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CLINICAL RESEARCH

Does Severity or Specific Joint Laxity Influence Clinical Outcomes of Anterior Cruciate Ligament Reconstruction?

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Abstract It generally is believed generalized joint laxity is one of the risk factors for failure of anterior cruciate ligament (ACL) reconstruction. However, no consensus exists regarding whether adverse effects on ACL reconstruction are attributable to joint-specific laxity or are related to the severity of generalized joint laxity. We therefore asked whether knee stability and functional outcomes would be related to joint-specific laxity and would differ according to the severity of generalized joint laxity. The Beighton and Horan criteria were used to assess joint laxity in 272 subjects. All elements are added to give an overall joint laxity score ranging from 0 to 5. Knee translation did not increase in proportion to the severity of the generalized joint laxity. Patients with scores less than 4 showed similar knee stability. When all variables, including the severity of generalized joint laxity, were considered, only hyperextension of the knee independently predicted knee stability and function. In patients with knee hyperextension, a bone-patellar tendon-bone autograft provided superior stability and function compared with a hamstring tendon autograft. Our data suggest knee hyperextension predicts postoperative stability and function regardless whether patients have severe generalized joint laxity.

Level of Evidence: Level III, prognostic study. See Guidelines for Authors for a complete description of levels of evidence.

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Each author certifies that his or her institution waived approval for the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.

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Introduction

Numerous factors are involved in a successful ACL reconstruction, including graft type, surgical technique, and rehabilitation [10]. Careful review of the literature reveals most studies do not take into account the inherent structural and physiologic characteristics of patients as factors influencing the outcome of ACL reconstruction. Studies regarding generalized joint laxity have dealt with the effect of joint laxity or knee hyperextension on ACL injury [15, 18, 25]. Especially, hyperextension of the knee has been highlighted as an intrinsic factor contributing to ACL injury [23]. However, few have considered generalized joint laxity or knee hyperextension as potential risk factors for knee stability and function after ACL reconstruction [1, 13]. The concerns with joint laxity are the inherent connective tissue extensibility of the autograft and laxity of the secondary knee restraints [1, 22].

We reported the negative effects of generalized joint laxity on ACL reconstruction [13]. According to the Beighton and Horan criteria [2], generalized joint laxity is present when four or more of five tests are positive, including contralateral knee hyperextension. We retrospectively studied 31 patients with generalized joint laxity after ACL reconstruction with either an autogenous bone-patellar tendon-bone (BPTB) graft or a hamstring tendon graft and found patients with a hamstring tendon graft had greater translation (average, 4.5 mm) on the KT2000™

arthrometer than did patients with a BPTB graft (average, 3.4 mm). However, the primary purpose of that study was to compare clinical outcomes of ACL reconstruction using different grafts in patients with generalized joint laxity. Therefore, no consensus exists regarding whether adverse effects on ACL reconstruction are attributable to joint-specific laxity or increase in proportion to the severity of generalized joint laxity.

The purpose of this study was to identify independent prognostic factors for clinical outcomes of ACL reconstruction. We specifically hypothesized knee stability and functional outcomes assessed by the International Knee Documentation Committee (IKDC) and Lysholm scores (1) would be worse in proportion to the total sum of positive tests according to the Beighton and Horan criteria, (2) would inversely correlate with knee hyperextension, and finally we hypothesized (3) the grafts would provide similar stability.

Materials and Methods

We retrospectively reviewed the records of 446 patients who underwent ACL reconstruction between February 2000 and August 2004. Subjects were selected on the basis of the following criteria: (1) a unilateral ACL injury without associated ligament injuries; (2) no articular cartilage erosion greater than Grade II according to the Outerbridge classification [20] at the time of surgery; (3) intact or meniscectomized meniscus with maintained hoop tension; and (4) followup greater than 24 months. Based on these criteria, 272 subjects (175 males and 97 females were eligible for this study. The mean age of the patients was 29.4 years and the mean duration of the symptoms was 13.6 months (Table 1). The Beighton and Horan criteria [2], which have gained international acceptance [12], were used to assess joint laxity: (1) passive dorsiflexion of the little fingers greater than 90°; (2) passive apposition of the thumbs to the flexor aspects of the forearms; (3) hyperextension of the elbows greater than 10°; (4) hyperextension of the knees greater than 10°; and (5) forward flexion of the trunk with the knees straight so the palms of the hands rest easily on the floor. The five elements of the scale that measure joint laxity are scored as "yes" or "no." All elements are added to give an overall joint laxity score ranging from 0 (normal laxity) to 5 (hyperlaxity). For the knee, the uninjured side was evaluated for laxity. We observed no differences in preoperative knee stability according to generalized joint laxity severity (Table 2). Preoperatively there were no differences in IKDC or Lysholm scores among the patients with different total sum of positive tests (Table 2).

For graft materials, we used either a BPTB or hamstring grafts (semitendinosus-gracilis). Graft selection was not randomized. However, all procedures were performed by the senior author (SJK), and the same rehabilitation

Table 1. Epidemiologic characteristics

Joint laxity total scores	Age (years)*	Duration of symptoms (months)*	Male:female	BPTB:hamstring
0 (n = 75)	31.5 (18–57)	15.4 (2–21)	51:24	53:22
1 (n = 29)	33.9 (18–47)	12.1 (5–24)	20:9	18:11
2 (n = 43)	26.9 (18–41)	12.8 (1–25)	29:14	25:18
3 (n = 64)	30.1 (16–49)	11.8 (2–23)	39:25	46:18
4 (n = 29)	29.1 (18–39)	15.1 (4–25)	18:11	17:12
5 (n = 32)	28.4 (18–34)	18.6 (1–23)	17:15	17:15

* Data are expressed as means, with ranges in parenthesis; BPTB = bone-patellar tendon-bone.

Table 2. Preoperative knee examination and functional scores

Joint laxity total scores	Lachman (> Grade 1)	Anterior drawer (> Grade 1)	Pivot shift (> Grade 1)	IKDC (A or B)	Lysholm score
0 (n = 75)	69 (92.0%)	60 (80.0%)	59 (78.7%)	3	45.0
1 (n = 29)	26 (89.7%)	26 (79.3%)	21 (72.4%)	0	43.0
2 (n = 43)	39 (90.7%)	38 (88.4%)	34 (79.1%)	1	42.3
3 (n = 64)	60 (93.8%)	49 (76.6%)	48 (75.0%)	3	41.8
4 (n = 29)	27 (93.1%)	26 (89.7%)	24 (82.8%)	0	42.3
5 (n = 32)	31 (96.9%)	30 (93.8%)	25 (78.1%)	0	43.3

IKDC = International Knee Documentation Committee.

protocol was followed. The selection of a BPTB graft was dependent on the length of the patellar tendon as measured on MRI: a BPTB graft was selected if the length of the patellar tendon was less than 4 cm to avoid graft length mismatch [14]. Otherwise, a hamstring graft was used.

The BPTB graft was harvested with a width of 10 mm. The patellar and tibial bone blocks were trapezoidal, 25 mm long and 8 mm deep. The patellar paratenon was sutured. A tibial tunnel was drilled with a 10-mm cannulated reamer. A femoral guide pin was positioned at the 10:30 o'clock position on the right knee or the 1:30 o'clock position on the left knee with the knee flexed 70° to 90°, and the femoral socket was reamed to a depth of 30 mm. The previously prepared BPTB graft was passed through the tibial tunnel, across the joint, and into the femoral socket. The graft was secured in the femoral socket with a bioabsorbable interference screw with the knee held at 90° flexion. The graft was pretensioned by pulling it tightly and moving the knee through a full range of motion 10 times. The graft then was fixed in the tibial tunnel with a bioabsorbable interference screw at 10° to 15° knee flexion.

For the semitendinosus-gracilis graft, the hamstring tendons were divided proximally at their musculotendinous junction with an open-loop tendon stripper without detachment of their distal insertions. The ends of the gracilis and semitendinosus tendons were whipstitched with #1 Ethibond® suture (Ethicon, Inc, Somerville, NJ). A tibial tunnel was drilled with a 10-mm cannulated reamer. A femoral socket was reamed to a depth of 30 mm with a 10-mm-diameter reamer. The femoral socket then was extended by making an EndoButton® tunnel (Acufex Microsurgical, Andover, MA) with a 4.5-mm-diameter reamer. Suspensory fixation of the proximal looped tendon then was performed in the femoral socket with a looped Mersilene® tape (Ethicon, Inc) that was passed through the EndoButton® and secured to the lateral femoral cortex. The leading sutures of both grafts were tied together and pulled through the tibial tunnel with a Kelly clamp so that tension was applied equally to both grafts. The tendons then were pretensioned using a method similar to that used for the BPTB grafts. When all four strands exhibited the same amount of tension, buckle staples (Smith and Nephew, Memphis, TN) were used to fix the graft to the tibial cortex. Absorbable interference bioscrews were placed in the tibial tunnel and the femoral socket [11].

The same rehabilitation protocol was followed for all patients. Patients were permitted a full range of motion and immediate partial weightbearing using crutches. Patients were allowed to bear full weight approximately 4 weeks after surgery. By 12 weeks, jogging, swimming, and cycling were permitted. Participation in sports involving jumping, pivoting, or sidestepping was allowed after 6 months.

We obtained clinical outcomes from data taken before surgery and at the 24-month followup. Manual examinations were performed by the senior author (SJK). Ligament stability was examined by the Lachman and pivot shift tests. The Lachman test was graded using a scale of 0(< 3 mm), 1 + (3–5 mm), 2 + (6–10 mm), or 3 + (> 10 mm). The pivot shift test was performed in the position of thigh abduction and internal rotation. The pivot shift phenomenon was graded using a scale of 0 (absent), 1 + (subluxation), 2 + (jump), or 3 + (transient lock). The side-to-side difference of anterior translation was measured with a KT2000™ arthrometer (MEDmetric® Corp, San Diego, CA) (134 N) at 30° knee flexion. Functional outcomes were assessed using the Lysholm score [16] and the IKDC score [7].

Measurements were expressed as mean and standard deviation (SD). To investigate the effect of generalized joint laxity severity, we analyzed differences in postoperative knee stability and Lysholm scores using the analysis of variance (ANOVA) test and differences in IKDC scores using the chi square test. Bivariate analysis (Pearson correlation coefficient for continuous data, Spearman correlation coefficient for categorical data) was used to determine the correlation of joint-specific laxity to postoperative knee stability, Lysholm scores, and IKDC scores. Regression analysis was used to assess association between postoperative knee translation, Lysholm score (stepwise linear regression), or IKDC (multiple logistic regression) as dependent variables and the total sum of positive tests or joint-specific laxity as independent variables. Statistical analysis was performed using SPSS® software (Version 13.0; SPSS Inc, Chicago, IL).

Results

We observed differences ($p = 0.001$) in postoperative knee translation among the patients with differing total sums of positive tests. A post hoc test showed increased mean knee translation in patients with a score of 5 compared with those with a score of 3 or less, although mean translation in patients with a score of 4 was similar to that in patients with a score of 3 or lower. The average postoperative anterior translation was 3.06 mm (SD, 1.4 mm) (Table 3). The severity of generalized joint laxity negatively correlated with postoperative Lysholm scores ($r = -0.116$; $p = 0.013$) and IKDC scores ($r = -0.193$; $p = 0.001$). Postoperative knee stability correlated with passive dorsiflexion of the little finger ($r = 0.271$), passive opposition of the thumb to the flexor aspect of the forearm ($r = 0.305$), and hyperextension of the knee ($r = 0.461$) (Table 4). We observed a correlation ($r = -0.285$) between postoperative Lysholm scores and hyperextension of the knee. IKDC scores correlated with passive opposition of the thumb to

Table 3. Postoperative knee stability and functional outcomes according to the severity of joint laxity

Joint laxity total scores	Knee anterior displacement (mm)*			IKDC (A or B)[†]	Lysholm scores*
	Overall	BPTB	Hamstring		
0 (n = 75)	2.83 ± 1.4	2.62 ± 1.4	3.48 ± 1.3	59 (78.7%)	89.9 ± 7.0
1 (n = 29)	2.86 ± 1.2	2.40 ± 1.3	3.64 ± 0.8	23 (79.3%)	92.9 ± 4.5
2 (n = 43)	2.93 ± 1.4	2.82 ± 1.5	3.08 ± 1.3	35 (81.3%)	90.6 ± 8.5
3 (n = 64)	2.75 ± 1.3	2.54 ± 1.3	3.30 ± 1.1	50 (78.1%)	90.3 ± 9.2
4 (n = 29)	3.57 ± 1.2	3.16 ± 1.2	4.26 ± 1.0	22 (75.9%)	88.0 ± 10.2
5 (n = 32)	4.10 ± 1.4	3.44 ± 1.2	4.64 ± 1.3	22 (68.8%)	81.1 ± 7.7
Total (n = 272)	3.06 ± 1.4	2.83 ± 1.3	3.73 ± 1.1	211 (77.6%)	89.1 ± 8.6

* Data are expressed as mean ± standard deviation; [†]number of patients scoring IKDC A or B; IKDC = International Knee Documentation Committee; BPTB = bone-patellar tendon-bone.

Table 4. Correlation of specific joint laxity with postoperative knee stability and functional outcomes

Outcome	Thumb opposition		Little finger dorsiflexion		Elbow hyperextension		Knee hyperextension		Forward flexion of trunk	
	SCC	p value	SCC	p value	SCC	p value	SCC	p value	SCC	p value
Knee anterior translation	0.305	0.001	0.271	0.005			0.461	0.000		
Lysholm score							−0.285	0.000		
IKDC score	−0.325	0.000	−0.169	0.006			−0.248	0.000		

Values without statistical significance are not presented; SCC = Spearman ρ correlation coefficient; IKDC = International Knee Documentation Committee.

Table 5. Comparison of clinical outcomes according to the knee hyperextension

Presence or absence of hyperextension	KT2000[TM] (mm)*			IKDC (A or B)[†]			Lysholm*		
	BPTB	Hamstring	p value	BPTB	Hamstring	p value	BPTB	Hamstring	p value
Normal knee laxity (n = 204)	2.50 (1.3)	3.53 (1.0)	0.009	110 (78.6%)	53 (79.1%)	0.257	90.2 (8.6)	87.3 (7.9)	0.72
Hyperextension (n = 68)	3.39 (1.2)	4.38 (1.2)	0.012	29 (80.6%)	19 (65.5%)	0.067	90.9 (8.2)	83.0 (7.4)	0.008

* Data are expressed as means, with standard deviations in parentheses; [†]number of patients scoring IKDC A or B. IKDC = International Knee Documentation Committee; BPTB = bone-patellar tendon-bone.

the flexor aspect of the forearm (r = −0.325) and knee hyperextension (r = −0.248). IKDC scores weakly correlated with passive dorsiflexion of the little finger (r = −0.169) (Table 4).

When total sum of positive tests or joint-specific laxity were considered as independent variables, only hyperextension of the knee independently predicted postoperative knee stability (p = 0.001), Lysholm (p = 0.017), and IKDC scores (p = 0.012).

BPTB grafts provided better knee stability than hamstring grafts (p = 0.008) (Table 3). Patients who had a positive finding of 5 and underwent ACL reconstruction using a hamstring tendon graft showed a greater anterior translation compared with patients who had a BPTB graft (Table 3). Among the patients who received a BPTB graft, differences were not observed. In patients with knee hyperextension, a BPTB graft showed superior knee stability and function (Table 5).

Discussion

Generalized joint laxity is considered one of the risk factors for failure of ACL reconstruction [1]. However, no consensus exists regarding whether adverse effects on ACL reconstruction are attributable to joint-specific laxity or are related to the severity of generalized joint laxity. The purpose of our study was to determine the effect of severity of generalized joint laxity on knee stability and functional outcomes. We also sought to find prognostic factors among the specific-joint laxity influencing postoperative clinical outcomes.

Our study has some inherent limitations that warrant review. First, we did not evaluate graft impingement on the intercondylar notch with imaging studies such as hyperextension lateral radiographs or MRI. Therefore, we are not certain to what extent the impingement occurred in knees with hyperextension. Second, manual examination of knee stability was performed only by the senior author (SJK). Therefore, we are not completely convinced of the accuracy of physical examination because the reliability was not assessed. However, this could lead to consistency of serial evaluation. Johnson et al. [11] found manual examination is reliable provided only one observer performs the test. Therefore, they recommended one observer perform the physical examination on each occasion to maximize reliability. Third, the clinical index for joint laxity is subject to observer bias. This may lead to misinterpretation of the effects of joint-specific laxity or the severity of generalized joint laxity. Therefore, to enhance reliability of the test, evaluation skills should be tested for consistency between the examiners. However, we could not provide consistency owing to the retrospective nature of the investigation. According to Remvig et al. [24], the Beighton and Horan method for diagnosis of generalized joint laxity showed high kappa values (intraobserver: 0.75; interobserver: 0.78). Therefore, they concluded the Beighton and Horan method is to some extent reproducible in the hands of experienced doctors. In our study, data collections were performed by five experienced clinical fellows, and consequently observer bias could be minimized.

Our data suggest greater anterior knee translation in patients with a joint laxity score of 5 than in those who scored 4 or lower. However, anterior knee translation did not increase in proportion to the severity of the generalized joint laxity. Patients with scores of 4 or lower showed comparable knee stability. It was similar to functional scores. Although we found a correlation between the severity of generalized joint laxity and functional outcomes, multivariate analysis revealed functional outcomes were not worse in proportion to the total sum of positive tests of joint laxity. We believe the main reason for this is the influence of knee hyperextension. The relationship between generalized joint laxity and knee laxity has not been well recognized. Knee laxity has been considered a trait of females, as the prevalence of joint laxity is greater in females than in males [5, 18, 19]. Pearsall et al. [22] investigated this issue to clarify influences of generalized joint laxity and did not find a correlation between instrumented measurement of knee laxity and generalized joint laxity. Our patients with knee hyperextension had greater anterior translation compared with those without knee hyperextension. We found knee hyperextension the strongest independent predictor for postoperative knee stability and function, even though other factors such as passive dorsiflexion of the little finger and passive opposition of the thumb also correlated with increased postoperative anterior translation and less favorable functional outcomes. These findings indicate knee hyperextension has potential harmful effects that may be related to an increased risk for anterior knee translation or low clinical outcome.

We assumed there would be two aspects of the negative effect of knee hyperextension on ACL reconstruction. First, mechanical factors such as secondary restraint laxity may influence knee stability or function [17]. There is a paucity of published information concerning the relationship between knee hyperextension and stress concentration on the reconstructed ACL. However, it is possible, in patients with knee hyperextension, a reconstructed ACL may undergo more consistent severe stress than in those with normal knee laxity because of the absence of sufficiently taut ligaments and tendons that surround the lower extremity, stabilize the knee, and absorb ground reaction force [18, 21]. Actually, hyperextension of the knee and physiologic joint laxity have been considered intrinsic factors contributing to traumatic ACL injuries [23, 25]. Second, the possibility of ACL graft impingement against the intercondylar roof may be increased. This has been implicated as a main cause of graft deterioration or rerupture after ACL reconstruction [3, 8, 9, 26].

We found a BPTB graft showed better stability than a hamstring tendon graft in patients with hyperextension of the knee. There are several potential reasons for the inferior result with hamstring tendon grafts, including delayed incorporation of the graft into the bone tunnel [6]. In a report on the effect of joint laxity in female patients, progressively increased translation was observed with a hamstring tendon graft [19]. Technically, some authors prefer serial dilation for a tighter graft-tunnel fit in ACL reconstruction using a hamstring graft [4]. In our technique, the femoral socket was created using extraction drilling instead of serial dilation to maintain even tension among the four strands of the hamstring tendon more easily. This discrepancy between the graft and the femoral socket may result in prolonged healing time [13].

Postoperative anterior knee translation does not increase in proportion to the severity of generalized joint laxity. Instead, hyperextension of the knee most strongly predicted postoperative knee instability and function among the clinical indices of joint laxity. In patients with knee hyperextension, an autogenous BPTB graft can achieve better stability and function than an autogenous hamstring tendon graft.

References

1. Alford JW, Bach BR Jr. Instrumented ligamentous laxity testing. In: Scott WN, Insall JN, eds. *Insall and Scott Surgery of the Knee.* Ed 4. Philadelphia, PA: Churchill Livingstone; 2006:584–614.
2. Beighton P, Horan F. Orthopaedic aspects of the Ehlers-Danlos syndrome. *J Bone Joint Surg Br.* 1969;51:444–453.

3. Cuomo P, Edwards A, Giron F, Bull AM, Amis AA, Aglietti P. Validation of the 65 degrees Howell guide for anterior cruciate ligament reconstruction. *Arthroscopy.* 2006;22:70–75.
4. Fu FH, Bennett CH, Ma CB, Menetrey J, Lattermann C. Current trends in anterior cruciate ligament reconstruction. Part II. Operative procedures and clinical correlations. *Am J Sports Med.* 2000;28:124–130.
5. Gobbi A, Domzalski M, Pascual J. Comparison of anterior cruciate ligament reconstruction in male and female athletes using the patellar tendon and hamstring autografts. *Knee Surg Sports Traumatol Arthrosc.* 2004;12:534–539.
6. Goradia VK, Rochat MC, Kida M, Grana WA. Natural history of a hamstring tendon autograft used for anterior cruciate ligament reconstruction in a sheep model. *Am J Sports Med.* 2000;28:40–46.
7. Hefti F, Muller W, Jakob RP, Staubli HU. Evaluation of knee ligament injuries with the IKDC form. *Knee Surg Sports Traumatol Arthrosc.* 1993;1:226–234.
8. Howell SM. Principles for placing the tibial tunnel and avoiding roof impingement during reconstruction of a torn anterior cruciate ligament. *Knee Surg Sports Traumatol Arthrosc.* 1998;6(suppl 1):S49–S55.
9. Jagodzinski M, Leis A, Iselborn KW, Mall G, Nerlich M, Bosch U. Impingement pressure and tension forces of the anterior cruciate ligament. *Knee Surg Sports Traumatol Arthrosc.* 2003;11:85–90.
10. Jaureguito JW, Paulos LE. Why grafts fail. *Clin Orthop Relat Res.* 1996;325:25–41.
11. Johnson DS, Ryan WG, Smith RB. Does the Lachman testing method affect the reliability of the International Knee Documentation Committee (IKDC) Form? *Knee Surg Sports Traumatol Arthrosc.* 2004;12:225–228.
12. Juul-Kristensen B, Rogind H, Jensen DV, Remvig L. Interexaminer reproducibility of tests and criteria for generalized joint hypermobility and benign joint hypermobility syndrome. *Rheumatology (Oxford).* 2007;46:1835–1841.
13. Kim SJ, Kim TE, Lee DH, Oh KS. Anterior cruciate ligament reconstruction in patients who have excessive joint laxity. *J Bone Joint Surg Am.* 2008;90:735–741.
14. Kim SJ, Kumar P, Oh KS. Anterior cruciate ligament reconstruction: autogenous quadriceps tendon-bone compared with bone-patellar tendon-bone grafts at 2-year follow-up. *Arthroscopy.* 2009;25:137–144.
15. Kramer LC, Denegar CR, Buckley WE, Hertel J. Factors associated with anterior cruciate ligament injury: history in female athletes. *J Sports Med Phys Fitness.* 2007;47:446–454.
16. Lysholm J, Gillquist J. Evaluation of knee ligament surgery results with special emphasis on use of a scoring scale. *Am J Sports Med.* 1982;10:150–154.
17. Menetrey J, Duthon VB, Laumonier T, Fritschy D. "Biological failure" of the anterior cruciate ligament graft. *Knee Surg Sports Traumatol Arthrosc.* 2008;16:224–231.
18. Myer GD, Ford KR, Paterno MV, Nick TG, Hewett TE. The effects of generalized joint laxity on risk of anterior cruciate ligament injury in young female athletes. *Am J Sports Med.* 2008;36:1073–1080.
19. Noojin FK, Barrett GR, Hartzog CW, Nash CR. Clinical comparison of intraarticular anterior cruciate ligament reconstruction using autogenous semitendinosus and gracilis tendons in men versus women. *Am J Sports Med.* 2000;28:783–789.
20. Outerbridge RE, Dunlop JA. The problem of chondromalacia patellae. *Clin Orthop Relat Res.* 1975;110:177–196.
21. Park HS, Wilson NA, Zhang LQ. Gender differences in passive knee biomechanical properties in tibial rotation. *J Orthop Res.* 2008;26:937–944.
22. Pearsall AW, Kovaleski JE, Heitman RJ, Gurchiek LR, Hollis JM. The relationships between instrumented measurements of ankle and knee ligamentous laxity and generalized joint laxity. *J Sports Med Phys Fitness.* 2006;46:104–110.
23. Ramesh R, Von Arx O, Azzopardi T, Schranz PJ. The risk of anterior cruciate ligament rupture with generalised joint laxity. *J Bone Joint Surg Br.* 2005;87:800–803.
24. Remvig L, Jensen DV, Ward RC. Are diagnostic criteria for general joint hypermobility and benign joint hypermobility syndrome based on reproducible and valid tests? A review of the literature. *J Rheumatol.* 2007;34:798–803.
25. Uhorchak JM, Scoville CR, Williams GN, Arciero RA, St Pierre P, Taylor DC. Risk factors associated with noncontact injury of the anterior cruciate ligament: a prospective four-year evaluation of 859 West Point cadets. *Am J Sports Med.* 2003;31:831–842.
26. Watanabe BM, Howell SM. Arthroscopic findings associated with roof impingement of an anterior cruciate ligament graft. *Am J Sports Med.* 1995;23:616–625.