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Quadriceps torque curve pattern in patients with anterior cruciate ligament injury

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Abstract We measured torque curve pattern and quadriceps muscle strength with the knee slightly flexed in 48 patients with an anterior cruciate ligament injury, and analyzed the factors associated with reduced quadriceps strength. Strength was measured under isokinetic contraction, and concentric and eccentric contractions were studied. Strength was significantly lower in the injured knee, which also showed abnormal patterns of torque curve. In addition to the rapid downward slope pattern usually associated with concentric contraction, there was a concave pattern during eccentric contraction.

Résumé Nous avons mesuré le moment de rotation et la force du quadriceps à la flexion légère du genou chez 48 malades ayant une lésion du ligament croisé antérieur (ACL), et a analysé les facteurs associés à l'affaiblissement de la force quadricipitale. La force des quadriceps a été mesurée sous contraction isocinétique, et les contractions concentriques et excentriques ont été étudiées. La force des quadriceps était considérablement inférieure sur le genou blessé comparé au genou opposé, indemne. Le genou blessé a aussi montré des modèles de moment de rotation distinct des modèles normaux. En plus de la rapide décroissance habituellement rapportée pendant la contraction concentrique, un modèle concave a été observé pendant la contraction excentrique.

Introduction

Patients with an anterior cruciate ligament (ACL) injury develop weakness in the quadriceps muscle. However,

characteristics of this weakness have not been well documented. The contraction of a muscle may be isometric, isotonic, or isokinetic; it also may be categorized according to the orientation of movement into concentric or eccentric contractions. Many movements in various sports, such as jumping, landing, and abrupt changes of direction require eccentric contraction. The recovery of muscle strength is important to rehabilitation after injury to the ACL or after reconstruction. Many studies of muscle strength after ACL injury have shown peak torque values during concentric contraction. There is very little information available, however, on torque curve pattern and quadriceps strength during eccentric contraction with the knee slightly flexed, as occurs in episodes of giving way. Thus, in knees with an ACL injury, we studied the torque curve pattern and quadriceps strength with the knee slightly flexed, and analyzed the factors associated with weakness.

Materials and methods

Forty-eight men with a mean age of 26 (18–35) years with an ACL injury and who had not undergone reconstructive surgery were recruited for the study. The ACL injury was unilateral and diagnosed by arthroscopy, a positive Lachman and anterior drawer test, and the characteristic appearances on MRI. The interval between injury or its confirmation by arthroscopy was more than 12 months, in order to avoid the effect of weakness due to pain. Mean interval was 15 months. Exclusion criteria included instability due to injury to other ligaments and symptoms such as locking caused by meniscal damage. Quadriceps strength was measured isokinetically using Biodex system 3 (Biodex Medical Systems, Inc., New York, USA) during concentric and eccentric contractions. At an angular velocity of 30°/s, a measurement was made for a to-and-fro excursion from 0° to 100° of the knee and repeated three times. Peak torque value and quadriceps torque pattern were analyzed. Parameters measured were the peak torque value per body weight (unit: feet–pounds/pounds×100), the angle of the knee at the peak torque, and the torque value per body weight at 30° knee flexion (unit: feet–pounds/pounds×100). Statistical significance was determined by Student's *t*-test.

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Fig. 1 Torque curve pattern in relation to type of contraction and to state of anterior cruciate ligament (ACL)

Results

Peak torque value per body weight

Mean torque value per concentric contraction was 78 ± 19 on the uninjured side and 66 ± 19 on the injured side (injured/uninjured ratio: 85%). The difference was statistically significant ($P < 0.01$). Knee angle at peak torque was $71 \pm 5^\circ$ on the uninjured side and $74 \pm 6^\circ$ on the injured side. This difference was not statistically significant. For eccentric contraction, the mean peak torque was 106 ± 29 on the uninjured side and 84 ± 24 on the injured side (injured/uninjured ratio 79%). This difference was statistically significant ($P < 0.01$). Knee angle at peak torque was $79 \pm 6^\circ$ and $80 \pm 9^\circ$ on the uninjured and injured sides, respectively. This difference was not statistically significant.

Torque values per body weight at 30° knee flexion

Mean torque during concentric contraction at 30° flexion was 38 ± 11 on the uninjured side and 31 ± 13 on the injured side (injured/uninjured ratio: 82%). This difference was statistically significant ($P < 0.01$). Mean torque value during eccentric contraction at 30° flexion was 49 ± 19 on the uninjured side and 37 ± 19 on the injured side (injured/uninjured ratio: 76%). This difference was also statistically significant ($P < 0.01$).

Torque curve pattern

Stratford et al. [8] reported a rapid downward pattern (Fig. 1) of the torque curve slope during concentric contraction, with a sharp descending curve from the peak torque to the torque at slight knee flexion. During concentric contraction in this study, this rapid downward pattern was seen on the uninjured side in two patients (4%) and the injured side in 11 (23%). In normal knees undergoing eccentric contraction, torque values from full extension to slight flexion usually have a convex curve). In the present study of patients with an ACL injury, however, a concave curve (Fig. 1) was seen on the uninjured side in seven patients (15%) and on the injured side in 31 (65%) (Table 1). Both the rapid downward slope pattern and the concave pattern were seen when the knees were in slight flexion.

Discussion

As Murray et al. [6] and Tegner et al. [10, 11] have reported, quadriceps strength in patients with an ACL injury is significantly reduced. Baugher et al. [1] also reported that quadriceps in patients with an ACL injury showed evidence of atrophy. Factors that may contribute to this weakness include atrophy due to reduced activity after injury, and impaired proprioception due to ACL damage. However, low muscular torque associated with ACL dysfunction may also contribute.

A review of the literature shows few reports of quadriceps torque curve in association with knee injuries. Kegerreis and Malone [5] reported different patterns of torque curve in the quadriceps associated with different injuries to the knee. Crocker [2] reported an abnormal torque curve in patients with patellar subluxation, which corrected after stabilization of the patella using a brace. Stratford et al. [8] showed a rapid downward slope torque curve pattern during concentric contraction in 25% of knees with an ACL injury, although this pattern was also found in 14% of normal knees, with a sensitivity of 25% and a specificity of 86%. In our study, the rapid downward slope pattern was seen also in 23% of knees with an ACL injury.

Impaired knee function presents as episodes of giving way in patients with an ACL injury when the quadriceps is under eccentric contraction, such as during landing and abrupt changing of direction. We therefore also investigated the torque curve during eccentric contraction and showed a significantly high incidence of a concave

Table 1 Results of torque curve pattern in relation to type of contraction and to state of anterior cruciate ligament (ACL)

		Uninjured ACL	Injured ACL
Concentric contraction	Normal curve	46	37
	Rapid down-slope curve	2	11
Eccentric contraction	Normal curve	41	17
	Concave curve	7	31

pattern in knees with an ACL injury, which has not previously been reported. These patterns may represent the characteristic muscular activity of knees with an ACL injury.

The relationship between quadriceps strength and forward displacement of the tibia has been described previously. Smidt [7] reported that during quadriceps contraction, a maximal forward shear force of 35 kg was exerted on the tibiofemoral joint when the knee was in 15° of flexion. Grood et al. [3] and Jurist and Otis [4] reported that when resistance is applied to the shin during quadriceps contraction, it acts to displace the tibia forward for the range of movement of the knee from full extension to slight flexion. Yasuda et al. [12] reported that 14% of quadriceps strength during isometric contraction at 5° knee flexion acted to displace the tibia forward. Takai et al. [9] reported that, in knees with an ACL injury, the forward movement of the tibia increased in proportion to the increase of quadriceps strength when the knee was in 30° of flexion. This suggests that the low quadriceps torque in patients with an ACL injury is due to the combined effects of loss of strength and reduced effect of the muscle due to biomechanical factors.

In the present study, we observed that, at slight knee flexion, in which position there is increased forward displacement of the tibial condyle, there were abnormal patterns of torque curve. Apart from the previously reported rapid downward slope during concentric contraction, we also found a new concave pattern during eccentric contraction, which has not been previously reported. These results indicate that impaired ACL function may be responsible for the low torque output when the knee is in slight flexion. The symptom of giving way in patients with an ACL injury is associated with eccentric quadriceps contraction at slight knee flexion and the related biomechanical changes in the proximal tibia.

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