INTRODUCTION: Recently, a significant decrease in deep knee flexion torque has been reported after harvesting the semitendinosus (and gracilis) tendon to be used as a replacement graft during anterior cruciate ligament (ACL) reconstruction [1]. A previous study suggested that the semimembranosus (SM) and biceps femoris (BF) cannot compensate for the loss of function of the original semitendinosus (ST) due to anatomical differences between the muscles [2]. These anatomical differences may produce differences in the activity of each hamstring muscle throughout the range of knee flexion. The purpose of this study was to investigate the relationship between electromyographic (EMG) activity of the hamstring muscles and knee flexion angle during isometric knee flexion. The hypothesis was that anatomical differences in each hamstring muscle may produce differences in EMG activity throughout the range of isometric knee flexion.

METHODS: Ten healthy males (age: 25±2 years, body height: 172±2.2 cm, body weight: 65±9.5 kg) participated in this study. All procedures were performed in accordance with the ethical standards of the Committee on Human Experimentation at the University of Tokyo. Informed consent was also obtained from all subjects.

Subjects were seated in a prone position with 0 degrees of hip flexion and 0 degrees of tibial rotation. At every 15 degrees of knee flexion from 15 to 105 degrees, each subject performed isometric flexion of the right limb for 5 seconds with maximum voluntary contraction (MVC), 50% MVC and 25% MVC. Isometric knee flexion torque was measured using an isokinetic dynamometer (CYBEX 770 NORM, CYBEX International, Inc., USA). EMG activity of the ST, SM and BF were also measured using bipolar urethane coated stainless steel fine wire electrodes (UNIQUE MEDICAL Co., LTD., Japan). The diameter of each electrode was 25 µm. Two millimeters of each electrode tip was exposed and the inter-tip distance was 5 mm. Electrodes placement was determined after confirming the location of the muscle belly using an ultrasonic apparatus (SSD-2000, Aloka, Japan). Each pair of electrodes was inserted into the muscle belly of the ST, SM and BF by an orthopaedic surgeon using a 25-gauge needle. Electrode depth was confirmed by palpation of the muscle using an electrical stimulator (EMG Electronic Stimulator SE-4201, NIHON KOHDEN Corp., Japan). The EMG signals and torque data were simultaneously digitized at a sampling rate of 1000 Hz and were recorded on a personal computer. Root-mean-square (RMS) values were calculated from each EMG data. The average RMS values were calculated with respect to a 3-s period for each contraction level (MVC, 50% MVC and 25% MVC). The average RMS values were normalized to those values at 60 degrees of knee flexion during MVC. The torque values were corrected to account for differences in the subject’s body weight.

All data were expressed as mean±SD. A two-way repeated measure ANOVA was used to determine the effect of muscle and angle of knee flexion on the normalized RMS value at each contraction level. The level of significance was set at p<0.05.

RESULTS: Knee flexion torque was highest at 15 degrees of knee flexion and decreased as the angle of knee flexion increased (Table 1). Two-way ANOVA yielded statistically significant interaction effects for all contraction levels (p=0.043 at MVC, p=0.0034 at 50% MVC, p=0.0001 at 25% MVC). Statistically significant main effects between each muscle were found for all three contraction levels (p=0.0229 at MVC, p=0.0069 at 50% MVC, p=0.0123 at 25% MVC). Statistically significant main effects between each knee flexion angle were only found during MVC (p=0.0410 at MVC, p=0.1789 at 50% MVC, p=0.1897 at 25% MVC). At each contraction level, the normalized RMS values of the ST and the BF decreased during isometric knee flexion at deeper flexion angles, while those values of the ST remained relatively constant at deeper angles of knee flexion (Fig. 1).

DISCUSSION: The changes in EMG activity of the ST as a function of knee flexion angle were different than those of the SM and the BF at every contraction level. The differences in EMG activity between the muscles may be influenced by the differences in the anatomical features of the hamstring muscles; i.e., the ST is a parallel fibered muscle with a longer fiber length than the SM and BF which are unipennate muscles.

EMG activity of the ST remained constant at deeper knee flexion angles, whereas those of the SM and the BF decreased during deep knee flexion. This result suggests that the activity of the ST plays an important role in producing knee flexion torque at deeper flexion angles for every level of muscle contraction.

The results of this study support our previous study that the SM and BF could not compensate for the loss of function of the ST in deep knee flexion [2]. Difference in the activity of the ST, SM, and BF may also influence the decrease in deep knee flexion torque after harvesting the ST tendon for ACL reconstruction.

REFERENCES:

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Table 1. Knee flexion torque during MVC

<table>
<thead>
<tr>
<th>Knee angle (deg.)</th>
<th>15</th>
<th>30</th>
<th>45</th>
<th>60</th>
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<th>105</th>
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<td>Torque (Nm/kg)</td>
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<td>0.35</td>
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<td>0.17</td>
<td>0.11</td>
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Fig. 1. Change in normalized RMS values of each muscle with respect to the knee flexion angle during (a) MVC, (b) 50% MVC, (c) 25% MVC.