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Original Article

A study of isokinetic strength and laxity with and without anterior cruciate ligament injury

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Abstract. [Purpose] The purpose of this study was to provide useful information for future treatments and to organize rehabilitation programs for anterior cruciate ligament injury by assessing isokinetic muscle strength and laxity of knee joints in athletes with anterior cruciate ligament injuries. [Subjects and Methods] Thirty-one high school athletes with anterior cruciate ligament injuries participated in this study. Isokinetic muscle strength at 60°/sec and anterior cruciate ligament laxity for non-involved and involved sides, classified on the basis of the severity of anterior cruciate ligament injury, were assessed. [Results] A comparison of isokinetic muscle strength measured from the non-involved and involved sides showed a significant difference in the maximum strength and knee flexor muscle strength. For laxity, a significant difference was observed in the anterior drawer test results obtained with a force of 88 N. [Conclusion] In conclusion, this study has shown that the assessment of isokinetic muscle strength and ligament laxity from athletes with anterior cruciate ligament injury should be utilized to provide baseline data for prevention and prediction of injury.
Kew words: Anterior cruciate ligament (ACL), Laxity, Isokinetic

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INTRODUCTION

Most common knee joint problems result from overuse of the knee joint and the resulting pressure and abrasion, as well as from weakness of the surrounding muscles due to instability[1, 2)]. As the knee is a complex joint, composed of the anterior and posterior cruciate ligaments (ACL and PCL) as well as medial and lateral collateral ligaments (MCL and LCL), a vicious cycle can result[3–5)], in which weakness of one ligament leads to weakness of other ligaments.

Making up 86% of restraining force in an anterior drawer test and constituting the axis of rotation, the ACL maintains stability of the knee joint[6, 7)]. Non-contact ACL injuries that occur from rapid change of direction while moving, improper landing, and hyperextension account for 72% of total ACL injuries, far exceeding that accounted for by contact ACL injuries[8–10)]. Therefore, in order to improve stability of the knee joint, it is desirable to promote muscle growth through isometric training and a balanced development of muscle strength and endurance[3, 11)]. Assessment of muscular function and stability provides both general people and athletes useful guidance[12, 13)] that is readily applicable to restoring balance in muscles, recovering from damage, and predicting injury risks[2, 14)]. Instability results in a malfunction, which is accompanied by the inability to maintain correct posture and problems in general motor abilities such as walk and stride[15, 16)]; therefore, preliminary research on the risk factors of ACL injury is important.

Assessment of muscle strength and laxity for non-involved (NIn) and involved (In) sides provides the gold standard for injury prevention and treatment in patients with ACL injury. In this study, functional capacity of athletes with ACL injury

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was compared by assessing isokinetic muscle strength and laxity, aiming to provide data useful for future treatments and organizing rehabilitation programs.

SUBJECTS AND METHODS

Thirty-one high school athletes (22 rugby players and 9 basketball players) with abnormal findings—past experience of ACL injury of grade 2 or under (grade 2 refers to mild ACL injury in which the ligament is partially torn, causing moderate instability)—participated in this study. Participants had the following general characteristics: average age=17.3 ± 1.4 years, height=179.1 ± 8.4 cm, and body weight=79.3 ± 14.6 kg. All the subjects understood the purpose of this study and provided their written informed consent prior to participation in the study in accordance with the ethical standards of the Declaration of Helsinki.

Depending on the severity, ACL injuries were divided into non-involved (NIn) and involved (In) sides. We evaluated functional capacity by the isokinetic muscle strength test on the knee joint and stability of the ACL by the laxity test. To evaluate the isokinetic muscle strength of the knee joint, a Humac Norm Test and Rehabilitation System (CSMi Medical Solutions, Stoughton, MA, USA) was used, and the peak torque (Nm) relative to the knee flexor and extensor torques at 60°/sec, peak torque/body weight (%), and bilateral balance ratio (%) were measured. After adjusting the axis of rotation of the dynamometer to correspond to the subject's knee joint, the lower leg and shaft length was adjusted to each subject's leg length to measure the peak torque. Moreover, we secured body parts that could hinder the application of external force on the joint according to repetitive femoral movements during knee flexion and extension exercises. In addition, the anatomical joint range of motion for each subject was controlled to prevent hyperextension or flexion relative to the knee joint. Knee flexion and extension exercises were performed five times at 60°/sec, and the contralateral side was measured after first measuring only the non-involved side. Furthermore, the gravity effect torque was corrected and used only to measure the torque of the knee joint.

For the laxity test, we excluded subjective judgments of the injury and pain and used a Kneelax 3 (Monitored Rehab Systems, Haarlem, the Netherlands) to obtain an objective assessment. The Kneelax3, along with KT-2000, is a knee ligament arthrometer often employed to provide objective measurements for cruciate ligament injuries[17]. The Kneelax 3 was calibrated before the measurements were performed to ensure reliability and eliminate errors in the data. Subjects assumed the supine position, and similar to the anterior drawer test, were asked to bend their knees to an angle of approximately 20–25° (Lachman position), while their soles were still touching the ground. We measured the non-involved side to the injury first. To measure the laxity of the cruciate ligament, a force sensor that measures each push and pull as a force value and a distance sensor to measure movement of the tibial tuberosity were used. Laxity was measured in terms of the distance traveled by the cruciate ligament according to the force from eight types of pressures caused by pulling (anterior) and pushing (posterior). The severity of injury was evaluated by measuring the laxity (at +88 N and +66 N), which served as the index employed for diagnosis of pathological laxity and the stability of ACL by compliance index.

All measured data were analyzed using IBM SPSS Statistics 20.0 (IBM Corp., Armonk, NY, USA), and the average and standard deviation (SD) values were extracted. We used the paired sample t-test to compare the non-involved and involved side functional levels, and $p<0.05$ was considered statistically significant.

RESULTS

Comparison results of isokinetic muscle strength measurement from athletes with ACL injuries for non-involved and involved sides (Table 1) showed a significant difference in the maximum strength ($p=0.012$) and the knee flexor muscle strength (normalized by the body weight, $p=0.027$) and a significant difference ($p=0.025$) in laxity of the ACL (obtained by anterior drawer test performed with an applied force of 88 N) (Table 2).

DISCUSSION

Associated with the movement of lower limbs, the knee extensor/flexor muscles and their strengths play a large role in one's movement and even in determination of injury possibilities. Strengths of the knee extensor/flexor muscles are important quantities in understanding the relationship between the severity of injuries and imbalance of the strengths[14]. The majority of functional impairment after ACL injury results from quadriceps weakness and the resulting instability[3, 4, 13]. The quadriceps weakness is a consequence of either failure to predict injury's risk factors or imbalance of flexor/extensor strengths, which occurs because of a lack of proper treatment required for recovery after injury. After the initial effects, other negative consequences such as loss of strength, limited range of motion, and secondary damages, which may even necessitate a surgical procedure, may occur. In light of these facts, the assessment of quadriceps strength has clinical importance for predicting ACL injury risks and functional recovery of the knee joint after a reconstruction surgery[10, 12].

In this study, isokinetic strengths of the knee extensor/flexor muscles were evaluated in order to predict the risk of ACL injury. Comparison results between non-involved and involved sides showed a statistical significance ($p<0.01$): the maximum strength was 127.7 ± 31.6 Nm (non-involved) and 117.3 ± 29.6 Nm (involved), and the normalized knee extensor strength

Table 1. Comparisons of isokinetic muscular strength of the knee joint (unit: Nm, %)

Variables		Non-involved side	Involved side
Peak torque (nm)	Extensors	200.3 ± 51.2	185.8 ± 46.0
	Flexors	127.7 ± 31.6	117.3 ± 29.6*
Body weight (% bw)	Extensors	248.9 ± 73.8	232.4 ± 68.8
	Flexors	157.9 ± 40.9	146.3 ± 40.4*
Ratio (%)		65.3 ± 12.8	65.1 ± 15.8

Values are mean ± SD, *p<0.05

Table 2. Comparisons of ACL laxity (unit: mm)

Variables	Non-involved side	Involved side
88 (N)	7.3 ± 2.6	6.5 ± 1.7*
66 (N)	5.9 ± 2.5	5.2 ± 1.5
Compliance index	1.5 ± 0.8	1.3 ± 0.7

Values are mean ± SD, *p<0.05, ACL: anterior cruciate ligament

to body weight was 157.9 ± 40.9 Nm (non-involved) and 146.3 ± 40.4 Nm (involved). Previous studies[18, 19], which also evaluated isokinetic muscle strengths from patients with ACL injuries, reported a functional instability with a deficit in quadriceps strength of over 17% in the involved side (compared to the non-involved side), similar to our results. Another study[20], in which 71 patients participated one year after reconstruction surgery, reported a deficit in the extensor muscle strength of 17.2 ± 12.2% and a deficit in the flexor muscle strength of 9.3 ± 8.4% (all measured at 60°/sec). Moreover, a study investigating the relationship between different deficits and quality of life found that the deficit in physiological function most highly correlated to the quality of life (r= −0.39, p=0.015) with the deviation of deficit less than 10%. The deficit range of the quadriceps strength serves as a criterion for an important clinical judgment; a deficit of less than 10% is considered the clinical milestone for returning an athlete back to sports[21]. Playing a major role in the quadriceps, the knee extensor muscle controls motion of the lower limbs and serves other important functions[22, 23] such as supporting body weight and maintaining body alignment and stability. Assessment of muscular function provides useful rehabilitation measures for both general people and athletes, and applies readily and safely to restoration of muscle balance, recovery from muscle injury, and rehabilitation[14, 24–26]. Therefore, the purpose of conservative treatments for patients with ACL injuries lies in strengthening the quadriceps and increasing functional stability through strength recovery.

The ACL prevents anterior tibial translocation relative to the femur and plays an important role in prevention of anterior dislocation of the knee joint[27] due to interoperative mechanisms of the quadriceps and hamstrings. In this study, assessment of ACL laxity by anterior drawer tests (at 88N) showed a statistical significance (p=0.025) with an anterior translation (0.8 mm) observed from the involved side (6.5 ± 1.7 mm) compared to the non-involved side (7.3 ± 2.6 mm). This suggests that the debilitating ACL's anterior translation leads to muscle weakness, which leads to instability, ultimately leading to an inability to maintain posture. However, a different study, which evaluated ligamentous laxity from the non-involved and involved sides of 40 male patients with ACL injuries, did not show a statistical significance, contrary to our results. This was attributed to the fact that the pivot shift of patients with ACL injuries greatly influenced the ability to maintain posture[28].

In conclusion, assessment of isokinetic muscular performance and ligamentous laxity from athletes with ACL injury should be used to provide baseline data for prevention and prediction of injury. Future studies toward having a more thorough database are anticipated, which will provide the framework for more efficient treatments for ACL injury.

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