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ORIGINAL STUDY

Comparison of Isokinetic Muscle Strength and Clinical Outcome between Isolated and Combined PCL Reconstruction

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The purposes of this study was to 1) compare the functional result and muscle strength between patients who underwent reconstruction by isolated posterior cruciate ligament (PCL) and combined PCL-poseterolateral corner sling (PLCS) reconstruction.
Nineteen (Group I: isolated PCL reconstruction) and 30 (Group II: combined PCL-PLCS reconstruction) were compared. The clinical results and isokinetic muscle strength were compared between groups.
The clinical results were comparable between groups and posterior stability was not different between the two groups, either. The isokinetic strength test result was not significantly different between the two groups, although absolute values of the flexion strength in Group I was higher than those in Group II. The HQ ratio of the affected side in Group I was similar to that of the contralateral side.
Isokinetic muscle strength, especially flexion, was not fully recovered as compared with the contralateral side in both groups, although clinical and stability results were improved. However, the isolated PCL reconstruction group that was managed with the accelerated rehabilitation protocol showed an HQ ratio similar to that of the contralateral side. Therefore, an earlier active strengthening program would be also necessary in PCL-PLCS reconstructed groups, and justification for prevention of early weight bearing in PCL-PLCS reconstruction should be re-evaluated because weight bearing is helpful for muscle strengthening.

Keywords: Knee; posterior cruciate ligament; reconstruction; Rehabilitation; Isokinetics.

INTRODUCTION

The keys to successful posterior cruciate ligament (PCL) reconstruction are to identify and treat all pathologies, use strong graft material, use an accurate surgical technique, ensure strong graft fixation, and use an appropriate rehabilitation program.*(3,8)* Posterolateral rotatory instability (PLRI) is frequently combined with PCL injury, and recognition and proper treatment of PLRI is important because it may affect the gait pattern, result in subjective complaints, and cause of failure of concomitant ligamentous reconstruction.*(13,31)* Posterolateral corner sling (PLCS) reconstruction

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for PLRI is frequently performed because it has several advantages, although the optimal technique for the treatment of PLRI has not yet been established.(9,10) An adequate rehabilitation protocol that is not harmful to stability is important for functional recovery. Traditional rehabilitation protocols after PCL or combined PLCS for PLRI reconstruction are not as well established as those for anterior cruciate ligament (ACL) reconstruction.(32) In contrast to ACL rehabilitation, accelerated PCL postoperative rehabilitation is generally undesirable, and most surgeons and physical therapist are using more conservative methods than those used for ACL reconstruction.(7,8) Delayed PCL postoperative rehabilitation can result in diminished hamstring activity due to the reduced demand on the PCL, much like diminished quadriceps activity reduces the demand on the ACL.(27,33) The negative aspects of these methods imply that it is possible to cause dysfunction to patients.

Muscle strength becomes critical for assessment of reconstructed ligaments and a rapid, uneventful return to pre-injury activities.(30) Quadriceps muscle strength has been shown to correlate with good outcomes after ACL reconstruction, but it is not well established for PCL or PLCS patients.(19) Evaluation of muscle strength can be accomplished using functional tools (hop test) or single-joint evaluation tools.(22,23) One of the most commonly used reliable tools to assess single-joint muscle strength is isokinetic dynamometry.(1,4,5)

Relatively more accelerated rehabilitation protocol as compared with other authors was used in this study (Tables 1 and 2).(26) After isolate PCL reconstruction, strengthening was encouraged within low grades of flexion and that early weight-bearing is started for co-contraction and proprioception, but range of motion (ROM) was similar to that of other protocols.(7,8,16,26) However, weight bearing and strengthening were delayed about 3 weeks after PCL-PLCS reconstruction although ROM and proprioceptive training were performed with similar protocol as like isolated PCL reconstruction. The purposes of this study were to 1) compare the functional result and muscle strength between patients who underwent reconstruction by isolated PCL and combined PCL-PLCS reconstruction and 2) to evaluate the efficacy of our relatively accelerated rehabilitation protocol and reevaluate the program according to the outcomes of this comparison. Our hypotheses were that 1) patients who underwent PCL-PLCS reconstruction would show a lower functional recovery and muscle strength than patients who underwent isolated PCL reconstruction and that 2) the more accelerated rehabilitation program would be needed in patients who underwent PCL-PLCS reconstruction.

MATERIALS AND METHODS

The study population comprised 171 patients who underwent primary PCL reconstruction between March 2006 and May 2011. The isolated PCL reconstruction was included as a case group and combined PCL-PLCS reconstructed group was included as a control group. PCL reconstruction was performed in the subacute (after about 3 weeks) or chronic stage because it was difficult to assess the instability in the acute stage. Patients had to be followed up for more than 2 years and had to agree to undergo clinical and muscle strength examinations. The exclusion criteria were an associated combined ACL injury, infection, revision surgery, combined lower extremity fracture, and prior surgery on the affected knee. Multi-ligament reconstructed patients such as combined ACL+PCL, ACL+PCL+PLCS, PCL+medial collateral ligament (MCL) repair or reconstruction were also excluded. However, meniscal injury that was treated as a meniscectomy or repair was included in this study. Institutional review board approval was obtained, and all patients provided informed consent for participation. The clinical results were evaluated in terms of Lysholm score, International Knee Documentation Committee (IKDC) subjective knee score, Tegner activity score, and side-to-side differences (KT-2000 arthrometer; MEDmetric, San Diego, CA) by an independent experienced 3rd party.

Isokinetic muscle strength measurements were performed with a dynamometer (Biodex System 3; Biodex Medical Systems, Shirley, NY) at postoperative 16.9 ± 7.3 months. Isokinetic muscle strength tests were performed at the common angles classified as 0° to 90°. Isokinetic muscle strength tests were performed in the concentric mode. For the evaluation of quadriceps and hamstring strength in the sitting position, patients were seated on the Biodex testing device with the chest, pelvis, and thigh immobilized with straps (figure 1). After measurement of the ROM of the knee joint in flexion and extension, the flexion angle of the knee joint was adjusted to 90°. Before starting the testing session, each patient completed a standardized stretching exercise program over a period of approximately 10 minutes. Two warm-up repetitions were then performed before measurement. After the patient had warmed up and was familiarized with the procedure, the measurements were repeated four times with an angular velocity of 60°/s. This angular velocity (60°/s) was used to evaluate muscle peak torque. Measurements were first taken on the contralateral side, then on the affected side. The peak torque value (the maximum value during the four repetitions) of the extensor and flexor muscles was assessed, and the measured value of the involved knee was compared with that of the contralateral knee. Isokinetic strength measurements were peak torque of the total range and the torque at 80° (strength of deep flexion). The hamstring-quadriceps (HQ) ratio was also calculated. Finally, for evaluation of recovery, the peak torque of the affected and contralateral sides was compared.

Demographic data, scores, and isokinetic strength tests were compared between the two groups using independent-sample *t* tests. The flexor peak torque between the affected versus contralateral sides was compared using a paired *t* test. All statistical analyses were performed using SPSS software (SPSS for Windows, release 18.0; SPSS, Chicago, IL). Significance was set at $p < 0.05$.

Under regional anesthesia, the patient was placed in the supine position. Instability of the knee joint was checked by the posterior and posterolateral drawer tests. If there was significant posterolateral rotation, PLCS reconstruction was performed simultaneously to correct the PLRI. The affected knee was hung free at the edge of the table in a 90° flexed position. The opposite limb was placed in a well-leg support with the knee and hip flexed, abducted, and externally rotated. A tourniquet was applied to the affected leg.

Figure 1. — For the evaluation of muscle strength, patients were seated on the Biodex testing device with the chest, pelvis, and thigh immobilized with straps

As the first step of the posterior trans-septal portal preparation, the posteromedial portal was made under direct arthroscopic visualization. Using the transillumination technique, the exact location for the posteromedial portal was marked by an 18G needle. By making a minimal skin incision and expanding the portal with a straight hemostat, the posteromedial portal was established. The posterolateral portal was made in a similar fashion. To create the trans-septal portal, a switching stick was inserted through the posteromedial portal to push the septum laterally and carefully create a hole. An arthroscope was inserted through the posteromedial portal. A motorized shaver was inserted through the posterolateral portal to widen the septum.

When using a Tibialis tendon allograft for PCL reconstruction, an assistant simultaneously prepared the allograft at a side table. The diameter was 8 to 9 mm. At the end of the tendon, No. 5 Ethibond (Ethicon, Somerville, NJ) was used to place whipstitch sutures.

A transtibial tunnel for the PCL graft, which was usually between 8 and 9 mm in diameter, was made depending on the diameter of the graft, while taking care not to damage the remnant PCL stump. Care was taken to protect any neurovascular structures during the process of drilling and reaming with the guide pin. For an graft passage, a new accessory portal was made below the anterolateral portal. A wire loop was inserted through the tibial tunnel and taken out to the accessory portal.

The retained anterolateral bundle of the PCL femoral attachment was detached with the shaver so that the central portion was exposed. This location is 7 mm posterior to the distal border of the articular cartilage of the medial femoral condyle, which is at the 1-o'clock position in the right knee and the 11-o'clock position in the left knee. The femoral tunnel was formed in an inside-out fashion. After formation of the femoral tunnel, the guide frame was inserted into the femoral socket and two pinholes were drilled, leaving two sleeves for the insertion of the cross-pins (RIGIDfix System; Mitek, Johnson & Johnson, USA).

While keeping the knee in a reduced position, the graft was fixed to the tibial tunnel with two bioabsorbable interference screws and an additional staple fixation was performed for firm fixation of the graft. After the graft fixation, instability of the joint was checked again by the posterior and posterolateral drawer tests. If there was significant posterolateral translation after the PCL reconstruction, a PLCS reconstruction operation was performed simultaneously to correct the PLRI.

The indication for PLCS reconstruction for PLRI was determined by thorough physical examination, examination under anesthesia, and arthroscopic examination. We performed PLCS reconstruction if PLRI of grade II or more was detected. Two femoral tunnels were made just proximal to the anatomical locations. The fibular head tunnel was directed from the anterior–inferior superficial aspect to the posterior–superior deep location and was made at the distal portion of the anatomical insertion sites, 6 mm in diameter. A commercially prepared tibialis anterior allograft was prepared as graft material.

Detailed rehabilitation protocols are described in Tables 1 and 2. The main differences between Groups I and II were in the strengthening exercise (immediate vs. postoperative 6 weeks) and weight bearing (immediate full vs. 6 weeks full). A delayed approach was recommended if associated PLRI was present because external rotation of the tibia could occur to compensate for foot pronation. Brace was usually maintained for the first postoperative 6 weeks and the determination of the brace-off was dependent on the status of the patient.

Table I. — Rehabilitation of isolated PCL reconstruction

	1-3 weeks	**4-6 weeks**	**6-12 weeks**	**12-24 weeks**	**24 weeks -**
Weight bearing	-Tolerable or Full weight bearing with crunch				
ROM	Immediately CPM in prone position	To 90 degrees	To 120 degrees		
Strength	Q-set, SLR Calf-raise Mini squat (0~30deg)	CKC & OKC Isometric to 30 degrees	Isotonic exercise without hamstring curl	Light Hamstring curl exercise start	
Proprioception		Muscle coordination	ballance		
Return to sports				Allow light running within muscle defict 30%	Allow sports specific activation within muscle defict 15 %

Table II. — Rehabilitation of combined PCL and PLCS reconstruction

	1-3 weeks	4-6 weeks	6-12 weeks	12-24weeks	24weeks -
Weight bearing	-Partial weight bearing With crunch, Full extension lock		Full weight bearing		
ROM	Immediately CPM in prone position	To 90 degrees	To 120 degrees		
Strength	Q-set, SLR	Q-set, SLR Calf raise Minisquat	CKC & OKC Isometric to 30 degrees	Light Hamstring curl exercise start	
Proprioception		Muscle coordination	ballance		
Return to sports				Allow light running within muscle deficit 30%	Allow sports specific activation within muscle deficit 15 %

RESULTS

Forty-nine patients fulfilled the above-mentioned criteria. For comparison, we divided the patients into two groups. The total numbers of patients were 19 (Group I: isolated PCL reconstruction) and 30 (Group II: combined PCL-PLCS reconstruction). The ratio of male:female patients was 27:3 in Group I and 18:1 in Group II. The mean follow-up period was 28.9 months (range, 20–48 months). In the comparison between preoperative and final follow-up clinical results, Lysholm, IKDC, and Tegner knee scales were significantly improved at the last follow-up as compared with preoperative values ($p < 0.05$). In the comparison of the last follow-up clinical results between Groups I and II, there were statistically significant differences in the Lysholm (94.6 ± 5.4 vs. 87.5 ± 10, $p = 0.007$) and IKDC (88.5 ± 10 vs. 79.7 ± 14.1, $p = 0.014$) scores, but there were no statistically significant differences in the Tegner activity score (5.6 ± 1.6 vs. 4.9 ± 1, $p = 0.117$) and side-to-side difference on the KT-2000 arthrometer (4.5 ± 3 vs. 4.7 ± 2.7, $p = 0.76$).

Isokinetic muscle strength was not significantly different in any of the variables, although Group I showed higher flexion strength on both the affected and contralateral sides as compared with Group II (Table 3). The flexion strengths of the affected and contralateral sides showed no statistical differences in either low-grade 30° flexion (flexion peak torque) or deep flexion (80° flexion) between both groups (Table 3). The affected sides showed statistically significant lower strengths than the contralateral sides (Table 4). Groups I and II showed no statistically significant difference in the HQ ratio (Table 3). However, the HQ ratio of the affected side in Group I was not statistically significantly different from that of the contralateral side, although the HQ ratio of the affected side in Group II was significantly higher than that of the contralateral side (Table 4).

DISCUSSION

The principle findings of this study were that 1) the clinical results were comparable between groups and posterior stability was not different between the two groups, either; 2) the isokinetic strength test result was not significantly different between the two groups, although absolute values of the flexion

Table III. — Comparison of isokinetic strength of the study groups

Variable	Group I	Group II	P values
Contralateral FPT*/BW†	126.6 ± 27.4	120.6 ± 36.5	0.546
Affected FPT*/BW†	108.2 ± 22.9	96.2 ± 38.6	0.177
Contralateral FPT*/BW† (80°)	67.6 ± 22.6	55.6 ± 24.1	0.112
Affected FPT*/BW† (80°)	50.1 ± 22.4	39.4 ± 19.8	0.109
Contralateral H/Q‡ ratio	52.6 ± 6	50.7 ± 7.7	0.377
Affected H/Q‡ ratio	53.7 ± 21.8	59.9 ± 18.7	0.247

*: flexor peak torque, †: body weight, ‡: hamstring/quadriceps. These data are mean ± standard deviations

Table IV. — Comparison of isokinetic strength between affected and contralateral sides

Variable	Group I	Group II
FPT*/BW†	0.01[§]	<0.001[§]
FPT*/BW† (80°)	0.001[§]	<0.001[§]
H/Q‡ ratio	0.918	0.009[§]

* : flexor peak torque, † : body weight, ‡: hamstring/quadriceps, § : statistically significant. These data are p values.

strength in Group I were higher than those in Group II; and 3) the HQ ratio of the affected side in Group I was similar to that of the contralateral side. The clinical and stability results were improved as compared with preoperative values in both groups. In addition, there were no differences between the groups. We thoroughly evaluated the combined injury (combined PLRI) and performed proper surgical treatment under strict indications using various methods. These endeavors may have produced the similar results in both groups.

Patients who underwent isolated PCL and PCL-PLCS reconstruction showed favorable clinical and stability improvements, but their muscle strength, especially flexion, was not fully recovered. As we described in the rehabilitation protocol, more aggressive and early weight bearing and co-strengthening exercises are encouraged in isolated PCL reconstruction. The isolated PCL reconstructed group showed higher flexion strength and a lower HQ ratio than the PCL-PLCS reconstruction group without statistical significance; however, they showed an HQ ratio similar to that on the contralateral side. This may imply that the isolated PCL reconstruction group had higher quadriceps strength than the PCL-PLCS reconstruction group.

Muscle strength after PCL reconstruction is not well established as compared with ACL reconstruction.(1,19,29) In a previous motion analysis of patients who underwent PCL-PLCS reconstruction, the patients were reluctant to engage in, or lacked strength for, daily activities at 6 months postoperatively.*(27)* Goudie et al.*(12)* evaluated the function of 23 patients who underwent PCL reconstruction (4 isolated and 19 combined) and reported good clinical results. However, muscle function remained abnormal in the reconstructed knee at both 12 and 24 months following surgery, and peak torque in both flexion and extension was significantly worse in the reconstructed knee than in the uninjured knee at both follow-up times. These results correspond well with those in a study by Chen et al.*(6)* and are in contrast to the commonly held opinion that functional recovery is complete at 12 months.*(11)* They concluded that muscle function in the reconstructed knee demonstrated a trend of gradual recovery over a 2-year period.*(12)*

In the common postoperative rehabilitation protocol after PCL reconstruction, hamstring strengthening is initiated at 3 months because of static stability.*(17,18,24)* This implies that the hamstrings may be weak, leading to a delay in hamstring muscle activation. These results in reduced co-contraction between the quadriceps and hamstring muscle because the quadriceps activation that provides a net flexor moment required to perform movement would also decrease.(14,15) However, the vector of the hamstring is not directed posteriorly within 30 degrees flexion. Therefore, hamstring exercise is possible within this angle using a calf-raise or minisqut. It could also support the early weight bearing because it could be a different kind of co-contraction and proprioceptive training.(21,25,26) The ideal HQ ratio for an ACL reconstruction may be the HQ ratio of the opposite healthy extremity, and the ideal absolute value of the HQ ratio is between 50% and 80%.(26) Our HQ ratio results were within the ideal absolute value, and the HQ ratio of the patients who underwent isolated PCL reconstruction was similar to that of the contralateral side. We believe that our relatively accelerated rehabilitation protocol contributed to these HQ ratios.

Nevertheless, our study has some weaknesses. First, the period of isokinetic testing was a bit variable (18–32 months), and some mismatches existed between clinical follow-up and isokinetic testing. Second, it could not be stated definitely that the improved muscle strength originated from the relatively accelerated rehabilitation program. Third, reconstructed patients were only considered and conservative treatment could be considered as a valid alternative control group. However, this study focused on the postoperative rehabilitation and used isolated PCL reconstruction as a case and PCL-PLCS reconstruction as a control.

CONCLUSION

Isokinetic muscle strength, especially flexion, was not fully recovered as compared with the contralateral side in both groups, although clinical and stability results were improved. However, the isolated PCL reconstruction group that was managed with the accelerated rehabilitation protocol showed an HQ ratio similar to that of the contralateral side. Therefore, an earlier active strengthening program would be also necessary in PCL-PLCS reconstructed groups, and justification for prevention of early weight bearing in PCL-PLCS reconstruction should be re-evaluated because weight bearing is helpful for muscle strengthening.

REFERENCES

1. **Ageberg E, Roos HP, Silbernagel KG, Thomee R, Roos EM.** Knee extension and flexion muscle power after anterior cruciate ligament reconstruction with patellar tendon graft or hamstring tendons graft: a cross-sectional comparison 3 years post surgery. *Knee Surg Sports Traumatol Arthrosc* 2009 ; 17 : 162.
2. **Ahn JH, Lee YS, Choi SH, Chang MJ, Lee DK.** Single-bundle transtibial posterior cruciate ligament reconstruction using a bioabsorbable cross-pin tibial back side fixation. *Knee Surg Sports Traumatol Arthrosc*, 2011.
3. **Ahn S, Lee YS, Song YD, Chang CB, Kang SB, Choi YS.** Does surgical reconstruction produce better stability than conservative treatment in the isolated PCL injuries? *Arch Orthop Trauma Surg* 2016 ; 136 : 811.
4. **Augustsson J, Thomee R, Karlsson J:** Ability of a new hop test to determine functional deficits after anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2004; 12:350.
5. **Bizzini M, Gorelick M, Munzinger U, Drobny T.** Joint laxity and isokinetic thigh muscle strength characteristics after anterior cruciate ligament reconstruction: bone patellar tendon bone versus quadrupled hamstring autografts. *Clin J Sport Med* 2006 ; 16 : 4.
6. **Chen CH, Chen WJ, Shih CH, Chou SW.** Arthroscopic posterior cruciate ligament reconstruction with quadriceps tendon autograft: minimal 3 years follow-up. *Am J Sports Med* 2004 ; 32 : 361.
7. **Edson CJ, Fanelli GC, Beck JD.** Postoperative rehabilitation of the posterior cruciate ligament. *Sports Med Arthrosc* 2010 ; 18 : 275.
8. **Fanelli GC.** Posterior cruciate ligament rehabilitation: how slow should we go? *Arthroscopy* 2008 ; 24 : 234.
9. **Fanelli GC.** Surgical treatment of lateral posterolateral instability of the knee using biceps tendon procedures. *Sports Med Arthrosc* 2006 ; 14 : 37.
10. **Fanelli GC, Larson RV.** Practical management of posterolateral instability of the knee. *Arthroscopy* 2002 ; 18 : 1.
11. **Fanelli GC, Orcutt DR, Edson CJ.** The multiple-ligament injured knee: evaluation, treatment, and results. *Arthroscopy* 2005 ; 21 : 471.
12. **Goudie EB, Will EM, Keating JF**. Functional outcome following PCL and complex knee ligament reconstruction. *Knee* 2010 ; 17 : 230.
13. **Harner CD, Vogrin TM, Hoher J, Ma CB, Woo SL.** Biomechanical analysis of a posterior cruciate ligament reconstruction. Deficiency of the posterolateral structures as a cause of graft failure. *Am J Sports Med* 2000 ; 28 : 32.
14. **Hewett TE, Myer GD, Ford KR.** Anterior cruciate ligament injuries in female athletes: Part 1, mechanisms and risk factors. *Am J Sports Med* 2006 ; 34 : 299.
15. **Hewett TE, Myer GD, Ford KR, et al.** Biomechanical measures of neuromuscular control and valgus loading of

the knee predict anterior cruciate ligament injury risk in female athletes: a prospective study. *Am J Sports Med* 2005 ; 33 : 492.

16. **Irrgang JJ, Fitzgerald GK.** Rehabilitation of the multiple-ligament-injured knee. *Clin Sports Med* 2000 ; 19 : 545.
17. **Jung YB, Jung HJ, Tae SK, Lee YS, Lee KH.** Reconstruction of the posterior cruciate ligament with a mid-third patellar tendon graft with use of a modified tibial inlay method. *J Bone Joint Surg Am* 2005 ; 87 : 247.
18. **Jung YB, Jung HJ, Tae SK, Lee YS, Yang DL.** Tensioning of remnant posterior cruciate ligament and reconstruction of anterolateral bundle in chronic posterior cruciate ligament injury. *Arthroscopy* 2006 ; 22 : 329.
19. **Keays SL, Bullock-Saxton J, Keays AC.** Strength and function before and after anterior cruciate ligament reconstruction. *Clin Orthop Relat Res* 2000 ; 174.
20. **Kim JG, Ha JG, Lee YS, Yang SJ, Jung JE, Oh SJ.** Posterolateral corner anatomy and its anatomical reconstruction with single fibula and double femoral sling method: anatomical study and surgical technique. *Arch Orthop Trauma Surg* 2009 ; 129 : 381.
21. **Kim JG, Lee YS, Yang BS, Oh SJ, Yang SJ.** Rehabilitation after posterior cruciate ligament reconstruction: a review of the literature and theoretical support. *Arch Orthop Trauma Surg* 2013 ; 133 : 1687.
22. **Ko MS, Yang SJ, Ha JK, Choi JY, Kim JG.** Correlation between Hamstring Flexor Power Restoration and Functional Performance Test: 2-Year Follow-Up after ACL Reconstruction Using Hamstring Autograft. *Knee Surg Relat Res* 2012 ; 24 : 113.
23. **Kong DH, Yang SJ, Ha JK, Jang SH, Seo JG, Kim JG:** Validation of functional performance tests after anterior cruciate ligament reconstruction. Knee Surg Relat Res 24 : 40, 2012.
24. **Lee YS, Ahn JH, Jung YB, et al.** Transtibial double bundle posterior cruciate ligament reconstruction using TransFix tibial fixation. *Knee Surg Sports Traumatol Arthrosc* 2007 ; 15 : 973.
25. **Lee YS, Jung YB.** Posterior cruciate ligament: focus on conflicting issues. *Clin Orthop Surg* 2013 ; 5 : 256.
26. **Lee YS, Kim NK.** Rehabilitation after posterior cruciate ligament reconstruction. *Minerva ortop traumatol* 2001 ; 62 : 291.
27. **Lee YS, Lim BO, Kim JG, et al.** Serial assessment of knee joint moments in posterior cruciate ligament and posterolateral corner reconstructed patients during a turn running task. *Arch Orthop Trauma Surg* 2011 ; 131 : 335.
28. **Lee YS, Ra HJ, Ahn JH, Ha JK, Kim JG.** Posterior cruciate ligament tibial insertion anatomy and implications for tibial tunnel placement. *Arthroscopy* 2010 ; 27 : 182.
29. **Moller E, Weidenhielm L, Werner S.** Outcome and knee-related quality of life after anterior cruciate ligament reconstruction: a long-term follow-up. *Knee Surg Sports Traumatol Arthrosc* 2009 ; 17 : 786.
30. **Myer GD, Paterno MV, Ford KR, Quatman CE, Hewett TE.** Rehabilitation after anterior cruciate ligament reconstruction: criteria-based progression through the return-to-sport phase. *J Orthop Sports Phys Ther* 2006 ; 36 : 385.
31. **Noyes FR, Barber-Westin SD, Albright JC.** An analysis of the causes of failure in 57 consecutive posterolateral operative procedures. *Am J Sports Med* 2006; 34 : 1419.
32. **Shelbourne KD, Klotz C.** What I have learned about the ACL: utilizing a progressive rehabilitation scheme to achieve total knee symmetry after anterior cruciate ligament reconstruction. *J Orthop Sci* 2006 ; 11 : 318.
33. **Thambyah A, Thiagarajan P, Goh Cho Hong J**. Knee joint moments during stair climbing of patients with anterior cruciate ligament deficiency. *Clin Biomech* 2004 ; 19 : 489.