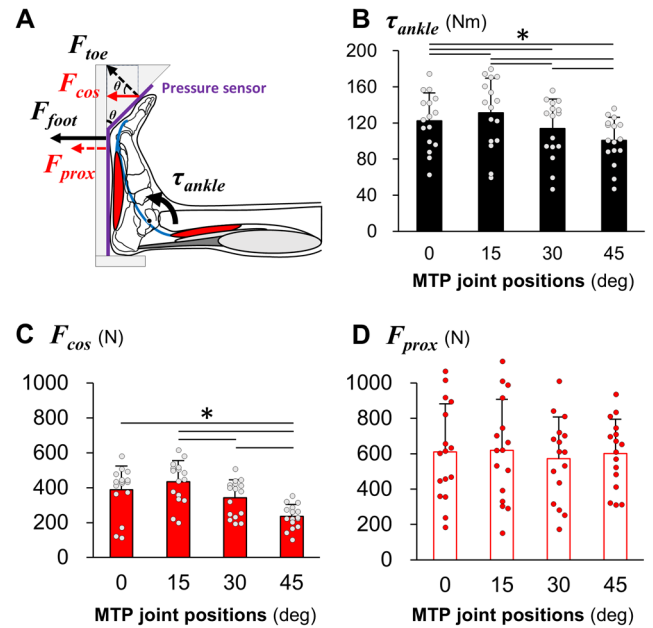

Figure 1: An illustration of torque calculation (A) and changes in τ_{ankle}, F_{cos}, and F_{prox} with MTP joint positions (B–D, *: $p < 0.05$).

Conclusions

To our knowledge, this is the first study to investigate the effect of MTP joint positions on τ_{ankle}. We revealed that τ_{ankle} changed with MTP joint positions and was maximized at the MTP joint 15° extension.

References

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