Effects of tendinous tissue on the torque–angle relationship of the knee joint

Takishita W., Takenaka M., Nagaoka D., Ogiso K.

Department of Education, Kogakkan University 1704 Kodakushimoto, Ise, Mie 516-8555 Japan (ogiso@kogakkan-u.ac.jp)

INTRODUCTION

The joint torque generated by muscle contraction depends on the joint angle. Behavior of the tendinous tissues to which muscle fibers are attached is also likely to influence the torque–angle relationship. In general, the more the joint is passively extended, the greater the slack in tendinous tissues of extensor muscles. If the tendinous tissue does influence the torque–angle relationship, the discrepancy between length of muscle shortening and joint torque will increase as the joint is extended. This study was designed to clarify the relationship between joint torque and fascicle behavior in vivo and to examine the indirect contributions of tendinous tissues to joint torque.

METHODS

Subjects

◆ Fifteen healthy men (age, 21.2 ± 1.0 years; height, 172.0 ± 5.8 cm; weight, 68.5 ± 7.1 kg)

Protocol

◆ Voluntarily (VOL) and electrically isometric knee extensions at knee joint angles of 30º, 60º and 90º (0º = full extension).

◆ In the voluntary condition

・ Knee joint torque (KJT) was increased at the same rate every 3s and let it reach the maximum in 27 s.

・The maximum KJT was measured beforehand at 30º (59.7 ± 21.1 Nm), 60º (121.4 ± 34.2 Nm) and 90º (138.7 ± 49.4 Nm), and divided into 9 intensity levels.

◆ In the electrical stimulation

・ Electrical stimulation (ES) at 20 Hz was applied to the vastus lateralis muscle (VL) in the same way as voluntarily.

・ The maximum ES was defined as the highest tolerable intensity (38.1 ± 14.9 mA), and divided into 9 intensity levels.

Date processing

◆ VL activity and movement were measured by electromyography (EMG) and ultrasonography (USG), respectively.

◆ Five points were digitized from USG.

・ Point (P) where a fascicle arises from the deep aponeurosis.

・ F_5, F_{10} and F_{15} on the fascicle 5 mm, 10 mm and 15mm horizontally from P, respectively.

・ D_5, D_{10} and D_{15} on the deep aponeurosis 5 mm, 10 mm and 15mm horizontally from P, respectively.

◆ Three pennation angles ($\angle F_5$ P D_5, $\angle F_{10}$ P D_{10} and $\angle F_{15}$ P D_{15}) were calculated from USG.

RESULTS

In voluntarily condition, strong positive relationships were observed between EMG and KJT at all knee joint angles (Fig.1). In electrical stimulation, KJT was almost constant at 30º regardless of ES intensity. As the knee joint angle became larger, positive relationships between ES intensity and KJT became gradually stronger. The smaller the knee joint angle, the larger P moved in the proximal direction (Fig.2) and the larger the pennation angle became (Fig.3), completely opposite to the result in VOL, where movement of P increased and the pennation angle decreased with knee joint angle.

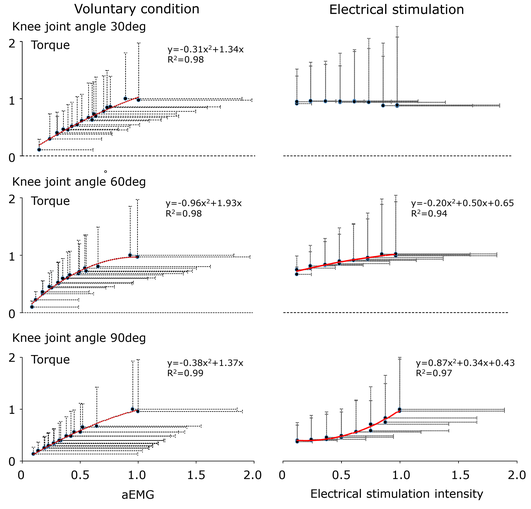

Fig.1 Relationships between KJT and aEMG in voluntary condition (left), and ES intensity in electrical stimulation (right). Values in the X-axis are represented at the ratio to values at the maximum KJT or at the maximum intensity of electrical stimulation, respectively. Values in the Y-axis are also represented at the ratio to values at the maximum KJT.

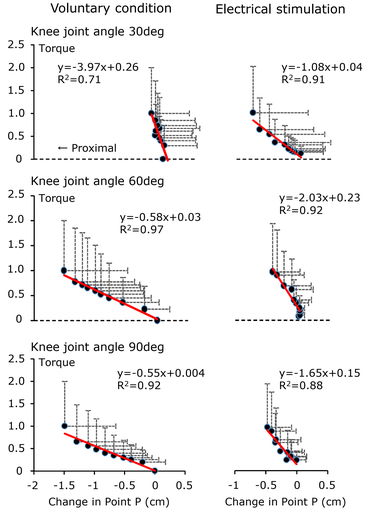

Fig.2 Relationships between KJT and movement of the point P in the proximal direction in voluntary condition (left) and in electrical stimulation (right). Values in the Y-axis are represented at the ratio to the maximum KJT.

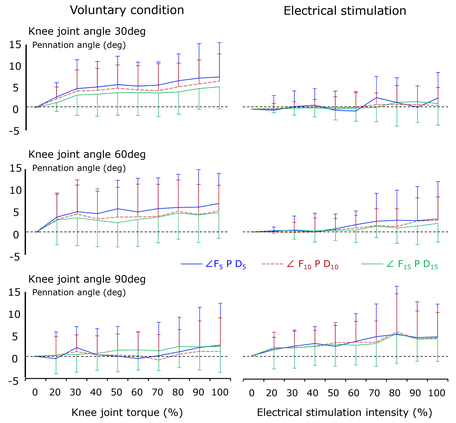

Fig.3 Changes in 3 pennation angles in voluntary condition (left) and in electrical stimulation (right) with the increases in KJT and ES intensity, respectively.

DISCUSSION

Maximum KJT evoked by ES (5.9 ± 7.5 Nm) was much smaller than that exerted by voluntary contraction. An interaction between the small KJT and muscle slack may explain the relationships among KJT, ES intensity, and P movement in the electrical stimulation. It is likely that tendinous tissue slack at more extended positions allowed for greater muscle length contraction but that the small force evoked by ES could not be transmitted to the joint. This is consistent with the increase in KJT with ES intensity at more flexed knee angles. In conclusion, joint torque was influenced not only by sarcomere length and moment arm but also by behavior of tendinous tissue.

REFERENCES

Lieber RL, Boakes JL. (1988) Am J Physiol, 254, 759-768.