Systemic Review With Video Illustration

Factors Used to Determine Return to Unrestricted Sports Activities After Anterior Cruciate Ligament Reconstruction

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Purpose: Anterior cruciate ligament (ACL) reconstruction is commonly performed in athletes, with the goal of return to sports activities. Unfortunately, this operation may fail, and the rates of either reinjuring an ACL-reconstructed knee or sustaining an ACL rupture to the contralateral knee range from 3% to 49%. One problem that exists is a lack of information and consensus regarding the appropriate criteria for releasing patients to unrestricted sports activities postoperatively. The purpose of this study was to determine the published criteria used to allow athletes to return to unrestricted sports activities after ACL reconstruction. **Methods:** A systematic search was performed to identify the factors investigators used to determine when return to athletics was allowed after primary ACL reconstruction. Inclusion criteria were English language, publication within the last 10 years, clinical trial, all adult patients, primary ACL reconstruction, original research investigation, and minimum 12 months' follow-up. **Results:** Of 716 studies identified, 264 met the inclusion criteria. Of these, 105 (40%) failed to provide any criteria for return to sports after ACL reconstruction. In 84 studies (32%) the amount of time postoperatively was the only criterion provided. In 40 studies (15%) the amount of time along with subjective criteria were given. Only 35 studies (13%) noted objective criteria required for return to athletics. These criteria included muscle strength or thigh circumference (28 studies), general knee examination (15 studies), single-leg hop tests (10 studies), Lachman rating (1 study), and validated questionnaires (1 study). **Conclusions:** The results of this systematic review show noteworthy problems and a lack of objective assessment before release to unrestricted sports activities. General recommendations are made for quantification of muscle strength, stability, neuromuscular control, and function in patients who desire to return to athletics after ACL reconstruction, with acknowledgment of the need for continued research in this area. **Level of Evidence:** Level IV, systematic review of Level I to IV studies.

Anterior cruciate ligament (ACL) tears are the most common, complete ligamentous injuries that occur in the knee joint. In the United States, ACL tears occur in an estimated 1 in 3,500 individuals each year,[1] and although exact data are not currently available, it is believed that approximately 125,000 to 200,000 ACL reconstructions are performed annually. Most patients who sustain ACL injuries and undergo reconstruction are athletes aged under 25 years who are frequently involved in high school, collegiate, or league sports. The goals of this operation for these individuals are to stabilize the knee to prevent future reinjuries and allow a safe return to their previous level of activity.

The published long-term rates of either reinjuring

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TABLE 1. *Risks of Reinjury to ACL-Reconstructed Knee and Injury to ACL in Contralateral Knee in Clinical Studies*

Lead Author (yr), Journal	No. of Patients	Follow-up	ACL Graft	Reinjured	Revised	Fully Positive Pivot Shift, Lachman, and IKDC Grade C-D	Injured ACL Contralateral Knee	Overall ACL Reinjury Rate*	Factors Statistically Associated with Reinjuries, Graft Failures
Hui (2011),[13] AJSM	90	15 yr	BPTB autograft	8%	8%	8%	24%	30%	Coronal graft inclination angle < 17° (vertical graft placement) for ACL-reconstructed knee. Age < 18 years for contralateral knee
Shelbourne (2009),[23] AJSM	1,415	5 yr	BPTB autograft	4.3%	NA	NA	5.3%	9.6%	Age < 18 years and participation in basketball or soccer for either knee. Female gender for contralateral knee
Nakata (2008),[37] *Arthroscopy*	68	10 yr	Allogeneic free tendon	5%	5%	8%	6%	16%	None
Pinczewski (2007),[14] AJSM	180	10 yr	BPTB autograft in 90 patients	8%	NA	8%	22%	27%	Increased laxity for ACL-reconstructed knees. Age < 21 years for contralateral knee
			STG autograft in 90 patients	13%		13%	10%		
Keays (2007),[38] AJSM	51	6 yr	BPTB autograft in 29 patients	0%	0%	0%	7%	7%	None
			STG autograft in 27 patients	7%	0%	7%	11%	18%	
Salmon (2006),[15] AJSM	67	5-13 yr	BPTB autograft	13%	13%	7%	22%	40%	Age < 21 years and meniscectomy for ACL-reconstructed knee
Drogset (2006),[39] JBJS	129	16 yr	Primary repair in 45 patients	NA	24%	51%	2%	49%	None
			Repair + LAD in 42 patients	NA	10%	36%	12%	43%	
			BPTB autograft in 42 patients	NA	2%	8%	12%	24%	
Ait Si Selmi (2006),[40] *Knee*	103	17 yr	BPTB autograft + iliotibial band extra-articular	NA	NA	40%	NA	40%	None
Hertel (2005),[41] KSSTA	96	9-12 yr	BPTB autograft	NA	NA	3%	NA	3%	None
Mykelbust (2003),[24] AJSM	57	6-11 yr	BPTB autograft	19%	19%	NA	11%	30%	Return to team handball

Abbreviations: AJSM, *The American Journal of Sports Medicine*; BPTB, bone–patellar tendon–bone; IKDC, International Knee Documentation Committee; JBJS, *Journal of Bone and Joint Surgery* (American Version); KSSTA, *Knee Surgery, Sports Traumatology, Arthroscopy*; LAD, ligament augmentation device; NA, not available; STG, semitendinosus-gracilis.

*Includes reinjuries to either knee, ACL revision, IKDC grades C or D for pivot-shift test, and Lachman test.

an ACL-reconstructed knee or sustaining an ACL rupture on the contralateral knee on return to activities after surgery vary widely (Table 1). Authors have investigated possible factors to account for reinjuries including young patient age, high sports activity level, prior meniscectomy, and improper graft placement. ACL reconstructions may also fail for reasons other than a traumatic reinjury. These include errors in surgical technique (improper placement of the ACL graft, use of low-strength grafts, inadequate fixation, graft impingement in the notch, or excessive or insufficient graft tensioning at surgery); failure of graft integration, tendon-to-bone healing, or remodeling; lateral, posterolateral,

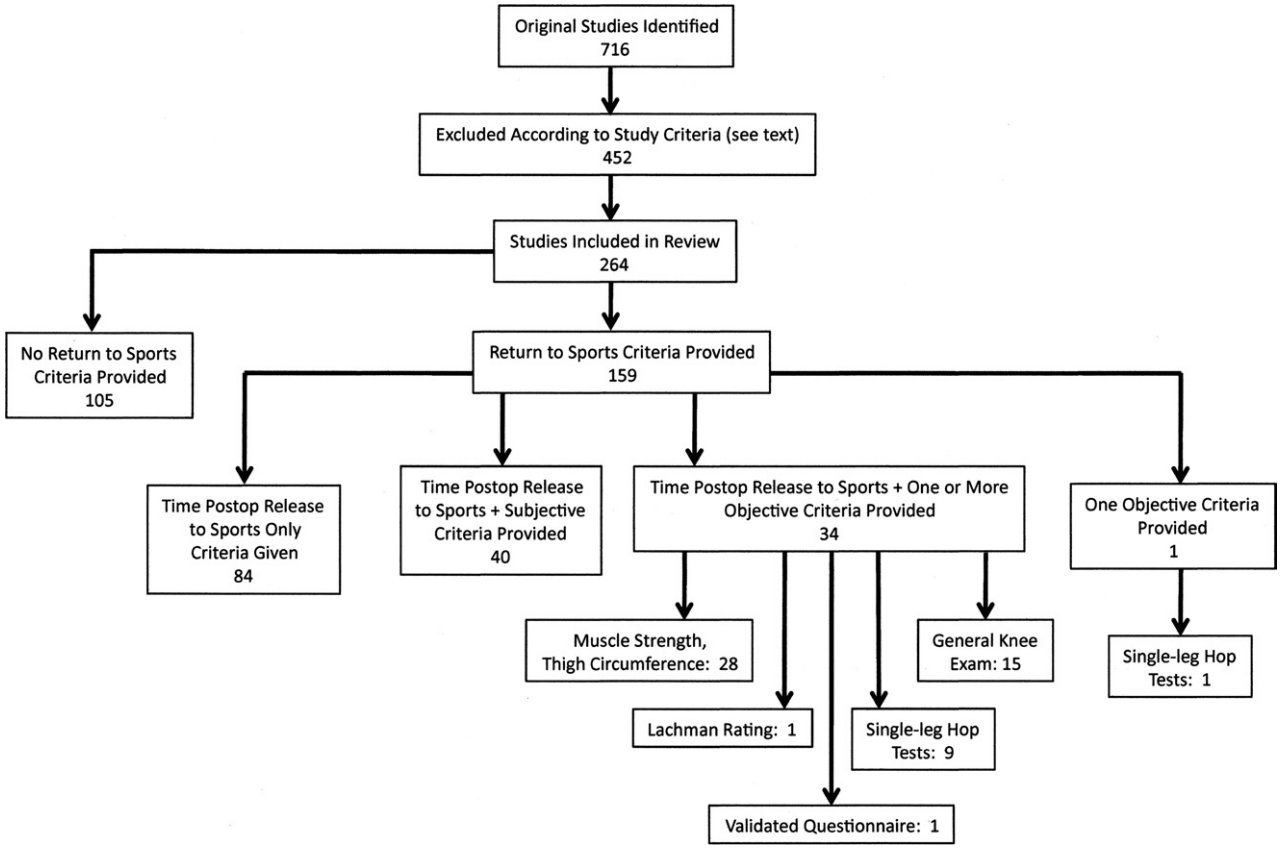

FIGURE 1. Flowchart of ACL reconstruction studies with criteria for return to athletics.

or medial ligament deficiency; postoperative infection; and inadequate rehabilitation.

Postoperative rehabilitation plays a critical role in returning patients to athletic or demanding occupational activities as safely as possible. Few studies have assessed the effectiveness of specific rehabilitation protocols with regard to restoring normal muscle strength, balance, proprioception, and other neuromuscular indices required for high-risk activities such as cutting, twisting, and pivoting. Importantly, there exist many questions and a lack of consensus regarding the appropriate criteria for releasing patients to unrestricted sports activities postoperatively.

The purpose of this systematic review was to examine the factors investigators have used over the last 10 years to determine when return to unrestricted athletics is appropriate postoperatively. To our knowledge, no such systematic review has been conducted on this topic to date.

METHODS

Literature Search

We searched Medline for all published literature from April 2001 to April 2011 using the following key words: anterior cruciate ligament reconstruction, ACL reconstruction, ACL reconstruction rehabilitation, and ACL reconstruction results. We also conducted manual searches of the following journals published during this time period: *The American Journal of Sports Medicine*; *Arthroscopy*; *The Journal of Bone and Joint Surgery* (both the American and British volumes); *The Knee*; *Clinical Orthopaedics and Related Research*; and *Knee Surgery, Sports Traumatology, Arthroscopy*.

Inclusion criteria were English language, original research report (any level of evidence), primary ACL reconstruction (any graft type), skeletally mature patients, and minimum 12 months' follow-up. Exclusion criteria were revision ACL reconstruction; dislocated knees; major concomitant procedures such as high

Table 2. *Time Allowed Postoperatively for Return to Sports According to Graft Type*

	No. of Studies					
Time Postoperatively	BPTB Autograft	STG Autograft	QT Autograft	Double-Bundle Grafts	Other Grafts*	Total
≥12 wk	—	1	—	—	1	1
3-4 mo	1	2	—	1	—	2
4 mo	—	—	—	—	2	2
4-5 mo	—	1	—	1	1	2
4-6 mo	1	3	—	—	1	4
>4 mo	2	2	—	—	—	3
≥5 mo	1	3	—	—	—	3
5-6 mo	2	1	—	—	1	2
≥6 mo	45	51	5	8	49	84
6-7 mo	1	1	—	—	—	1
6-8 mo	3	2	—	—	—	4
6-9 mo	5	3	—	2	2	8
6-10 mo	2	5	—	1	2	5
6-12 mo	1	—	—	—	—	1
7-9 mo	1	—	—	—	1	1
≥8 mo	2	3	—	—	—	4
8-9 mo	—	2	—	—	—	2
≥9 mo	4	10	—	—	2	11
9-10 mo	—	1	—	—	1	2
9-12 mo	2	—	—	—	—	2
10 mo	—	1	—	—	—	1
10-11 mo	—	1	—	1	—	1
10-12 mo	3	1	1	—	2	4
≥12 mo	4	4	—	2	2	8

Abbreviations: BPTB, bone–patellar tendon–bone; QT, quadriceps tendon; STG, semitendinosus-gracilis.
NOTE. There were multiple grafts observed in 54 of the 158 studies that provided criteria for time postoperatively.
*Allografts, primary repair, or synthetic ligaments.

tibial osteotomy, meniscus allograft, or other knee ligament reconstructions; follow-up of less than 12 months; and other types of articles such as reviews, case reports, abstracts, and technical notes.

Data Abstraction

The data from each study that met the inclusion criteria were abstracted for information regarding the type of ACL graft used and whether the following categories were used to release patients to athletic activities: (1) time postoperatively; (2) knee range of motion (ROM) and knee effusion; (3) stability, as indicated by knee arthrometer testing or results of Lachman or pivot-shift testing; (4) muscle strength testing (hamstring, quadriceps, hip, core) or thigh circumference measurement; (5) dynamic function with single-leg hop tests; (6) neuromuscular function with drop-jump tests; (7) aerobic capacity assessment for maximal oxygen uptake; (8) sports-specific testing that included results required to return to competition; and (9) validated questionnaire results.

RESULTS

Literature Search

Our search initially identified 716 articles, of which 452 were excluded according to our study criteria. This led to 264 articles appropriate for this review. Of these, 105 (40%) failed to provide any criteria for return to sports after ACL reconstruction (Fig 1). In the remaining 159 studies, 6 of the 9 categories of return-to-sports criteria that were searched for were found. The number of categories identified per study was 1 in 125 studies, 2 in 19 studies, 3 in 13 studies, 4 in 1 study, and 5 in 1 study.

Time Postoperatively

Of the 264 studies, 158 (60%) listed the amount of time postoperatively that patients were allowed to return to sports activities (Table 2). In 84 studies (32%) the amount of time postoperatively was the only criterion provided. In 40 other studies (15%), the amount of time along with subjective criteria (that

TABLE 3. *Subjective Criteria Provided for Release to Sports Activities*

Criteria	No. of Studies
Good firm anterior tibial stop	1
Good firm point on clinical evaluation	1
Knee stability confirmed on clinical examination	3
Stable knee	1
Good stability	1
Normal laxity of knee	1
Satisfactory stability	1
Ability to pass sports-specific tests such as cutting, squatting, and jumping	1
Knee function normal or nearly normal on clinical examination	1
Satisfactory clinical examination	1
Confirmation of recovery of quadriceps strength	2
Functional quadriceps control	1
Sufficient muscle recovery after specified athletic training accomplished	1
Depending on functional capacity	2
Good recovery of ROM, muscle strength, and stability	1
Regained full subjective functional stability	5
Regained full functional stability	9
Regained full functional strength and stability	2
Full functional stability in terms of strength, coordination, and balance	3
No significant side-to-side deficits	
If all parameters met	1
Depending on individual progress	1
After ACL accelerated rehabilitation program	1
No problematic symptoms in knee joint	1
Only after rehabilitation goals met	1
Controlled functional training had been performed without difficulty	2
Good muscle coordination in agility training and balance equal to opposite side	1
If patient's rehabilitation of limb and stability warrant	1
Satisfactory performance on agility drills	1
Depending on functional ability, including run-to-sprint intervals, sidestep cutting, and timed recreational drills	1
Close to full ROM and muscle strength	1

NOTE. Multiple subjective criteria were given in 10 of the 40 studies included.

could not be measured) was given (Table 3). Only 35 studies (13%) noted objective criteria required for return to athletics (Table 4). All but 1 of these 35 studies also provided criteria for time postoperatively.

There appeared to be no effect of the type of graft on the time sports could be resumed postoperatively. Although there was high variability among the investigations (ranging from ≥12 weeks to ≥12 months), 84 studies listed 6 months or greater as the time period allowed for return to athletics.

Muscle Strength

Of the 264 studies, 25 (9%) reported muscle strength criteria (Table 5) required for return to athletics. Recommendations ranged from greater than 80% to greater than 90% for isokinetic testing of the quadriceps and hamstrings compared with the contralateral side. We were unable to find data regarding the hamstring-quadriceps ratio or other muscle groups in our review. Three other studies noted that thigh circumference measurements of less than 1 cm or less than 0.5 cm (difference between limbs) were required for return to athletics.

General Knee Examination

Effusion and/or ROM criteria were listed in 15 studies (6%): 11 listed both factors, 2 provided effusion criteria only, and 2 listed ROM criteria only. In all studies no effusion and a full ROM were given as required criteria for return to sports.

Dynamic Function: Single-Leg Hop Tests

Single-leg hop testing was included in 10 studies (4%) as a criterion in their assessment for return to sports (Table 6). Six defined a result of greater than 90% of the distance hopped on a single-hop test compared with the opposite side as acceptable. One study noted that 90% or greater was required on 4 hop tests:

TABLE 4. *Objective Criteria Provided for Release to Sports Activities*

Criteria Categories	No. of Studies
Time postoperatively, muscle strength	16
Time postoperatively, muscle strength, ROM/effusion	3
Time postoperatively, thigh circumference, single-leg hop test	3
Time postoperatively, ROM/effusion	4
Time postoperatively, muscle strength, single-leg hop test	2
Time postoperatively, muscle strength, ROM	2
Time postoperatively, Lachman rating, effusion	1
Time postoperatively, muscle strength/thigh circumference, single-leg hop test	1
Time postoperatively, muscle strength, single-leg hop test, ROM/effusion	1
Time postoperatively, muscle strength, 4 single-leg hop tests, ROM/effusion, validated questionnaires	1
Single-leg hop test	1

NOTE. Data are presented for 35 studies that provided objective criteria for return to sports.

TABLE 5. *Muscle Strength Criteria for Return to Sports According to Graft Type*

Muscle Strength Criteria (Compared With Opposite Side)	No. of Studies				
	BPTB Autograft	STG Autograft	Double-Bundle Grafts	Other Grafts*	Total
>90% isokinetic strength	9	5	2	1	11
≥85% isokinetic strength	3	3	2	3	7
>80% isokinetic strength	2	3	0	1	5
≥90% quadriceps index	0	3	0	1	1
≥90% weighted leg extension	1	0	0	1	1

NOTE. There were multiple grafts observed in 15 of the 25 studies that provided muscle strength criteria.
Abbreviations: BPTB, bone–patellar tendon–bone; STG, semitendinosus-gracilis.
*Allografts or BPTB plus ligament augmentation device.

single hop, triple hop, triple crossover hop, and timed hop.[2]

Stability

Only 1 study provided objective knee stability criteria (negative Lachman test), although 7 other studies noted subjective stability criteria (Table 4). In 1 other study, the results of knee arthrometer testing determined whether a brace was required when patients returned to sports activities.

Validated Questionnaire

Only 1 study included data from validated questionnaires in its criteria for return to sport. In that investigation a score of 90% or greater was required on the Knee Outcome Survey activities-of-daily-living scale and on the global rating of an overall knee function scale for release to full athletics.

DISCUSSION

The primary findings of this systematic review suggest that noteworthy problems and a lack of objective assessment methods exist in the published literature before release to unrestricted sports activities after ACL reconstruction. Only 35 (13%) of the 264 articles reviewed included some measurable objective criteria that patients had to achieve before resuming unrestricted athletics. However, even in those articles, only 1 to 2 criteria other than time postoperatively were included in most of the studies (33).

The goals of ACL reconstruction in athletes are to restore normal knee joint stability and function and allow a return to sports activities. However, even with modern operative techniques and rehabilitation programs, there is strong evidence that deficits in balance, proprioception, muscle strength, and neuromuscular control exist for many months postoperatively.[3-6] Bonfim et al.[7] reported sensory and motor deficits in ACL-reconstructed knees with a postoperative period of 12 to 30 months compared with matched controls. Altered knee joint kinematics have been noted 4 to 12 months after ACL reconstruction during single-leg hop landings,[8,9] 5 to 12 months postoperatively during downhill running,[10] and 3 months postoperatively during a forward lunge[11] and walking.[12] Some long-term studies,[13-15] as well as a short-term study,[16] have reported high reinjury rates in athletes on return to

TABLE 6. *Single-Leg Hop Test Criteria for Return to Sports According to Graft Type*

Single-Leg Hop Test Criteria (Compared With Opposite Side)	No. of Studies				
	BPTB Autograft	STG Autograft	Double-Bundle Grafts	Other Grafts*	Total
>90% single hop	4	3	1	1	6
≥90% on 4 tests: single hop, triple hop, crossover hop, and timed hop	0	1	0	1	1
≥85% single hop	0	2	0	2	2
>90% "hop/jump testing"	1	0	0	1	1

NOTE. There were multiple grafts observed in 7 of the 10 studies that provided single-leg hop test criteria.
Abbreviations: BPTB, bone–patellar tendon–bone; STG, semitendinosus-gracilis.
*Allografts.

activity, and the factors most responsible for this problem remain unknown. The contralateral knee is at risk for ACL rupture as well, and some studies have documented a higher rate of this injury than a tear of the ACL-reconstructed knee.[13,15,16]

In this systematic review, a multifactorial analysis of knee function was determined by only 2 studies in which 3 to 4 categories (other than time postoperatively) were included for release to sports activities.[2,17] Hartigan et al.[2] required scores of 90% or greater on the quadriceps strength index, 4 single-leg hop tests (single hop, triple hop, triple crossover hop, and timed hop), the Knee Outcome Survey activities-of-daily-living scale, and a global rating of overall knee function for return to sports. They also included less than 1+ knee effusion and full ROM in their assessment. Mascarenhas et al.[17] proposed 90% or greater on a weighted leg extension test, 90% or greater on hop/jump tests (specific tests were not provided), full ROM, and no effusion for return to athletics.

A few other authors have proposed rigorous testing before return to sports. These were not clinical outcome studies and were therefore not included in our systematic review. Neeter et al.[18] developed a test battery to determine quadriceps and hamstring power in ACL-reconstructed knees in both open and closed kinetic chain conditions. They proposed that 90% of muscular power or greater on the reconstructed knee compared with the opposite knee represented a normal result. In their study, 9 of 10 patients who were assessed 6 months after ACL reconstruction had abnormal muscular power compared with healthy controls. Kvist[19] in 2004 reviewed ACL rehabilitation programs and concluded that the criteria for release to sports activities were unknown. It was noted that many authors decided on the timeline first and developed the rehabilitation program according to that criterion only, which is not a desirable approach. A listing of proposed criteria in that investigation included rehabilitation factors (<10% to 15% deficit muscle strength and single-leg hop test, no pain or effusion, full ROM, functional knee stability evaluated by objective measurements such as motion analysis), surgical factors (static knee stability measured by KT-1000 testing [MEDmetric, San Diego, CA]), and other factors (social factors, psychological factors, associated injuries).

Van Grinsven et al.[20] recently conducted a systematic review of the rehabilitation literature to develop an evidence-based postoperative ACL program that would allow a return to athletics within 6 months. They recommended the following for return-to-sports criteria: full ROM, 85% or greater on strength (quadriceps and hamstrings) and single-leg hop tests compared with the opposite leg, less than 15% deficit on hamstring-quadriceps strength ratio, no pain or swelling with sport-specific activities, and a stable knee in active situations.

A few authors have assessed certain risk factors associated with reinjury rates, including patient age, sex, sports activity level, type of graft, and meniscectomy. Borchers et al.[21] found that the use of allografts and a return to high levels of sports activities were significant risk factors for ACL graft failure in 21 of 322 patients followed up 2 years postoperatively. Their criteria for return to play were "good quadriceps control"; no functional complaints; confidence when running, cutting, and jumping at full speed; and 85% or greater on the single-leg hop test. This was the only study that did not provide time postoperatively as an additional criterion; instead, the authors stated that progression was based on the patient achieving functional criteria. Paterno et al.[16] reported that alterations in neuromuscular control of the hip and knee on a drop-jump task and postural stability predicted ACL injury on return to activities after reconstruction in 43 athletes followed up for 1 year postoperatively. They did not provide criteria for return to sports after ACL reconstruction, and in 10 of the 13 patients who had a reinjury, it occurred in the contralateral knee. Patient age of either less than 18 years[22,23] or less than 21 years[14,15] has been cited by other authors as a risk factor for reinjuries. Return to high-risk sports such as soccer,[23] basketball,[23] and team handball[24] has also been noted to be associated with higher injury rates. Unfortunately, studies that have assessed factors that may be responsible for reinjury rates have not taken into account the status of the athletes' strength, stability, neuromuscular control, and general knee condition on return to sports. The possibility exists that many athletes have not regained acceptable levels of function in these categories in both lower limbs and that the premature release to unrestricted activities may be a factor for the subsequent reinjuries.

Postoperative rehabilitation plays a critical role in returning patients to athletic activities as safely as possible. In discussing their high rate of reinjury after ACL reconstruction, Salmon et al.[15] noted that a motor-retraining rehabilitation program was worthy of future study, even though they did not allow a return to sports until 9 months postoperatively. Risberg and Holm[25] concluded that the combination of strength training and neuromuscular exercises was required to

achieve the best outcomes, including the patient's perception of knee function and knee performance on strength and hop tests. Future studies are required to determine whether advanced rehabilitation programs that include neuromuscular retraining are effective in reducing the reinjury rate after surgery.

Reducing the risk of reinjury after ACL reconstruction on return to athletics requires a multifaceted approach. The reconstructive procedure itself is of paramount importance, because a nonanatomic or vertically placed graft has a high risk of failure even without return to strenuous activities.[26] The postoperative physical therapy program should be structured and gradually intensified to be effective without causing complications such as anterior knee pain or tendinitis (Video 1, available at www.arthroscopyjournal.org). In addition, consideration is required of any major concomitant procedures such as meniscus repairs, which require modifications to the protocol. Advanced neuromuscular retraining should be accomplished along with strength training before return to high-risk activities.[25,27] Finally, we believe that factors related to muscle strength, stability, neuromuscular control, and lower limb function should be measured before release to unrestricted activities. Our criteria for release include less than 10% deficit in strength of the quadriceps and hamstring on isokinetic testing at 180°/s and 300°/s, less than 15% deficit in lower limb symmetry on single-leg hop testing (single hop, triple hop, crossover hop, and timed hop[28]), less than 3 mm of increased anterior-posterior tibial displacement on Lachman or knee arthrometer testing, greater than 60% normalized knee separation distance on a video drop-jump test,[29] no effusion, full knee motion, normal patellar mobility, no or only slight patellar crepitus, and no pain or swelling with all activities. Other tests to consider are the single-leg squat test to determine postural and lower limb control as well as hip muscular function,[30,31] the multistage fitness test to determine maximal oxygen uptake,[32] and the 60-second sit-up test[33] or other core strength measures.[34] If isokinetic test equipment is not available, a 1-repetition maximum bench press and leg press are recommended if weight room equipment is available, along with an experienced test administrator and a sufficient amount of time to safely conduct these tests.[35,36]

One limitation to this review is the potential that some of the investigations did in fact objectively measure certain indices before athletes were released to full sports activities but did not include this information in the article. Authors of future studies are encouraged to provide these important details. Although recommendations are made for tests and achievement of certain criteria, whether this detailed analysis will reduce the rate of injury to either knee after ACL reconstruction remains to be determined. We did not assess each study for its methodologic quality. However, because we were examining the methods used by investigators, and not outcomes, we did not believe such an assessment was required.

CONCLUSIONS

The published literature shows that a lack of consensus regarding the appropriate criteria for releasing patients to unrestricted sports activities exists after ACL reconstruction. A systematic review of the literature was conducted to identify the factors investigators have used over the last 10 years to determine when return to athletics is appropriate. Of 264 studies that met our study inclusion criteria, 105 (40%) failed to provide any measures for return to sports after surgery. Only 35 studies (13%) included objective criteria that consisted of the categories of muscle strength or thigh circumference, general knee examination, single-leg hop tests, Lachman rating, or validated questionnaires. Only 2 studies used 4 to 5 measurable factors to determine whether release to unrestricted activities was appropriate. The results of this systematic review show noteworthy problems and a lack of objective assessment before release to athletics. Measurement of muscle strength, stability, neuromuscular control, and function is recommended before release to unrestricted activities.

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