



Original Article

Comparison of knee laxity and isokinetic muscle strength in patients with a posterior cruciate ligament injury

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Abstract. [Purpose] The aim of this study was to compare knee laxity and isokinetic muscle strength in patients with an isolated posterior cruciate ligament injury. [Subjects and Methods] Twenty high school rugby players with a previous posterior cruciate ligament injury and abnormal findings higher than surgical grade I were included. Laxity with 132 N of pressure was measured using Kneelax 3 to assess the stability of the posterior cruciate ligament, and flexor and extensor torques were measured at 60°/sec, 180°/sec, and 240°/sec to measure the isokinetic muscle strength of the knee joint. The average and standard deviation values were extracted from all data to assess the measured data. [Results] Regarding the ipsilateral and contralateral laxity, the deviation value at the peak force and maximum manual drawer was statistically significant. The peak torque and peak torque per body weight in isokinetic measurements were significantly different only for knee extensor torque at 60°/sec, 180°/sec, and 240°/sec. [Conclusion] Return to normal activities post injury is important. Thus base data gathered by comparing patients' ipsilateral and contralateral sides will serve as essential criteria for structuring future rehabilitation programs to facilitate functional improvements.

Key words: Isolated posterior cruciate ligament injury, Knee laxity, Isokinetic muscle strength

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INTRODUCTION

The knee joint is a complex joint that consists of anterior and posterior cruciate ligaments, medial and lateral collateral ligaments, and the meniscus. Therefore, simple and complex injuries can easily occur in the knee joint^{1, 2)}, and since it has a pathologically disadvantageous circular structure, the weakening of one ligament can weaken other ligaments^{3, 4)}. In the knee joint complex, the posterior cruciate ligament is located at the posterior side of the knee joint, preventing excessive extension and providing rotational stability⁵⁾. Moreover, because it limits the tibia from shifting dorsally to the femur, the posterior cruciate ligament is important for stabilizing the knee joint^{6, 7)}.

Approximately 32% of various sports activities cause knee joint injuries⁸⁾, 72% of which are contactless injuries⁹⁾ and 28% of which are contact injuries¹⁰⁾. The frequency of posterior cruciate ligament injuries has been reported to range from 1–44%^{11, 12)}, and the accident rate of contact sports with many abrupt landings and turnabouts, such as football and rugby, is >40%^{13–15)}. The frequent site of injury in contact sports is the posterior cruciate ligament, and the stability of ligament laxity and muscle development are required to prevent instability and pain in the knee joint¹⁶⁾. When there are no associated ligament injuries, conservative treatment that improves elasticity of the ligaments and increases muscle strength can lead to a good prognosis¹⁷⁾. However, when left untreated, arthritis and patellar pain can occur in the patellofemoral joint¹⁸⁾.

The posterior cruciate ligament is twice as strong as the anterior cruciate ligament, and it has intrinsic healing abilities and plays an important role in stabilizing the knee joint^{2, 19)}. The posterior drawer laxity test for posterior cruciate ligament injury

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categorizes this injury into three grades (I, II, and III)²⁰). Conservative nonsurgical treatments are generally recommended for grade I (≤ 5 mm) and grade II (5–10 mm) isolated injuries or when the medial femoral plateau is pushed dorsally¹⁹). A reasonable assessment of the knee joint considers the torque level of the quadriceps and hamstring muscles, and can provide important data for determining intrinsic lesions^{21, 22}). Failure to treat the injury properly can result in instability of the knee joint, meniscal cartilage damage, and patellofemoral degeneration²³). Thus collecting base data may help surgeons manage these injuries.

Therefore, a comparative evaluation of knee laxity and isokinetic muscle strength in patients with a posterior cruciate ligament injury may provide optimal criteria for injury prevention and treatment. We aimed to use the present study's results as base data for future treatment and rehabilitation by assessing the ipsilateral and contralateral functional levels in patients with a previous isolated posterior cruciate ligament injury in accordance with their participation in sports by using laxity and isokinetic muscle strength tests.

SUBJECTS AND METHODS

Twenty high school rugby players with a previous posterior cruciate ligament injury in the knee joint and abnormal findings higher than a surgical grade I were included as subjects in the present study. The average age, height, and weight of the subjects were 18.8 ± 1.0 years, 177.2 ± 6.7 cm, and 76.7 ± 13.4 kg, respectively. Patients were divided into the ipsilateral and contralateral side groups according to the severity of their posterior cruciate ligament injuries. All the subjects understood the purpose of this study and provided written informed consent prior to participation in the study in accordance with the ethical standards of the Declaration of Helsinki. We conducted a laxity test to assess the stability of the posterior cruciate ligament and an isokinetic muscular strength test to evaluate the function of torque in the knee joint. For the laxity test, we excluded subjective judgments of the injury and pain and used Kneelax 3 (Monitored Rehab Systems, Haarlem, the Netherlands) to obtain an objective assessment.

The Kneelax 3 was calibrated before the measurements were performed to ensure reliability and eliminate errors in the data. Subjects asked to assume in the supine position, and similar to the posterior drawer test, they were asked to bend their knees to an angle of about $70\text{--}90^\circ$ while their soles were still touching the ground. We measured the side ipsilateral to the injury first. To measure the laxity of the cruciate ligament, we used a force sensor that measures each push and pull as a force value and a distance sensor to measure movement of the tibia tuberosity. Laxity was measured in terms of the distance traveled by the cruciate ligament according to the force from eight types of pressures (± 44 N, ± 66 N, ± 88 N, and ± 132 N) caused by pulling (+, anterior) and pushing (–, posterior). We used results from previous studies that measured and assessed laxity of posterior cruciate ligament injuries using the deviation value at the peak force of 132 N^{24–26}). In accordance with the guidelines from the manufacturer of the Kneelax 3, we also used the results for 132 N and the maximum manual drawer in this study.

To measure 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 $60^\circ/\text{sec}$, $180^\circ/\text{sec}$, and $240^\circ/\text{sec}$; 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, we then adjusted the lower leg and shaft length to each of the 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 three times at $60^\circ/\text{sec}$, 10 times at $180^\circ/\text{sec}$, and 20 times at $240^\circ/\text{sec}$, and the contralateral side was measured after first measuring only the ipsilateral side. Furthermore, the gravity effect torque was corrected and used only to measure the torque of the knee joint.

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

RESULTS

Laxity of the ipsilateral and contralateral sides of patients with a posterior cruciate ligament injury was statistically significant in terms of the deviation value and the maximum manual drawer at the peak force of 132 N, as shown in Table 1. Regarding the peak torque in the ipsilateral and contralateral sides of the patients with a posterior cruciate ligament injury, only the knee flexor torque at $60^\circ/\text{sec}$ ($p = 0.003$), $180^\circ/\text{sec}$ ($p = 0.002$), and $240^\circ/\text{sec}$ ($p = 0.000$) was statistically significant (Table 2). Peak torque per body weight was significantly different only for the knee flexor torque at $60^\circ/\text{sec}$ ($p = 0.009$), $180^\circ/\text{sec}$ ($p = 0.001$), and $240^\circ/\text{sec}$ ($p = 0.000$) (Table 3). In addition, the bilateral balance ratio was statistically significant at $180^\circ/\text{sec}$ ($p = 0.034$) and $240^\circ/\text{sec}$ ($p = 0.022$) (Table 4).

Table 1. Comparisons of PCL laxity

Variables	Non-involved side	Involved side
132 (N)	-2.0±1.0	-2.8±0.8***
MMD (mm)	2.7±1.2	3.9±1.0***

Values are shown as the mean±SD, ***p<0.001. MMD: maximum manual drawer

Table 2. Comparisons of peak torque of the knee joint

Variables (Nm)	Non-involved side	Involved side
60°/sec	Extensors	206.4±55.0
	Flexors	120.2±32.1
180°/sec	Extensors	123.7±29.9
	Flexors	81.3±22.3
240°/sec	Extensors	108.3±23.9
	Flexors	74.6±19.9

Values are shown as the mean±SD, **p<0.01, ***p<0.001

Table 3. Comparisons of peak torque/body weight of the knee joint

Variables (%)	Non-involved side	Involved side
60°/sec	Extensors	261.5±87.4
	Flexors	152.5±49.6
180°/sec	Extensors	156.1±49.6
	Flexors	102.7±37.6
240°/sec	Extensors	136.5±42.2
	Flexors	94.6±34.8

Values are shown as the mean±SD, **p<0.01, ***p<0.001

Table 4. Comparisons of bilateral balance ratios of the knee joint

Variables (%)	Non-involved side	Involved side
60°/sec	60.5±15.0	66.5±13.4
180°/sec	68.3±20.4	77.6±17.5*
240°/sec	72.5±25.9	84.0±20.6*

Values are shown as the mean±SD, *p<0.05

DISCUSSION

The posterior cruciate ligament has a large per unit area compared with the anterior cruciate ligament, and its stable force protects it from damage^{2, 19}. However, the accident rate of contact sports has been gradually increasing, and it is hypothesized that the posterior cruciate ligament has low consequences and recovery compared with other ligaments^{2, 15, 27}. In particular, because the rugby players in the present study participated in games without special protective gear, there was a high risk of injuring their posterior cruciate ligaments^{14, 28}. Similar to the present study, a cohort study by Lee et al.¹⁴ examined 1,169 rugby players and reported that 26% of them retired due to injury, of which >35% of cases were due to injury of the knee joint, including cruciate ligament injury.

Another previous study stability resulting from use of knee braces after posterior cruciate ligament reconstruction in patients according to severity of the pulled posterior ligament and found that stability was 4.1 ± 1.7 mm for general braces and 1.8 ± 1.3 mm for tibia support braces (p = 0.0006)². Similarly, the present study, which compared the ipsilateral (-2.0 ± 1.0 mm) and contralateral (-2.8 ± 0.8 mm) sides, also showed a statistically significant difference (p = 0.000) between the two sides. It was determined that more aggressive treatment on the contralateral side can ensure greater stability. To investigate instability of the posterior cruciate ligament while walking downstairs, Iwata et al.²⁵ examined laxity by categorizing

study subjects according to the presence of giving way. The results did not reveal a statistically significant difference, which was contradictory to the results of our study. However, when we examined the results more closely, stability of the group that did and did not experience giving way were 5.0 ± 3.1 mm and 4.8 ± 3.7 mm, respectively, and this indicated that posterior laxity of the ipsilateral side was stiffer than that of the contralateral side, which was similar to the trend observed in our study.

Fundamentally, the knee joint uses flexor and extensor muscles for stable movements²⁹⁾, and the extensor muscle plays a primary role in the quadriceps for important functions such as supporting weight, aligning the body, and ensuring stability^{30, 31)}. Knee flexor and extensor forces that largely affect leg movements can increase the possibility of injury due to accumulated leg movements, and this becomes an important criterion for resolving muscle imbalances and applying indices for the severity of muscle damage^{32, 33)}. In studies that conducted an isokinetic muscle strength test for the knee joint in terms of flexion and extension of the quadriceps and hamstring muscles, there was no difference in the knee flexor torque at each speed ($p > 0.05$), but there was a statistically significant difference in knee extensor torque ($p < 0.01$). It was determined that these results from comparison of the ipsilateral and contralateral isokinetic muscle strength can be attributed to a functionally unstable quadriceps due to insufficient extensor movement on the ipsilateral side.

Kim et al.³⁴⁾ compared the correlation of the effect of knee pain on the quadriceps torque, proprioceptive sense, and balance in 33 patients with knee osteoarthritis and evaluated the ipsilateral and contralateral sides of the corresponding patients. Although there was a significant difference in the knee extensor torque on both sides of the knee joint ($p < 0.05$), there was no difference in the knee flexor torque, which is similar to the results of the present study. Messier et al.³⁵⁾ studied torque and reduced stability in subjects with knee pain, as determined by 30 months of longitudinal observation, and reported that weakening of the quadriceps, which occurred in a group with chronic knee joint pain, was statistically significant compared with that of their control group. Furthermore, Lee et al.³⁶⁾ divided eight female patients with an isolated cruciate ligament injury into ipsilateral and contralateral side groups; they found that isokinetic exercises affected the rotational force of the knee joint and that isokinetic exercises had a statistically significant association between peak torque and peak torque per body weight, which is similar to the results of the present study.

As posterior cruciate ligament injuries are associated with a positive prognosis, conservative treatment is possible, but lesions such as abnormal agitation to the knee joint and early degenerative changes can become problematic. As a result, aggressive interventions, e.g., structured rehabilitation programs, may be required.

Therefore, because return to normal activities after injury is important, base data gathered by comparing patients' ipsilateral and contralateral sides will be important criteria for structuring future strategic rehabilitation programs to facilitate functional improvements.

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