CEU

Quadriceps Strength Deficit at 6 Months After ACL Reconstruction Does Not Predict Return to Preinjury Sports Level

João Victor Novaretti, MD,* Carlos Eduardo Franciozi, MD, PhD, Andrea Forgas, PT, Sheila Jean McNeill Ingham, MD, PhD, and Rene Jorge Abdalla, MD, PhD

Background: There is a lack of literature-based objective criteria for return to sport after anterior cruciate ligament (ACL) injury. Establishing such objective criteria is crucial to improving return to sport after ACL reconstruction (ACLR).

Hypotheses: Patients who return to their preinjury level of sport will have higher isokinetic, postural stability, and drop vertical jump test scores 6 months after surgery and greater patient satisfaction compared with those who did not. Additionally, quadriceps strength deficit cutoff values of 80% and 90% would differentiate patients who returned to preinjury sports level from those who did not.

Study Design: Cohort study.

Level of Evidence: Level 3.

Methods: A retrospective search was conducted to identify all patients who underwent ACLR and completed isokinetic evaluation, postural stability analysis, and drop vertical jump testing at 6 months postoperatively. Patients were asked to complete 3 questionnaires at a minimum 1 year after surgery. Chi-square and logistic regression analyses were used for categorical dependent variables, while the Student *t* test, Pearson correlation, or analyses of variance with Bonferroni post hoc testing were used for continuous dependent variables. A post hoc power analysis was completed. Based on the results regarding correlations between return to preinjury level and all other variables, effect sizes from 0.24 to 3.03 were calculated. With these effect sizes, an alpha of 0.05 and sample size of 58, a power ranging from 0.15 to 0.94 was calculated.

Results: The rates of return to preinjury level and to any sports activity were 53.4% and 84.4%. Those who were able to return to their preinjury level of sport (n = 33) showed significantly higher Lysholm (91.6 ± 9.7 vs 76.7 ± 15.4) and International Knee Documentation Committee (IKDC) (83.6 ± 10.6 vs 69.8 ± 14.6) values compared with those who were unable to return to their preinjury level of sport (n = 25) ($P < 0.001$). No significant differences were found for the clinical evaluations between those who were and those who were not able to return at the same level for the clinical evaluations (isokinetic evaluation, postural stability, drop vertical jump test) ($P > 0.05$). No significant differences were found when comparing quadriceps strength deficit with cutoff values of 80% and 90% for return to preinjury activity level (Tegner), Lysholm, and IKDC scores.

Conclusion: Quadriceps strength deficit, regardless of cutoff value (80% or 90%), at 6 months after ACLR does not predict return to preinjury level of sport. Patients who returned to sport at their preinjury level were more satisfied with their reconstruction compared with those who did not.

Clinical Relevance: Quadriceps strength deficit is not a reliable predictor of return to sports, and therefore it should not be used as the single criterion in such evaluations.

Keywords: anterior cruciate ligament; reconstruction; return to sport; rehabilitation

*Address correspondence to João Victor Novaretti, MD, Department of Orthopaedics and Traumatology, Paulista School of Medicine (EPM), Federal University of São Paulo, Rua Borges Lagoa, 783, 5th Floor, São Paulo, SP 04038-031, Brazil (email: jvnovaretti@gmail.com).

All authors are listed in the Authors section at the end of this article.

The following authors declared potential conflicts of interest: Carlos Eduardo Franciozi, MD, PhD, is a paid consultant for Smith & Nephew, and Rene Jorge Abdalla, MD, PhD, is a paid consultant for Smith & Nephew and DePuy Synthes.

DOI: 10.1177/1941738118759911

Return to preinjury activity level with an asymptomatic and normally functioning knee are the expectations for most patients who undergo anterior cruciate ligament reconstruction (ACLR).[16] However, studies have shown that up to 38% of patients do not return to their preinjury level of sport after ACLR.[2,4,17,24,35-37] Furthermore, even when preinjury level of sport is achieved, it may decline sooner than expected.[1,10] A study of professional soccer players observed that 95% of athletes returned to the same level of activity as prior to injury 1 year after ACL surgery, but only 62% were still playing at preinjury level 4 years after the procedure.[43] Return to preinjury activity level involves several factors: physical factors, such as muscle strength, proprioception, concomitant injuries, knee stability, and biomechanics,[25,40] and psychological factors, such as fear of reinjury, lack of motivation, and fear of pain.[3,4,21,23,38]

Meanwhile, objective criteria for patient clearance to return to sport after ACLR is a controversial topic. Common criteria used to clear a patient to return to sport include length of time postoperative, muscle strength, postural stability analysis, the drop vertical jump test, anterior-posterior knee laxity, the single-leg hop test, range of motion, and validated questionnaires.[19,27,32] A systematic review found that only 13% of studies used objective criteria to clear patients for return to sport after ACLR.[7] Other review studies evaluating criteria for return to sport also found high variability and poor reporting among studies regarding ACLR published in the literature.[4,14,18] Therefore, there is a lack of literature-based objective criteria for return to sport after ACL injury. The establishment of such objective criteria is important to improve the rate of return to sport at the preinjury level as well as to reduce the risk of reinjury, which is still high.[10,13]

The objectives of this study were to (1) evaluate rates of return to sport after ACLR, (2) correlate 3 objective tests (isokinetic evaluation, postural stability analysis, and drop vertical jump test) completed 6 months postoperatively to return to preinjury activity level, (3) correlate patient satisfaction and return to play after ACLR, and (4) compare quadriceps strength deficit cutoff values of 80% and 90% to return to preinjury sport level. It was hypothesized that patients who returned to their preinjury level of sport would have higher scores on the objective tests at 6 months after surgery and greater patient satisfaction compared with patients who did not return to their preinjury level of sport. It was also hypothesized that using the quadriceps strength deficit cutoff values of 80% and 90% would differentiate patients who returned to their preinjury level of sport from those who did not.

METHODS

Institutional review board approval was obtained prior to conducting this study, and all participants signed an informed consent form. A retrospective search was conducted from January 2011 to June 2014 through the database of our institution to identify all patients with a complete ACL injury who underwent primary ACLR by a single experienced knee surgeon (senior author) and had completed objective testing at 6 months postoperatively. The diagnosis of ACL tear was made by physical examination and magnetic resonance imaging and confirmed arthroscopically. Exclusion criteria were concomitant ligament injury, meniscal repair, osteochondral lesion higher than grade 2, reinjury during the first 6 months after surgery, contralateral knee injury, lack of adherence to the same rehabilitation program proposed to all patients, and a preinjury activity level that did not correspond to participation in any level of sports activity (Tegner score <5). After screening criteria had been applied, 159 patients were identified as being eligible for the study. Patients were asked to complete 3 questionnaires (International Knee Documentation Committee [IKDC], Lysholm, and Tegner) at a minimum of 1 year after surgery.

Objective Testing

Three tests were chosen based on previous literature regarding objective criteria for return to sport after ACLR: isokinetic evaluation,[12] postural stability analysis,[34] and the drop vertical jump test.[29] All tests were performed at the same location and conducted by the same experienced sports medicine physical therapist. Patients wore appropriate sports clothing and were not allowed to wear any type of brace.

Isokinetic Evaluation

Patients were evaluated using an isokinetic dynamometer (Biodex System III; Biodex, Inc).[12] Patients completed a 10-minute warm-up on a stationary bicycle from 40 to 50 rpm. Knee range of motion was set from full extension to 90° of flexion. Isokinetic concentric knee extensor and knee flexor peak torques were quantified at angular velocities of 60, 120, and 180 deg/s. For this study, we used the values obtained at 60 deg/s as these have been reported as being reliable to assess strength recovery after ACLR.[15] Before testing, patients performed a trial session of 3 repetitions with submaximal effort, followed by a 1-minute pause before the test. Patients performed the test first with the uninjured limb followed by the ACLR limb. Each test consisted of 5 maximal repetitions. The peak torque values of the quadriceps and hamstrings muscles from both limbs were obtained, and the highest value of all 5 trials was used. Quadriceps and hamstrings deficits were calculated as a percentage. To analyze differences using different cutoff values for quadriceps strength deficit as objective criteria, cutoff values of 80% and 90% were used. Peak torques of the hamstring/quadriceps ratio for the uninjured and the ACLR limbs were also calculated.

Postural Stability Analysis

The Biodex Balance System (Biodex, Inc) was used to analyze postural stability on unstable ground.[31,32,34] It objectively measures the ability to maintain posture under dynamic stress on a circular platform, with up to 20° of tilting. The system records the movement of the platform away from the initial position, generating data regarding overall stability and

anterior-posterior and medial-lateral translations. Patients were positioned at the center of the platform on a single limb. The tested limb was maintained in 10° of knee flexion, with the nontested limb flexed and arms crossed with hands resting on the contralateral shoulder. Patients were instructed to maintain posture at the center of the platform for 20 seconds at level 4 stability testing. Each test was performed 3 times on each limb.

Drop Vertical Jump Test

The drop vertical jump test was performed by dropping from a box, landing, and immediately performing a maximum vertical jump, as described by Noyes et al.[29] The camera was also positioned as reported by Noyes et al.[29] The camera was placed on a stand 1.02 m in height. The stand was positioned 3.65 m in front of a box that was 30.5 cm in height and 38.1 cm in width. The video was advanced frame by frame, and 3 images were captured as still photographs on the frontal view: prelanding, landing, and takeoff.[29] Hip separation distance was measured between the reflective markers placed at the greater trochanter, in absolute centimeters. Normalized knee separation distance was measured between the markers placed at the center of the patella (knee separation distance) and was calculated as knee separation/hip separation distance. The distances were measured in the landing phase, when the patient underwent total downward movement (full phase of deceleration).

Questionnaires

One author, who had no involvement in the clinical care of the patients, administered a survey by telephone and email to patients consisting of 3 questionnaires: IKDC,[20] Lysholm,[26] and Tegner.[39] Complete answers to all questionnaires were obtained from 58 patients. All questionnaires were carried out at a minimum 1 year after surgery, since most patients are usually cleared to return to sport by 12 months post-ACLR.

The Tegner score evaluates the highest level of sports activity before the injury and at the time of assessment using increasing activity levels ranging from level 0 (inability to work by knee problems—certificate or disability) to level 10 (competitive sport: soccer—national and international elite). Since Tegner scores from before injury and at least 1 year postoperatively were collected, the Tegner score was used in this study to evaluate the return to preinjury level of activity, dividing patients into 2 groups: those who returned to their preinjury level of sport (difference in Tegner score before and after surgery ≤0) and those who did not (difference >0).

The Lysholm score is a patient-reporting outcome questionnaire that estimates knee function in 8 categories: limp, use of cane or crutches, locking sensation in the knee, giving way sensation from the knee, pain, swelling, stair climbing, and squatting. The IKDC is another subjective patient-reporting outcome questionnaire frequently used in the literature to evaluate patients after ACLR. The IKDC has 3 categories: symptoms, sports activity, and knee function. Both the Lysholm and IKDC are scored from 0 to 100, with 100 representing the best possible result.[9,20,28]

Statistical Analysis

A post hoc power analysis using G*Power 3.1.9.2 (Franz Paul) software was used to determine the power of the present study. Based on the results regarding correlations between return to preinjury level (Tegner score ≤0 or >0) and all other variables, effect sizes from 0.24 to 3.03 were calculated. With these effect sizes, an alpha of 0.05, and sample size of 58, a power ranging from 0.15 to 0.94 was calculated. Statistical analysis was performed using SPSS version 15 (IBM Corp). Chi-square and logistic regression analyses were used for categorial dependent variables, while normality was checked using the Shapiro-Wilk test for continuous variables. Student *t* tests, Pearson correlation, or analyses of variance using Bonferroni post hoc testing were used for continuous dependent variables. The level of statistical significance was set at $P < 0.05$.

RESULTS

This study included 58 patients with ACL tears confirmed arthroscopically, all of whom had complete objective test results and outcome questionnaire data available. Patients had a mean age of 34.5 ± 11.3 years at the time of surgery, and 81.1% were men. Outcome questionnaires were completed at a mean of 2.1 years (range, 1.0-4.4 years) post-ACLR. The rate of return to preinjury level of sport was 53.4%. The rate of return to any sports activity was 84.4%. The objective test results for those who were (n = 33) and were not (n = 25) able to return to their preinjury level of sport are presented in Table 1. Those who did return to their preinjury level of sport showed significantly higher Lysholm (91.6 ± 9.7 vs 76.7 ± 15.4) and IKDC (83.6 ± 10.6 vs 69.8 ± 14.6) values compared with those who did not ($P < 0.001$). No significant differences were noted between groups regarding isokinetic evaluation ($P > 0.05$), postural stability analysis ($P = 0.60$), and drop vertical jump tests ($P = 0.96$) (Table 1). No significant differences were found when comparing quadriceps strength deficit using cutoff values of 80% and 90% in return to preinjury activity level (Tegner) and subjective reported knee outcomes (Lysholm and IKDC) (Table 2).

DISCUSSION

The main finding of this study was that the deficit of quadriceps strength, regardless of the cutoff value used (80% or 90%), did not predict return to preinjury level of sport at 6 months postoperatively. There is no consensus in the literature on the quadriceps strength deficit to be used as an objective parameter for return to sports. Published values vary from 75% to 90%.[19,27,33] In this study, patients were divided into 2 groups using the value of quadriceps peak torque compared with the uninjured side: 80% cutoff (quadriceps deficit ≤20% and >20%) and 90% cutoff (quadriceps deficit ≤10% and >10%). These values are the most commonly used,[19,27] and we compared these 2 groups with the objective of evaluating whether the difference between the application of 1 of the 2 cutoff values (80% or 90%) at 6 months postoperatively was relevant in identifying patients

Table 1. Values from the isokinetic evaluation, postural stability analysis, and drop vertical jump test from return to preinjury sports level (RPS) and the nonreturn to preinjury sports level (NRPS) groups

Values	RPS, Mean ± SD	NRPS, Mean ± SD	*P*
Quadriceps peak torque uninvolved limb, N·m	223.3 ± 56.2	251.7 ± 51.9	0.05
Quadriceps peak torque involved limb, N·m	163.2 ± 49.5	175.8 ± 54.0	0.35
Quadriceps deficit, %	25.7 ± 17.4	29.9 ± 16.0	0.34
Hamstring peak torque uninvolved limb, N·m	117.9 ± 29.9	125.9 ± 18.8	0.21
Hamstring peak torque involved limb, N·m	104.7 ± 37.7	116.9 ± 23.2	0.13
Hamstring deficit, %	6.1 ± 15.6	7.4 ± 12.6	0.74
Hamstrings/quadriceps ratio uninvolved limb	53.5 ± 8.7	51.0 ± 7.0	0.24
Hamstrings/quadriceps ratio involved limb	69.1 ± 15.2	70.5 ± 20.1	0.76
Postural stability analysis	–1.07 ± 25.3	4.6 ± 29.7	0.60
Drop vertical jump test, %	71.9 ± 17.1	72.1 ± 17.7	0.96

Table 2. Comparison between quadriceps strength cutoff values of 80% and 90% and return to preinjury sports level

	Quadriceps deficit ≤10% (n = 11)	Quadriceps deficit >10% (n = 47)	*P*	Quadriceps deficit ≤20% (n = 19)	Quadriceps deficit >20% (n = 39)	*P*
RPS (Tegner score ≤0)	7	26	0.61	12	21	0.50
NRPS (Tegner score >0)	4	21		7	18	

NRPS, nonreturn to preinjury sports level; RPS, return to preinjury sports level.

who would return to their preinjury level of sports activity. No significant difference between groups was found, thus rejecting the hypothesis. This result is interesting because the isokinetic evaluation as a single objective criterion is used by many surgeons. To clear a patient to return to sport based on the restoration of muscle strength in the operated limb compared with the contralateral limb should be addressed with caution, since the contralateral limb may be at greater risk of a second ACL injury.[41] Thus, the comparison of muscle strength between the ACLR and the uninjured limb, which is also at a greater risk of sustaining an ACL tear (ie, not an ideal model for comparison), should not be used as the only criterion for return to sport.

Currently, determination of return to sports after ACLR lacks adequate published criteria. As a recent study stated, only 13% of studies report objective criteria with this purpose.[6] The present study aimed to relate which criteria applied at 6 months after surgery would be associated with a higher rate of return to preinjury level of sports activity. In this study, patients were also divided into 2 groups: those who were and were not able to return to their preinjury level of sport. However, no between-groups differences were observed regarding the 3 objective criteria tests when applied at 6 months postoperatively, rejecting this hypothesis. The rate of return to preinjury level of sport (53.4%) in this study is lower than that reported by previous studies.[1,2,4,30] Since there are several factors involved in return to sports after ACLR that were not addressed in this study (eg, psychological factors), it is not possible to suggest a specific reason for the lower return to preinjury rate presented. Meanwhile, the rate of return to sports activity (84.4%) observed in the present study is similar to the literature.[2,4,22,30]

Regarding subjective outcome questionnaires, patients who returned to their preinjury level of sport were more satisfied with their ACLR compared with those who did not. This is in concordance with the literature. A previous study reported that patients who returned to play were more satisfied with the outcome of surgery compared with those who did not.[30]

Postural stability and drop vertical jump tests were not significantly correlated with other parameters evaluated in this

study. The lack of relation between better scores in the isokinetic evaluation and better scores in the stability and drop vertical jump tests is interesting because of the debatable competence of the isokinetic evaluation to be able to analyze the patient's capacity to perform complex sports gestures that require not only muscular strength but certainly other abilities, such as proprioception, balance, and correct sport-specific technique. Future studies should evaluate objective criteria tests other than those used in this study and correlate them with return to preinjury level of sport since there is still a lack of literature on objective criteria that may aid the decision for a safer return to sport activity.

This study has several limitations. Because of the retrospective design of this study, as the outcome questionnaires were collected on patients up to 4 years postoperatively, there was a risk of recall bias at the time of follow-up. Another limitation is the lack of information about secondary factors that could determine return to sport after ACL injury, such as psychological factors, and were not addressed in this study. Additionally, sports activity level was based on self-designation, which may have led to some misclassification. Finally, the questionnaires were administered via telephone or email instead of self-administered using paper. However, previous studies have shown that telephone interview and web surveys are reliable and have comparable results to those of self-administered paper questionnaires.[5,8,11,42]

CONCLUSION

The data from this study show that the deficit of quadriceps strength, regardless of cutoff value (80% or 90%), at 6 months postoperatively does not predict return to preinjury sports level. Therefore, quadriceps strength deficit should not be used as the single criterion for return to sport after ACLR. Patients who returned to their preinjury level of sport were more satisfied with their ACLR than those who did not.

AUTHORS

João Victor Novaretti, MD (Department of Orthopaedics and Traumatology, Paulista School of Medicine [EPM], Federal University of São Paulo, São Paulo, Brazil); **Carlos Eduardo Franciozi, MD, PhD** (Department of Orthopaedics and Traumatology, Paulista School of Medicine [EPM], Federal University of São Paulo, São Paulo, Brazil); **Andrea Forgas, PT** (Knee Institute, Hospital do Coração [Hcor], São Paulo, Brazil); **Pedro Henrique Sasaki, PT** (Knee Institute, Hospital do Coração [Hcor], São Paulo, Brazil); **Sheila Jean McNeill Ingham, MD, PhD** (Department of Orthopaedics and Traumatology, Paulista School of Medicine [EPM], Federal University of São Paulo, São Paulo, Brazil); and **Rene Jorge Abdalla, MD, PhD** (Department of Orthopaedics and Traumatology, Paulista School of Medicine [EPM], Federal University of São Paulo, São Paulo, Brazil; Knee Institute, Hospital do Coração [Hcor], São Paulo, Brazil).

REFERENCES

1. Ardern CL, Taylor NF, Feller JA, Webster KE. Return-to-sport outcomes at 2 to 7 years after anterior cruciate ligament reconstruction surgery. *Am J Sports Med*. 2012;40:41-48.
2. Ardern CL, Taylor NF, Feller JA, Webster KE. Fifty-five per cent return to competitive sport following anterior cruciate ligament reconstruction surgery: an updated systematic review and meta-analysis including aspects of physical functioning and contextual factors. *Br J Sports Med*. 2014;48:1543-1552.
3. Ardern CL, Taylor NF, Feller JA, Whitehead TS, Webster KE. Psychological responses matter in returning to preinjury level of sport after anterior cruciate ligament reconstruction surgery. *Am J Sports Med*. 2013;41:1549-1558.
4. Ardern CL, Webster KE, Taylor NF, Feller JA. Return to sport following anterior cruciate ligament reconstruction surgery: a systematic review and meta-analysis of the state of play. *Br J Sports Med*. 2011;45:596-606.
5. Ariza-Ariza R, Hernández-Cruz B, Navarro-Compán V, Leyva Pardo C, Juanola X, Navarro-Sarabia F. A comparison of telephone and paper self-completed questionnaires of main patient-related outcome measures in patients with ankylosing spondylitis and psoriatic arthritis. *Rheumatol Int*. 2013;33:2731-2736.
6. Barber-Westin SD, Noyes FR. Factors used to determine return to unrestricted sports activities after anterior cruciate ligament reconstruction. *Arthroscopy*. 2011;27:1697-1705.
7. Barber-Westin SD, Noyes FR. Objective criteria for return to athletics after anterior cruciate ligament reconstruction and subsequent reinjury rates: a systematic review. *Phys Sportsmed*. 2011;39:100-110.
8. Bot AG, Becker SJ, Mol MF, Ring D, Vranceanu AM. Validation of phone administration of short-form disability and psychology questionnaires. *J Hand Surg Am*. 2013;38:1383-1387.
9. Briggs KK, Lysholm J, Tegner Y, Rodkey WG, Kocher MS, Steadman JR. The reliability, validity, and responsiveness of the Lysholm score and Tegner activity scale for anterior cruciate ligament injuries of the knee: 25 years later. *Am J Sports Med*. 2009;37:890-897.
10. Brophy RH, Schmitz L, Wright RW, et al. Return to play and future ACL injury risk after ACL reconstruction in soccer athletes from the Multicenter Orthopaedic Outcomes Network (MOON) group. *Am J Sports Med*. 2012;40:2517-2522.
11. Cerrada CJ, Weinberg J, Sherman KJ, Saper RB. Inter-method reliability of paper surveys and computer assisted telephone interviews in a randomized controlled trial of yoga for low back pain. *BMC Res Notes*. 2014;7:227.
12. Coplin TH. Isokinetic exercise: clinical usage. *Athl Train*. 1971;6:110-114.
13. Crawford SN, Waterman BR, Lubowitz JH. Long-term failure of anterior cruciate ligament reconstruction. *Arthroscopy*. 2013;29:1566-1571.
14. Davies GJ, McCarty E, Provencher M, Manske RC. ACL return to sport guidelines and criteria. *Curr Rev Musculoskelet Med*. 2017;10:307-314.
15. Eitzen I, Holm I, Risberg MA. Preoperative quadriceps strength is a significant predictor of knee function two years after anterior cruciate ligament reconstruction. *Br J Sports Med*. 2009;43:371-376.
16. Feucht MJ, Cotic M, Saier T, et al. Patient expectations of primary and revision anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2016;24:201-207.
17. Gobbi A, Francisco R. Factors affecting return to sports after anterior cruciate ligament reconstruction with patellar tendon and hamstring graft: a prospective clinical investigation. *Knee Surg Sports Traumatol Arthrosc*. 2006;14:1021-1028.
18. Harris JD, Abrams GD, Bach BR, et al. Return to sport after ACL reconstruction. *Orthopedics*. 2014;37:e103-e108.
19. Hartigan EH, Axe MJ, Snyder-Mackler L. Time line for noncopers to pass return-to-sports criteria after anterior cruciate ligament reconstruction. *J Orthop Sports Phys Ther*. 2010;40:141-154.
20. Irrgang JJ, Anderson AF, Boland AL, et al. Development and validation of the International Knee Documentation Committee Subjective Knee Form. *Am J Sports Med*. 2001;29:600-613.
21. Kvist J, Ek A, Sporrstedt K, Good L. Fear of re-injury: a hindrance for returning to sports after anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2005;13:393-397.
22. Lai CC, Ardern CL, Feller JA, Webster KE. Eighty-three per cent of elite athletes return to preinjury sport after anterior cruciate ligament reconstruction: a systematic review with meta-analysis of return to sport rates, graft rupture rates and performance outcomes. *Br J Sports Med*. 2018;52:128-138.
23. Lee BI, Kwon SW, Kim JB, Choi HS, Min KD. Comparison of clinical results according to amount of preserved remnant in arthroscopic anterior cruciate ligament reconstruction using quadrupled hamstring graft. *Arthroscopy*. 2008;24:560-568.

24. Lee DY, Karim SA, Chang HC. Return to sports after anterior cruciate ligament reconstruction—a review of patients with minimum 5-year follow-up. *Ann Acad Med Singapore*. 2008;37:273-278.
25. Lynch AD, Logerstedt DS, Grindem H, et al. Consensus criteria for defining 'successful outcome' after ACL injury and reconstruction: a Delaware-Oslo ACL cohort investigation. *Br J Sports Med*. 2015;49:335-342.
26. 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.
27. Mascarenhas R, Tranovich M, Karpie JC, Irrgang JJ, Fu FH, Harner CD. Patellar tendon anterior cruciate ligament reconstruction in the high-demand patient: evaluation of autograft versus allograft reconstruction. *Arthroscopy*. 2010;26(suppl 9):S58-S66.
28. Metsavaht L, Leporace G, Riberto M, de Mello Sposito MM, Batista LA. Translation and cross-cultural adaptation of the Brazilian version of the International Knee Documentation Committee Subjective Knee Form: validity and reproducibility. *Am J Sports Med*. 2010;38:1894-1899.
29. Noyes FR, Barber-Westin SD, Fleckenstein C, Walsh C, West J. The drop-jump screening test: difference in lower limb control by gender and effect of neuromuscular training in female athletes. *Am J Sports Med*. 2005;33:197-207.
30. Nwachukwu BU, Voleti PB, Berkanish P, et al. Return to play and patient satisfaction after ACL reconstruction: study with minimum 2-year follow-up. *J Bone Joint Surg Am*. 2017;99:720-725.
31. Paterno MV, Myer GD, Ford KR, Hewett TE. Neuromuscular training improves single-limb stability in young female athletes. *J Orthop Sports Phys Ther*. 2004;34:305-316.
32. Paterno MV, Schmitt LC, Ford KR, et al. Biomechanical measures during landing and postural stability predict second anterior cruciate ligament injury after anterior cruciate ligament reconstruction and return to sport. *Am J Sports Med*. 2010;38:1968-1978.
33. Paulos L, Noyes FR, Grood E, Butler DL. Knee rehabilitation after anterior cruciate ligament reconstruction and repair 1. *J Orthop Sports Phys Ther*. 1991;13:60-70.
34. Pickerill ML, Harter RA. Validity and reliability of limits-of-stability testing: a comparison of 2 postural stability evaluation devices. *J Athl Train*. 2011;46:600-606.
35. Shah VM, Andrews JR, Fleisig GS, McMichael CS, Lemak LJ. Return to play after anterior cruciate ligament reconstruction in National Football League athletes. *Am J Sports Med*. 2010;38:2233-2239.
36. Shelbourne KD, Benner RW, Gray T. Return to sports and subsequent injury rates after revision anterior cruciate ligament reconstruction with patellar tendon autograft. *Am J Sports Med*. 2014;42:1395-1400.
37. Smith FW, Rosenlund EA, Aune AK, MacLean JA, Hillis SW. Subjective functional assessments and the return to competitive sport after anterior cruciate ligament reconstruction. *Br J Sports Med*. 2004;38:279-284.
38. te Wierike SC, van der Sluis A, van den Akker-Scheek I, Elferink-Gemser MT, Visscher C. Psychosocial factors influencing the recovery of athletes with anterior cruciate ligament injury: a systematic review. *Scand J Med Sci Sports*. 2013;23:527-540.
39. Tegner Y, Lysholm J. Rating systems in the evaluation of knee ligaments. *Clin Orthop Relat Res*. 1985;198:43-49.
40. van Melick N, van Cingel RE, Brooijmans F, et al. Evidence-based clinical practice update: practice guidelines for anterior cruciate ligament rehabilitation based on a systematic review and multidisciplinary consensus. *Br J Sports Med*. 2016;50:1506-1515.
41. Wiggins AJ, Grandhi RK, Schneider DK, Stanfield D, Webster KE, Myer GD. Risk of secondary injury in younger athletes after anterior cruciate ligament reconstruction: a systematic review and meta-analysis. *Am J Sports Med*. 2016;44:1861-1876.
42. Wu XM, Bennett DH, Lee K, Cassady DL, Ritz B, Hertz-Picciotto I. Feasibility of using web surveys to collect time-activity data. *J Expo Sci Environ Epidemiol*. 2012;22:116-125.
43. Zaffagnini S, Grassi A, Marcheggiani Muccioli GM, et al. Return to sport after anterior cruciate ligament reconstruction in professional soccer players. *Knee*. 2014;21:731-735.