Effects of Knee Joint Angle on the Force-length and Velocity Characteristics of Gastrocnemius Muscle

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INTRODUCTION
Static plantar flexion torque developed in a knee extended position is greater than that in knee flexed position[1], in which the muscle fibers of gastrocnemius shorten. In concentric actions, however, the difference in torque between the knee extended and flexed positions decreases with increasing angular velocity of the ankle[2]. The reasons for this torque discrepancy between the static and concentric actions have not been clarified. This study aimed to examine the effect of knee joint angle on the plantar flexion torque from the viewpoint of the length-force and force-velocity relationships in the muscle fiber (fascicle) of the medial gastrocnemius (MG).

METHODS
Six male subjects performed static and concentric plantar flexions at two different knee joint angles [fully extended (K0) and flexed at 45° (K45)] with the maximal effort. The ankle joint was fixed at 0° (neutral position) in the static action. The range of motion of the ankle joint in the concentric actions was –10° (dorsiflexed) to 30° (plantar flexed) and the angular velocities were set at 30 and 350°/s by a dynamometer. The Achilles tendon force was calculated from the measured plantar flexion torque divided by the moment arm of the Achilles tendon. The fascicle length, pennation angle at the mid belly of MG, and the length change of the external tendon of MG were measured by two ultrasound apparatuses. Surface electromyograms (EMGs) were recorded from the MG, lateral gastrocnemius (LG), soleus and tibialis anterior muscles.

RESULTS AND DISCUSSION
The difference in peak torque and tendon force between K0 and K45 decreased with increasing angular velocity of the ankle, i.e. no significant differences at higher angular velocity (Table 1). The average EMG activity of MG at 350°/s was significantly lower in K45 than in K0 (Table 1), while no significant differences were observed between K0 and K45 in the other angular velocities for MG and at all velocities for the EMGs of LG and soleus muscle.

We estimated the sarcomere lengths which were calculated from the fascicle lengths obtained from ultrasonography. It is considered that the MG muscle at the peak force had a greater force potential in K0 at static and 30°/s (Figure 1). However in the case of 350°/s, the MG fascicle may perform with higher force potential in K45 than in K0 (Figure 1).

The fascicle velocities were significantly lower in K45 than in K0 (Figure 2), even though nearly identical angular velocities. Thus, MG fascicles in K45 were more advantageous for producing force in the concentric actions, according to the force-velocity characteristics of a muscle.

CONCLUSIONS
The present study showed the plantar flexion torque developed during concentric actions did not always decrease with knee flexion. This would be attributed to the length-force and force-velocity relationships and activation levels of the MG.

REFERENCES

<table>
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<tr>
<th>Table 1: Peak values of plantar flexion torque and tendon force, and mEMG of MG.</th>
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<td>Static</td>
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<tr>
<td>Peak torque (Nm)</td>
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<td>Peak force (N)</td>
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<td>mEMG of MG(µV)</td>
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<sup>*</sup> denotes a significant difference between K0 and K45.