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Torque-velocity Relationships during Concentric and Eccentric Contractions of the Quadriceps

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The purpose of this study was to investigate torque-velocity relationships during concentric and eccentric contractions of the quadriceps. Thirteen healthy female volunteers (mean age, 19.5±1.2 years) participated in this study. Isokinetic peak torque and peak angle of the quadriceps were measured during concentric and eccentric contractions at three different angular velocities of 30°/sec, 60°/sec and 90°/sec using a Rehamate, isokinetic dynamometor. Concentric peak angle decreased significantly as angular velocity increased from 30°/sec to 90°/sec ($p<0.01$). On the other hand, eccentric peak angle increased significantly with the increase of angular velocity ($p<0.01$). Concentric peak torque decreased significantly as angular velocity increased from 30°/sec to 90°/sec ($p<0.01$). Although eccentric peak torque showed no significant differences among 30°/sec, 60°/sec and 90°/sec, it was significantly greater than concentric peak torque at each angular velocity ($p<0.01$). E/C ratio showed significantly higher values with the increase of angular velocity ($p<0.01$). The results suggested that the differences between concentric and eccentric torques became larger as angular velocities increased.

Key Words
Torque-velocity relationships,
Concentric contraction,
Eccentric contraction,
Quadriceps.

INTRODUCTION

Increased interest in characteristics of muscle performance have led clinicians and physical therapists to contribute to assessment of muscle strength in various conditions. The most commonly used protocol of evaluation has included the testing of isometric and isokinetic muscle strength. Many studies have put focus on peak torque or angular specific torque at various angular velocities during concentric contraction, however, the number of reports concerning eccentric muscle strength is relatively limited. In the previous investigation on concentric contraction, peak torques decreased during increasing angular velocity. For eccentric contraction, it is generally agreed that the eccentric torque is greater than the concentric torque in maximum voluntary contraction (1–15), when compared at various speeds of joint movement. On the other hand, there is a controversy in eccentric torque-velocity relationships (6–15). The patterns of eccentric torque-velocity relationships in previous studies can be divided into three types; the first is an eccentric torque increase (6,7), the second is eccentric torque decrease after an initial increase (8–10,15), and the

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third is an unchanged eccentric torque (11,12) during increasing angular velocity.

The purpose of this study was to investigate torque-velocity relationships during concentric and eccentric contractions of the quadriceps.

MATERIAL AND METHOD

1. Subjects

Thirteen healthy female volunteers (mean ages, 19.5±1.2 years) participated in the study after giving informed consent to undertake and complete this study. None of the subjects had any previous history of hip, knee and ankle injury and were engaged in any sort of competitive exercise. They had taken part in sports occasionally, at a recreational level.

2. Test Procedure

The Rehamate (Kawasaki heavy industries Ltd. Japan), which was computerized strength testing apparatus, was used to obtain maximum voluntary concentric and eccentric torques of the quadriceps muscle for all subjects. After the subjects were laied on a bed in a supine position, secured around the thigh and across the pelvis with stabilizing straps, they were instructed to hold the side-guardrail of the bed with both hands. Each subject was coupled to dynamometer by aligning the lateral femoral condyle with the axis of rotation of the dynamometer, and attaching the ankle cuff proximal to the lateral malleolus.

Dynamic quadriceps strengths of the left leg were measured during concentric and eccentric contractions within the angle range of 5° to 100° (0° = fully extended leg) at three different angular velocities of 30°/sec, 60°/sec and 90°/sec. The highest torque from three maximum efforts was considered to be peak torque, and the knee angle at the peak torque was used as the peak angle.

3. Data Analysis

All data were stored in a computer. Simple descriptive statistical analyses were performed on all variables. These analyses included the means and standard deviations of peak torque and peak angle in each speed (30°/sec, 60°/sec and 90°/sec) in both concentric and eccentric contractions. The E/C ratio, which was expressed as percentage of eccentric peak torque / concentric peak torque × 100, was calculated for the determination of the numerical differences between eccentric peak torque and concentric peak torque at each angular velocity. Statistical calculations comparing the differences between mean values were made with an analysis of variance (ANOVA) and a student's T test. The 0.05 level was adopted as the minimal level for statistically significant differences throughout testing.

RESULTS

Means and standard deviations of peak angles and peak torques in each condition are presented in Table 1 and Table 2, respectively. Concentric peak angle decreased significantly as angular velocity increased from 30°/sec to 90°/sec ($p < 0.01$). Eccentric peak angle, on the other hand, increased significantly with increasing angular velocity ($P < 0.01$). Concentric peak torque decreased significantly as angular velocity increased from 30°/sec to 90°/sec ($p < 0.01$). Eccentric peak torque showed no significant differences among 30°/sec, 60°/sec and 90°/sec. Eccentric peak torque was significantly greater than concentric peak torque at all angular velocities ($p < 0.01$).

Table 1 Mean and standard deviation of peak angle in concentric(CON) and eccentric(ECC) contractions of the quadriceps.

Measuerd Variable	30°/sec	60°/sec	90°/sec	P
Peak angle(degree)				
CON	70.5±9.3	64.4±14.8	61.6±8.5	0.01
ECC	77.1±12.9	82.7±7.3	86.8±8.8	0.01

Table 2 Mean and standard deviation of peak torque in concectric(CON) and eccentric(ECC) contractions of the quadriceps.

Measuerd Variable	30°/sec	60°/sec	90°/sec	P
Peak torque(kgm)				
CON	10.6±1.9	7.4±1.9	6.6±1.6	0.01
ECC	14.4±2.5	15.0±1.7	15.1±1.8	NS

Table 3 Mean and standard deviation of E/C ratio [eccentric peak torque / concentric peak torque × 100(%)] at each angular velocity.

Measured Variable	30°/s	60°/s	90°/s	P
E/C ratio	136±34	218±72	246±79	0.01

E/C ratio showed significantly higher values with increasing angular velocity as presented in Table 3 ($p < 0.01$). The results suggested that the differences between concentric and eccentric torques became larger as angular velocities increased.

DISCUSSION

1. Concentric and Eccentric Muscle Actions

In this study, eccentric peak torques were greater than concentric peak torques at three angular velocities. These results were supported with a number of previous studies (1–15). Komi (7) reported that eccentric elbow flexion force was nearly twice as large as concentric force at 120°/sec. Rodger et al (8) found eccentric torque to be nearly twice as large as

concentric torque at 45°/sec in the measurement of elbow flexor strength. In our study, eccentric peak torques were 136%, 218% and 246% of concentric peak torque at 30°/sec, 60°/sec and 90°/sec, respectively.

We performed the measurements of torque produced by the quadriceps under the conditions of maximal concentric and eccentric contractions. Maximally activated muscle contractions would be expected in both conditions, while produced torques were larger in eccentric conditions than in concentric conditions and this phenomenon was more pronounced in higher angular velocity. Such phenomenon could be found in the value of E/C ratio. An interesting speculation can be made concerning the muscle elastic components utilized in eccentric contraction phase. Muller et al(16) presented a theory that overstretching of muscle elastic components (i.e., tendons, connective tissue among fibers and fibrils, and elastic elements in the sarcolemma) along with the accompanying delay in the recoil would serve as an additional stimulus to increase the force produced by muscle contraction. Assuming that the role of the viscoelastic elements in the muscle are minor during the concentric contraction, concentric torque can be consider to the amount of strength which independent torque generators —cross bridges — are able to produce the attachment — pull — detachment cycles completed in maximal concentric contraction. During eccentric contractions, the contributors to the torque output generated by muscle are not only the cross bridge attachment but also the other elastic components of muscle. Therefore, the muscle elastic components might contribute to the effective torque production much more in the eccentric condition than in concentric condition.

2. Torque-velocity Relationships

When the dynamic strength is expressed as torque, it depends on the level of angular velocity and types of contraction (8–15). The concentric torque-velocity relationships found in this study were consistent with the findings obtained in previous studies, which have demonstrated that peak torque decreased with increasing angular velocity. In the study of eccentric condition, there are a few variances in the relationship of torque-velocity(6–12,15). According to Hill's classic work(17), the eccentric force increased as stretching velocity of muscle increased. On the other hand, in our study, eccentric peak torque showed no significant differences among 30°/sec, 60°/sec, and 90°/sec. The results of our study were supported by Westing et al (12), who reported in their recent study that peak torque did not significantly change from low speed of 30°/sec to high speed of 270°/sec during the eccentric trials. It is not surprising that a certain degree of differences in the results of force-velocity relationships exists between Hill's study(17) and our study, because the former experiments was performed in isolated muscle in vitro and optimum conditions, while the latter was performed in vivo i.e., the complete system with nerve, muscle, tendon and skeleton.

A possible reason for no remarkable increase in eccentric torque with increasing velocity in the present study is that neural mechanisms might restrict the maximal tension in a muscle by an inhibitory feedback loop (Ib inhibition) evoked by the excessive stretch intensity. This hypothesis was supported by Westing et al (12). As the tension restricting mechanism has been suggested to maintain a maximum "safe" tension level during isometric and low velocity concentric

contractions, the tension is probably not allowed to rise above the level in usual conditions(12,18,19). Therefore, it is likely that the neural inhibiting factors may contribute to the constant of eccentric peak torque output in spite of the increase in velocity. We hope further investigations for various muscles will confirm our findings.

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