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 45º (K45)] with the maximal effort. The ankle joint was fixed at 0º (neutral position) in the static action. The range of motion of the ankle joint in the concentric actions was –10º (dorsiflexed) to 30º (plantar flexed) and the angular velocities were set at 30 and 350º/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 350º/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 30º/s (Figure 1). However in the case of 350º/s, the MG fascicle may perform with higher force potential in K45 than in K0 (Figure 1).

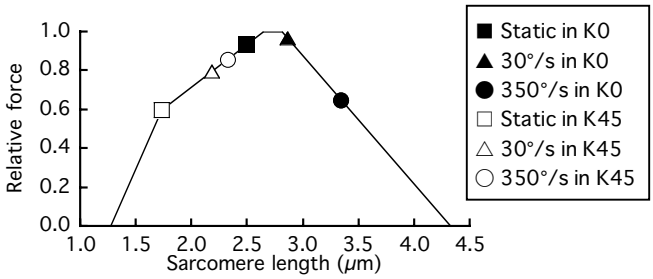

Figure 1: Estimated sarcomere lengths at peak tendon force and the length-force relationship of human sarcomeres[3].

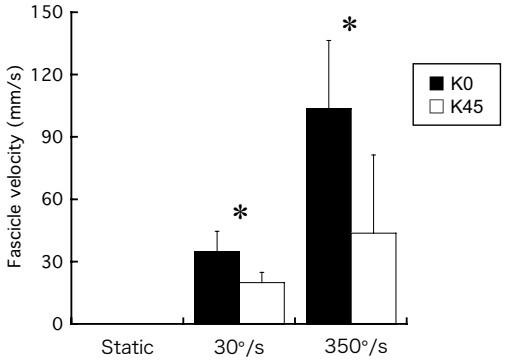

Figure 2: Shortening velocity of fascicle at the peak tendon force. * denotes a significant difference between K0 and K45.

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

1. Sale et al. *J Appl Physiol*. **52**, 1636-42, 1982
2. Fugl-Meyer et al. *Acta Physiol Scand.* **107**, 47-56, 1979
3. Walker & Schrodt. *Anat Rec*. **178**, 63-81, 1974

Table 1: Peak values of plantar flexion torque and tendon force, and mEMG of MG.

	Static		30º/s		350º/s	
	K0	K45	K0	K45	K0	K45
Peak torque (Nm)	122 ± 18**	92 ± 10	84 ± 13	70 ± 12	58 ± 10	57 ± 13
Peak force (N)	2653 ± 437*	2006 ± 257	1814 ± 289	1566 ± 276	1322 ± 229	1320 ± 295
mEMG of MG(μV)	198 ± 84	145 ± 61	221 ± 91	129 ± 36	325 ± 138*	157 ± 37

* denotes a significant difference between K0 and K45.