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## Variables Associated With Return to Sport Following Anterior Cruciate Ligament Reconstruction: A Systematic Review

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### Abstract

**Background**—As one of the purposes of anterior cruciate ligament reconstruction (ACLR) is to return athletes to their pre-injury activity level, it is critical to understand variables influencing return to sport. Associations between return to sport and variables representing knee impairment, function and psychological status have not been well studied in athletes following ACLR.

**Purpose**—The purpose of this review is to summarize the literature reporting on variables proposed to be associated with return to sport following anterior cruciate ligament reconstruction.

**Study Design**—Systematic Review

**Methods**—Medline, Embase, CINAHL and Cochrane databases were searched for articles published before November 2012. Articles included in this review met these criteria: 1) included patients with primary ACLR, 2) reported at least one knee impairment, function or psychological measure, 3) reported a return to sport measure and 4) analyzed the relationship between the measure and return to sport.

**Results**—Weak evidence existed in sixteen articles suggesting variables associated with return to sport included higher quadriceps strength, less effusion, less pain, greater tibial rotation, higher Marx Activity score, higher athletic confidence, higher pre-operative knee self-efficacy, lower kinesiophobia and higher pre-operative self-motivation.

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**Conclusion**—Weak evidence supports an association between knee impairment, functional, and psychological variables and return to sport. Current return to sport guidelines should be updated to reflect all variables associated with return to sport. Utilizing evidence-based return to sport guidelines following ACLR may ensure athletes are physically and psychologically capable of sports participation, which may reduce re-injury rates and the need for subsequent surgery.

### Keywords

anterior cruciate ligament reconstruction; return to sport; psychological; rehabilitation

## BACKGROUND

Anterior cruciate ligament (ACL) tears are the most commonly reported knee injury in athletes, with nearly 300,000 anterior cruciate ligament reconstructions (ACLR) performed yearly in the United States.[1] Previous reports indicate that 98% of orthopaedic surgeons recommend surgery if patients wish to return to sport,[2] but not all patients return to sport following ACLR. Clinical guidelines suggest that patients should be expected to return to sport by nine months post-surgery, but many patients have not achieved this activity level up to 18 months after receiving clearance to return to sport.[3] Declines in sports participation compared to pre-injury levels are noted as far as five and seven years post-surgery,[4–7] though reasons for activity level changes may be unrelated to knee function.

Improved understanding of variables influencing patients' ability to return to sports is needed. Return to sport recommendations following ACLR are varied and often based on clinical experience or reviews reporting the criteria utilized in randomized control trials (RCTs).[8–11] Most return to sport criteria following ACLR includes assessments of knee impairment and function, such as knee range of motion (ROM), quadriceps strength and functional test performance. Achieving knee ROM equivalent to the uninvolved limb is frequently emphasized[12–17] as ROM asymmetry between limbs has been linked to worse subjective outcomes 10 years post-surgery, though the ability of these patients to return to sport is unknown.[18] Quadriceps and hamstring strength are the most commonly utilized objective criteria when determining patient readiness to return to sport,[13, 14, 16, 19–26] and published reports note persistent quadriceps weakness years after surgery.[27, 28] Typical criteria include a quadriceps limb symmetry index (LSI) equivalent to >80–90% of the opposite side.[13, 14, 16, 19–26] Although quadriceps weakness may alter knee kinematics during running and cutting,[29] the actual relationships between quadriceps strength and functional test performance such as hop testing is unclear.[30–34] Single leg hop LSI 90% is also often cited,[15, 23, 25, 35–38] but the relationship between functional test performance and athletic performance is not well established.[39] Despite post-surgical emphasis on strengthening and functional performance, abnormal lower limb kinematics are evident during hopping and jumping two to four years following ACLR.[40, 41] The ability of these frequently utilized clinical criteria to predict athletes' ability to return to sport is unknown.

Some patients without impairments in ROM or strength may choose not to return to their pre-injury level of sports participation for reasons unrelated to knee function, such as lifestyle changes. Conversely, some patients reporting substantial knee impairments after ACLR return to competitive sport.[42] Psychological variables may partially explain the lack of association between physical function and return to sport.[43–45] Fear of movement and re-injury, or kinesiophobia, is one of the most commonly cited reasons patients do not return to sport following ACLR.[46] Although kinesiophobia declines during rehabilitation,[47] it is still reported in as high as 20–24% of patients.[6, 48] Higher perceived self-efficacy (one's judgment about whether one can perform a task)[49, 50] and an internal

health locus of control[51, 52] have been linked to better quality of life scores, knee function and subjective outcomes post-ACLR. Despite these reports, psychological measures are not typically used in current return to sport criteria following ACLR.

The evidence supporting current clinical criteria used to allow patients to return to sport following ACLR has not been thoroughly examined. The primary purpose of this systematic review is to summarize the published literature reporting on knee impairment, functional, and psychological variables proposed to be associated with return to sport following ACLR. Knowledge of variables associated with athletes' return to play following surgery may aid clinicians in counseling patients and focusing rehabilitation programs. The secondary purpose of this review is to provide recommendations for future research to develop evidence-based return to sport criteria.

## METHODS

### Search Strategy

Medline, CINAHL, Embase and the Cochrane Database were searched for articles published in print or electronically prior to November 2012. Subject mapping and key words were used for each search engine, including anterior cruciate ligament surgery and/or injury, pre-operative care, post-operative care, range of motion, muscle strength, proprioception, kinesiophobia, psychological, recovery of function and return to sports/return to play/sports re-entry. A reference librarian assisted with the database searches. A sample search is shown in Appendix 1. Two board-certified orthopaedic physical therapists independently applied the inclusion/exclusion criteria to these articles. The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) flow diagram of the search results is shown in Figure 1.[53]

### Selection Criteria

Inclusion criteria for the articles selected were: (1) patients had undergone primary ACLR, (2) English language, (3) at least one knee impairment, functional, or psychological measure was reported, (4) return to sport (defined as any sport, the same sport, and the same level of pre-injury sport at any post-surgical timeframe) was reported via subjective report or any measure directly identifying the patients' level of active sports participation, such as the Tegner Activity score or study-defined criteria, and (5) studies contained statistical analyses examining the association between variables of interest and return to sport. Exclusion criteria were concomitant surgery of other ligaments or microfracture surgery. Concomitant meniscectomy or meniscal repair, or history of contralateral ACLR was permitted. Studies simply identifying whether patients could perform sport-related tasks but not reporting actual return to sport were excluded. Thus, measures such as the International Knee Documentation Committee (IKDC) objective form score, Cincinnati Knee Rating Scale score and the Lysholm Knee score did not meet the definition of a return to sport measure for this review. Two reviewers independently reviewed titles and abstracts, then full text of potentially relevant articles, and attained consensus on articles to be included in the review.

### Data Extraction and Analysis

Once articles meeting the inclusion criteria were identified, the lead author independently extracted information from each article. Information identified for descriptive analysis included study population, follow-up timeframe, pre-injury athletic participation, return to sport rate, knee impairment and functional outcomes, psychological outcomes, and statistical analyses relating variables of interest to return to sport. If data such as return to sport rate was not directly reported within a study, it was calculated with available data. A second reviewer confirmed all information. As a framework for data analysis, strength of evidence

was classified according to Logerstedt et al.[54] Evidence is considered strong when supported by numerous high-quality RCTs, moderate when supported by either a single high quality RCT or numerous low-quality RCTs or cohort studies, and weak when supported by retrospective or case controlled studies.

### Assessment for Risk of Bias

Using the 11 item checklist recommended by the Cochrane Collaboration Back Review Group,[55] two reviewers independently assessed each study for methodological risk of bias and discrepancies were resolved by consensus (Appendix 2). These criteria assess study characteristics related to selection bias, performance bias, attrition bias and detection bias. Van Tulder et al.[56] reported that RCTs meeting fewer than 6 criteria reported approximately 50% greater effect sizes than those meeting 6 criteria, indicating that studies with lower methodologic quality may have exaggerated results. Therefore, in this review, articles were classified as having a “high risk” (<6 “yes” responses) or “low risk” of bias (6 “yes” responses).

Two reviewers independently rated the level of evidence of the final selected articles according to the Oxford Centre for Evidence Based Medicine.[57] This system is a systematic approach to rank strength of evidence according to the type of clinical question involved. Levels of evidence range from 1 to 5 where Level 1 studies are regarded to contain the highest quality of evidence. Consensus was obtained between both reviewers for each article's risk of bias and level of evidence rating.

## RESULTS

Initial database searches identified 1372 potential articles with 183 articles selected for detailed review (Figure 1). 16 articles were included in the final review (Table 1).

### Study design

Of the 16 articles,[6, 48, 49, 58–70] four were RCTs.[62, 63, 67, 70] The remaining 12 studies were prospective cohort design[49, 58–60, 64, 68] or cross-sectional studies.[6, 48, 61, 65, 66, 69] Four included multivariate analyses to control for variables (such as age, gender, education, height, weight, body mass index, time since surgery) that may have affected their results.[49, 64–66] Six studies were rated as Level 2[49, 58, 63–67, 69] and ten were rated Level 4.[6, 48, 58–62, 68, 70] All studies[6, 48, 49, 58–70] were rated as having a high risk of bias (Appendix 2).

### Patient Characteristics

All 16 studies[6, 48, 49, 58–70] included both men and women. Women comprised between 3–45% of patients within studies. Mean age ranged from 22–30 years. Patellar tendon graft was used exclusively for reconstruction in four studies,[59, 60, 65, 70] hamstring graft exclusively in four studies,[6, 58, 63, 67] and both graft types were utilized in six studies.[48, 49, 62, 64, 68, 69] Two studies did not report graft type.[61, 66]

One study excluded patients with any previous history of knee surgery.[69] Two studies excluded patients who specifically had a previous history of ACLR[6, 48] and three excluded patients with a history of meniscectomy.[62, 63, 67] Three studies included patients with ipsilateral partial meniscectomy[62] or contralateral ACL reconstruction.[66, 68] Nine studies[49, 58–61, 64, 65, 68, 70] did not provide information regarding patients' previous surgical history. Surgical details beyond graft type and fixation, including information regarding meniscectomy or meniscal repair, was stated in one study.[6]

Concurrent meniscal repair during surgery was permitted in two studies[6, 67] but not in two others.[64, 68]

Each study defined athletic status based on patients' pre-injury competition level or Tegner activity level. Competitive athletes were generally defined as anyone participating in non-professional sports leagues locally, regionally or nationally. Recreational athletes were defined as anyone participating in sports who did not meet the definition of a competitive athlete. Ten studies included patients participating in at least recreational sports.[6, 49, 60–63, 65, 66, 69, 70] Two studies included only patients participating in competitive sports.[58, 68] Four studies did not report pre-injury athletic status.[59, 64, 66, 67]

### Patient Follow-up

Patients were tracked for return to sport between six months and 7.9 years after ACLR. The most common re-evaluation timeframe was at one year post-surgery.[49, 58, 63–66, 68, 69] Other timeframes used were 6 months,[68] 1–2 years,[61] 2–3 years,[62, 63, 67, 70] 3–4 years,[48, 60] five years,[6] and eight years.[59]

### Return to Sport Outcomes

Return to sport information was obtained using two methods: through patient self-report[48, 58, 65, 66, 68–70] including the Tegner Activity Scale,[6, 49, 61–64, 67] and study-defined criteria.[59, 60] In studies where patient self-report was used but not with the Tegner Activity Scale, patients compared their current sports participation frequency[65, 70] and/or competition level[48, 58, 65, 66, 68, 70] to their pre-injury participation level. For study-defined criteria, Arvidsson et al.[59] grouped patients from I–IV, where Group I included patients with “no complaints, sports possible as normal” to Group IV which included those with “pronounced instability and pain made sports impossible.” Barrett et al.[60] graded activity from I–IV, where Grade I included national or county level sports and Grade IV included those not participating in any sport. Though patients may not have returned to the same pre-injury sports, they classified these patients as having returned to their pre-injury level of sports if they rated their current and pre-injury activity levels the same at follow-up. At follow-up, an average of 50.7% of patients returned to pre-injury level of sports activity.[6, 48, 58–60, 62, 63, 68–70] Modified sports participation, defined as patients achieving a lesser activity level compared to their pre-injury level, was reported in 32.9% of patients and 17.2% of patients did not return to sports at all.[6, 58–60, 62, 63, 66, 70] Patient reported reasons for not returning to pre-injury sports participation included fear of re-injury,[6, 48, 60, 62, 69, 70] impaired knee function,[48, 70] social/family reasons,[6, 70] instability,[6, 69] pain, [62, 69] no motivation,[48] effusion,[69] muscle weakness,[69] and knee extension deficit.[62]

### Variables Associated with Return to Sport

**Variables Representing Knee Impairment and Function**—The evidence reporting the association between knee impairment and function and return to sport is limited. Based on four level 4 studies and one level 2 study, weak evidence[54] supports associations between return to sport and higher post-operative quadriceps torque,[59, 69, 70] less knee effusion[60, 69] and a higher Marx Activity Score[62]. Based on two level 2 studies and one level 4 study, weak evidence[54] supports associations between return to sport and greater post-operative tibial rotation,[67] less pain[60, 69] and fewer episodes of instability.[69] Based on one level 2 study and four level 4 studies, weak evidence[54] indicates no association between return to sport and pre-operative quadriceps torque,[64] pre-operative anterior knee joint laxity,[64] post-operative anterior knee joint laxity,[60, 68, 69] pre-operative knee extension ROM,[64] post-operative knee extension or flexion ROM,[69] or pre-injury activity level.[64] There is conflicting evidence for associations between return to

sport and the IKDC subjective form score,[6, 62, 69] IKDC Grade,[6, 58, 62] post-operative hamstring torque,[59, 61] Lysholm Knee score[6, 61, 62] and post-operative LSI for single hop or crossover hop for distance.[58, 61, 68] Available raw data and between-group statistics for each study is presented in Table 2.

**Psychological Variables**—Studies utilized several standardized measures to assess psychological variables, including the Tampa Scale of Kinesiophobia (fear of movement or re-injury),[48, 65, 69] Anterior Cruciate Ligament-Return to Sport after Injury Scale (athletic confidence, emotions and risk appraisal),[66, 68] Psychovitality questionnaire (self-motivation to return to sport),[62, 63] Knee Self-Efficacy Scale (evaluates beliefs about the ability to perform tasks),[49] Shortened Profile of Mood States (negative affect),[65] Pain Catastrophizing Scale (evaluates people's thoughts and feelings about pain)[65] and Emotional Responses of Athletes to Injury Questionnaire.[68]

Based on three level 2 and two level 4 studies, weak evidence[54] supports associations between return to sport and kinesiophobia[48, 65, 69] and athletic confidence.[66, 68] Based on one level 2 and one level 4 study, weak evidence[54] supports associations between return to sport and pre-operative knee self-efficacy[49] and pre-operative self-motivation.[62, 63] Weak evidence[54] exists indicating that emotional response to injury/surgery.[68] negative affect and pain catastrophizing[65] are not associated with return to sport. Available raw data and between-group statistics are presented in Table 2.

## DISCUSSION

Surgery is commonly recommended for athletes with ACL tears wishing to return to their previous level of sports activity.[2] However, many of these athletes never return to their pre-injury level of play.[3, 5] This review summarizes the literature on knee impairment, function and psychological variables associated with return to sport following ACLR. In this review, we broadly defined return to sport to include all possible definitions (any sport, the same sport and the same level in pre-injury sport) and at any post-surgical timeframe. A limited number of articles met our inclusion criteria. Many potentially relevant articles only included self-report of function as the primary outcome and were excluded. Although functional improvement is important, return to sport is often the main reason patients elect surgery.[2] Based on our review, weak evidence[54] exists suggesting that higher post-operative quadriceps strength,[59, 69, 70] less knee effusion,[60, 69] lower pain,[60, 69] fewer episodes of instability,[69] greater tibial rotation ROM,[67] lower kinesiophobia,[48, 65, 69] higher athletic confidence,[66, 68] higher pre-operative knee self-efficacy[49] and higher pre-operative self-motivation[62, 63] are associated with return to sport. Although post-surgical anterior knee joint laxity has been linked with patient satisfaction[71] and general knee function[72] following ACLR, there was insufficient evidence that anterior knee laxity influences return to sport.[60, 68, 69]

Return to sport criteria following ACLR includes various assessments of knee impairment and function. Recently, Barber-Westin and Noyes[10] reported the most commonly cited post-surgical return to play criteria included achieving specific LSI for quadriceps strength and hop testing, full knee ROM and no knee effusion. They also advocated for the inclusion of a drop-jump test, single-leg squat test to 90 degrees, assessment of knee laxity and examination of sports-specific drill performance. Thomeé et al.[9] recommended strength and hop test performance criteria utilizing both absolute values and between-limb comparisons prior to return to sport, and proposed criteria be adjusted according to type of sport patients are returning to (e.g. cutting/pivoting, recreational/competitive, contact/noncontact). Our review supports including assessment of LSI for quadriceps strength and measurement of knee effusion. However, we found conflicting evidence to support the use

of hop testing, and insufficient evidence to support using anterior knee joint laxity assessment or knee flexion and extension ROM in return to sports criteria following ACLR. Although functional testing, which traditionally evaluates differences between the surgical and non-surgical limb, is considered important to assess athletes' neuromuscular control and has been linked to better self-reported knee function,[73] only three studies examined the association between hop testing and return to sport.[58, 61, 68] Although two studies found no association between LSI on the single hop for distance[61, 68] or crossover hop for distance[61, 68] and return to sport, Ardern et al.[58] noted that a LSI  $\geq 85\%$  on both hop tests significantly increased the likelihood of return to pre-injury level of sports participation. Baltaci et al.[61] also studied the triple hop for distance and found no association with return to sport. Additional studies investigating the relationship between hop testing and return to sport are needed for more definitive conclusions.

General return to sport criteria does not include assessments of psychological variables, yet evidence exists for their inclusion. Fear of re-injury is a frequently cited reason patients do not return to pre-injury level of sport[46] and may relate to some athletes' confidence in their ability to safely return to sport following surgery. In this review, lower athletic confidence was associated with decreased likelihood of return to sport.[66, 68] Psychological variables such as fear of re-injury[48, 65, 69] and reduced athletic confidence[66, 68] may explain why some athletes without physical or functional impairments choose not to return to sport. [45] Physical and psychological readiness to return to sport following injury do not always coincide,[43] so techniques addressing fear and athletic confidence may need to be incorporated during rehabilitation. Patients receiving pre-surgical education by patients who have completed their post-ACLR rehabilitation, known as "modeling," demonstrate higher rehabilitation self-efficacy and earlier functional achievements six weeks post-ACLR.[74] In the post-lumbar fusion population, combined psychomotor training to improve movement patterns and address maladaptive psychological behaviors decreases kinesiophobia, improves self-efficacy and decreases functional disability up to three years post-surgery.[75] The short-and long-term effectiveness of modeling and psychomotor training on return to sport in the post-ACLR population warrants further attention.

For this review, we broadly defined return to pre-injury sport to include the same level of sport, whether or not participation in the actual pre-injury sport was achieved, at any timeframe post-surgery. Overall, 50.7% of patients returned to their pre-injury level of sports,[6, 48, 58–60, 62, 63, 68–70] which is lower than previously published reviews.[3, 46] At two years post-surgery, two separate reviews reported 63–79% return to pre-injury sports participation.[3, 46] In contrast to these reviews, post-surgical follow-up in this review ranged from one year to eight years post-surgery, which may have influenced reported rates. Additionally, ten studies in this review included recreational athletes,[6, 49, 60–63, 65, 66, 69, 70] but the athletic participation levels in previous reviews[3, 46] was not described. Athletes participating at higher competitive sports levels have shorter physical recoveries post-surgery[76] and professional athletes' motivation to return to pre-injury level of sport is likely higher than non-professional athletes. However, compared to recreational athletes, professional athletes' drive to return to play may yield greater negative psychological responses following injury and/or surgery, which may also affect return to sport. Future research addressing the influence of the level of athletic participation on return to sports rates is needed.

There are some limitations to this review. First, relevant articles may have been missed. In an attempt to capture all relevant articles, multiple databases were searched with the aid of a reference librarian and no limitation on publication year was applied. Only one exclusion criterion of no concomitant ligamentous surgery or microfracture surgery was used. This did not affect the number of studies examined, as studies including concomitant ligamentous

surgery or microfracture surgery had already been eliminated for not meeting the inclusion criteria, including analysis between variables of interest and return to sport or utilizing a specific return to sport measure. Second, we restricted our search to articles published in English, which may have limited our results. Resources to translate foreign publications were not available. Additionally, we included articles using the Tegner Activity Scale, which categorizes individuals who are playing sport as well as those who are not. By not differentiating between sports and work activities, articles utilizing this measure may not accurately report actual return to sport. We chose to include these articles because they made attempts to quantify regular physical activity levels, as opposed to articles which were excluded because they used scales that only identified potential activity levels. Finally, four studies [59, 64, 66, 67] did not indicate patients' pre-injury sports participation. It is possible these patients were not participating in sports before surgery so returning to sport was not a relevant outcome. This may have affected the accuracy of our return to sport analysis.

Many studies provided only Level 4 evidence and all studies were rated as having a high risk of bias. Although RCTs are ideal, prospective cohort designs including assessment of the multiple variables thought to be associated with return to sport, such as age, gender and time since surgery, would be appropriate. Fourteen studies had 100 patients or less [6, 48, 49, 59–65, 67–70] and of these, six had less than 50 patients. [49, 60, 61, 65, 67, 70] With relatively small sample sizes, it is possible the magnitude of the results was overstated. Studies with larger cohorts are needed to clarify these relationships. The type of post-operative rehabilitation, such as accelerated versus conservative, may influence patients' ability to return to sport. Patients' post-operative rehabilitation course was reported in varying detail in only ten studies, [6, 58, 60, 63, 64, 66–70] making it difficult to critically examine all variables that may be related to patient outcomes. Only four prospective cohort studies accounted for potential confounders to surgical outcomes, such as age, gender, time since surgery and body mass index. [49, 64–66] These studies did not find significantly different results compared to those not statistically adjusting for these confounders, but the strength of associations reported in this review may have been altered if all studies performed these analyses. Although several studies included documentation of anterior knee laxity [62, 63, 67, 70] and ROM, [60, 61, 63, 68] their association with return to sport was not examined. Four articles examining these relationships found no association between return to sport and laxity [60, 64, 68, 69] or ROM [64, 69] but these conclusions may have been altered if the associations were consistently analyzed across all studies. Finally, gender-related differences in return to sport may exist but were not explored in any study in this review. Ardern et al. [58] reported men were more likely than women to attempt full competition in their pre-injury sport one year post-surgery and Noojin et al. [77] reported that males scored higher on the Tegner Activity Scale than females three years post-surgery. However, Ferrari et al. [78] found no gender difference in Tegner scores 4.5 years post-ACLR. These limitations highlight the need for further studies in this area.

The influence of multiple variables representing knee impairment, function, and psychological status on return to sport following ACLR has been investigated. Commonly utilized post-surgical return to play criteria include evaluation of knee impairments such as quadriceps strength and effusion that, in this review, were weakly [54] associated with return to sport. Evidence was lacking to definitively support associations between return to sport and other variables representing knee impairments and function, such as knee joint laxity and hop testing. The ability of athletes to return to their pre-injury level of sport following surgery is likely multifactorial, but currently there is not enough evidence to make strong recommendations about current return to play criteria. Greater attention should be placed on the effectiveness of these objective criteria in accurately identifying when patients can safely return to pre-injury activity levels. Additionally, including psychological criteria in return to sports guidelines is likely warranted. Future research should include larger randomized



studies that investigate multiple variables representing knee impairment, function and psychological status, their interactions and return to play.

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## Appendix

## Appendix 1

## Sample CINAHL Search

Search ID#	Search Terms	Search Options	Last Run Via	Results
S25	S8 or S10 or S16 or S18 or S22 or S24	Search modes – Boolean/Phrase	Interface – EBSCOhost Search Screen – Advanced Search Database – CINAHL Plus	23
S24	S6 and S23	Search modes – Boolean/Phrase	Interface – EBSCOhost Search Screen – Advanced Search Database – CINAHL Plus	1
S23	(MH “Adaptation, Psychological+”) OR psychological	Search modes – Boolean/Phrase	Interface – EBSCOhost Search Screen – Advanced Search Database – CINAHL Plus	91257
S22	S26 and S21	Search modes – Boolean/Phrase	Interface – EBSCOhost Search Screen – Advanced Search Database – CINAHL Plus	2
S21	Psychosocial	Search modes – Boolean/Phrase	Interface – EBSCOhost Search Screen – Advanced Search Database – CINAHL Plus	195414
S20	S6 and S19	Search modes – Boolean/Phrase	Interface – EBSCOhost Search Screen – Advanced Search Database – CINAHL Plus	0
S19	kinesiophobia	Search modes – Boolean/Phrase	Interface – EBSCOhost Search Screen – Advanced Search Database – CINAHL Plus	99
S18	S6 and S17	Search modes – Boolean/Phrase	Interface – EBSCOhost Search Screen – Advanced Search Database – CINAHL Plus	4
S17	(MH “Postoperative Care+”)	Search modes – Boolean/Phrase	Interface – EBSCOhost Search Screen – Advanced Search Database – CINAHL Plus	9280
S16	S6 and S15	Search modes – Boolean/Phrase	Interface–EBSCOhost Search Screen – Advanced Search Database – CINAHL Plus	1

Search ID#	Search Terms	Search Options	Last Run Via	Results
S15	(MH "Preoperative Care+")	Search modes – Boolean/Phrase	Interface – EBSCOhost Search Screen – Advanced Search Database – CINAHL Plus	9586
S14	S6 and S13	Search modes – Boolean/Phrase	Interface – EBSCOhost Search Screen – Advanced Search Database – CINAHL Plus	0
S13	Proprioception	Search modes – Boolean/Phrase	Interface–EBSCOhost Search Screen – Advanced Search Database – CINAHL Plus	1569
S12	S6 and S11	Search modes – Boolean/Phrase	Interface–EBSCOhost Search Screen – Advanced Search Database – CINAHL Plus	1
S11	Quadriceps muscle	Search modes – Boolean/Phrase	Interface–EBSCOhost Search Screen – Advanced Search Database – CINAHL Plus	416
S10	S6 and S9	Search modes – Boolean/Phrase	Interface – EBSCOhost Search Screen – Advanced Search Database – CINAHL Plus	8
S9	Muscle strength	Search modes – Boolean/Phrase	Interface – EBSCOhost Search Screen – Advanced Search Database – CINAHL Plus	8071
S8	S6 and S7	Search modes – Boolean/Phrase	Interface – EBSCOhost Search Screen – Advanced Search Database – CINAHL Plus	18
S7	Range of motion	Search modes – Boolean/Phrase	Interface–EBSCOhost Search Screen – Advanced Search Database – CINAHL Plus	11621
S6	S1 and S2 and S5	Search modes – Boolean/Phrase	Interface–EBSCOhost Search Screen – Advanced Search Database – CINAHL Plus	51
S5	S3 or S4	Search modes – Boolean/Phrase	Interface – EBSCOhost Search Screen – Advanced Search Database – CINAHL Plus	10568
S4	(MH "Sports Re-entry")	V	Interface – EBSCOhost	831

Search ID#	Search Terms	Search Options	Last Run Via	Results
S3	Recovery function OR (MH "Recovery")	Search modes – Boolean/Phrase	Search Screen – Advanced Search Database – CINAHL Plus	9760
S2	(MH "Surgery, Reconstructive+")	Search modes – Boolean/Phrase	Interface–EBSCOhost Search Screen – Advanced Search Database – CINAHL Plus	5042
SI	(MH "Anterior Cruciate Ligament") OR (MH "Anterior Cruciate Ligament Injuries.")	Search modes – Boolean/Phrase	Interface–EBSCOhost Search Screen – Advanced Search Database – CINAHL Plus	3421

Appendix 2

Sources of Bias and Quality Assessment[55]

Risk of bias assessment	Ardern [58]	Arvidsson [59]	Baltaci [61]	Barrett [60]	Gobbi [63]	Gobbi [62]	Heijne [64]	Krist [48]	Langford [68]	Lee DY[6]	LeeS [67]	Lentz [69]	Mikkelsen [70]	Thomeé [49]	Tripp [65]	Webster [66]
Was the method of randomization adequate?	N/A	N/A	N/A	N/A	No	No	N/A	N/A	N/A	N/A	No	N/A	No	N/A	N/A	N/A
Was treatment allocation concealed?	N/A	N/A	N/A	N/A	No	No	N/A	N/A	N/A	N/A	Don't Know	N/A	Don't Know	N/A	N/A	N/A
Were groups similar at baseline regarding most important prognostic indicators?	N/A	N/A	No	N/A	Don't Know	Don't Know	N/A	N/A	N/A	N/A	Yes	N/A	Don't Know	N/A	N/A	N/A
Was the patient blinded to intervention?	No	No	No	No	Yes	Don't Know	No	No	No	No	Don't Know	No	No	No	No	No
Was the care provider blinded to intervention?	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Was the outcome assessor blinded to intervention?	No	No	No	No	Yes	Don't Know	No	No	No	No	No	No	Don't Know	No	No	No
Were cointerventions avoided or similar?	Yes	Don't Know	N/A	Yes	Yes	Don't Know	Don't Know	Don't Know	Don't Know	No	Yes	Yes	Yes	Don't Know	Don't Know	Don't Know
Was compliance acceptable in all groups?	Don't Know	Don't Know	Don't Know	Don't Know	Don't Know	Don't Know	Don't Know	Don't Know	Don't Know	Don't Know	Don't Know	Don't Know	Don't Know	Don't Know	Don't Know	Don't Know
Was the dropout rate described and acceptable?	No	No	N/A	No	No	No	Yes	N/A	No	N/A	Yes	N/A	No	Don't Know	N/A	N/A
Was the timing of the outcome	Yes	No	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No

Risk of bias assessment	Ardern [58]	Arvidsson [59]	Baltaci [61]	Barrett [60]	Gobbi [63]	Gobbi [62]	Heijne [64]	Kvist [48]	Langford [68]	Lee DX[6]	Lee S [67]	Lentz [69]	Mikkelsen [70]	Thoméé [49]	Tripp [65]	Webster [66]
assessment in all groups similar?																
Did the analysis include an intention to treat analysis?	N/A	N/A	N/A	N/A	Yes	Yes	N/A	N/A	N/A	N/A	No	N/A	Yes	N/A	N/A	N/A
Risk of bias	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High

N/A = not applicable

Note: Operationalization of the risk of bias criteria available in van Tudur et al.[55]

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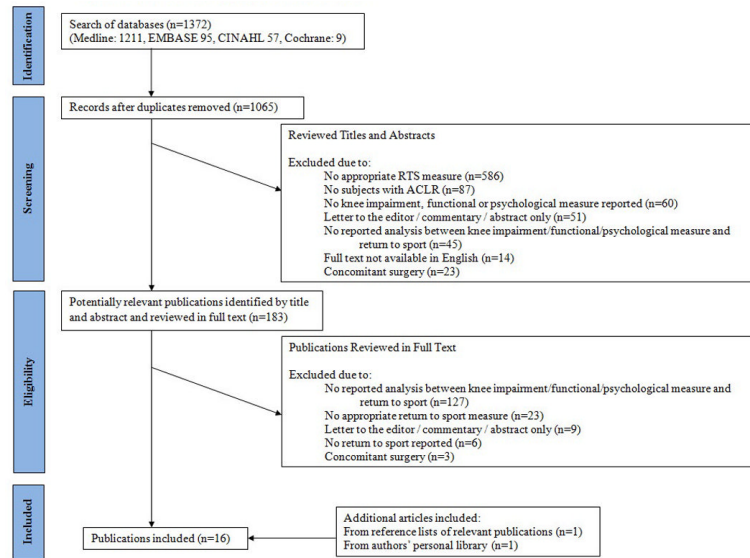
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**Summary Box: What are the new findings?**

- Variables that may be associated with good functional outcome and patient satisfaction following anterior cruciate ligament reconstruction have been examined, but few studies have examined whether these variables are also associated with return to sport.
- There is weak evidence for some of the existing return to sport criteria following anterior cruciate ligament reconstruction.
- Weak evidence exists supporting an association between psychological variables and return to sport, suggesting that psychological variables should be considered for inclusion in return to sport criteria.



**Figure 1.**  
PRISMA Flow Diagram of Search Results[53]

TABLE 1

## PATIENT CHARACTERISTICS

Literature	Level of Evidence [57]/Risk of Bias [55]	Total Patients	Mean Age (Years)	Graft Type	Pre-Injury Athletic Participation	Patient Follow-up	Return to Sport Rate (%)			Variables Associated with Return to Sport		Variables Not Associated with Return to Sport	
							Pre-Injury Level	Modified Level	Did Not Return	Knee Impairment or Functional	Psychological	Knee Impairment or Functional	Psychological
<b>Overall</b>		<b>1574 (67% M/33% F)</b>	<b>27.3 *</b>	<b>378 PT/867 HS/329 NR</b> ‡			<b>50.7</b>	<b>32.9</b>	<b>17.2</b>				
Ardern et al.[58]	4 / High	503 (68% M/32% F)	27.2	503 HS	Competitive	1 year	33.4	33.6	33.0	LSI 85% hop tests	-	IKDC Grade	-
Arvidsson et al.[59]	4 / High	87 (97% M/3% F)	25.3	87 PT	NR	7.9 years	25.3	66.7	8.0	Higher quadriceps torque	-	Hamstring torque	-
Ballaaci et al.[61]	4 / High	15 (gender NR)	29.6	NR	Recreational	1.5–2 years	NR	NR	NR	Faster 6 meter shuttle run test, higher hamstring torque	-	LSI on hop tests, Lysholm Knee Score, Step hop test, Vertical Jump, 10 step climb test	-
Barrett et al.[60]	4 / High	45 (73% M/27% F)	26.4	45 PT	Competitive and recreational	3 years	53.3	31.1	15.6	Lower knee effusion and pain	-	Anterior knee laxity	-
Gobbi et al.[63]	2 / High	60 (67% M/33% F)	30.4*	60 HS	At least recreational	1,2,3 years	100	0	0	-	Higher pre-operative psychovitality	-	-
Gobbi et al.[62]	4 / High	100 (67% M/33% F)	28	50 PT / 50 HS	At least recreational	2 years	65.0	24.0	11.0	Higher Marx Activity Score	Higher pre-operative psychovitality	Lysholm Knee Score, IKDC subjective form score, IKDC Grade	-
Hejine et al.[64]	2 / High	64 (55% M/45% F)	30.1	32 PT / 32 HS	NR	1 year	NR	NR	NR	Higher pre-operative quadriceps torque	-	Pre-operative knee extension ROM, pre-operative anterior knee laxity, pre-injury sports activity level	-
Kvist et al.[48]	4 / High	62 (55% M/45% F)	27	55 PT / 7 HS	NR	3–4 years	53.0	NR	NR	-	Lower TSK score	-	-
Langford et al.[68]	4 / High	87 (63% M/37% F)	27.5	4 PT / 83 HS	Competitive	6 months;	51.0	NR	NR	-	Higher ACL-RSI	LSI on hop tests, postoperative	ERAIQ

Literature	Level of Evidence [57]/Risk of Bias [55]	Total Patients	Mean Age (Years)	Graft Type	Pre-Injury Athletic Participation	Patient Follow-up	Return to Sport Rate (%)			Variables Associated with Return to Sport		Variables Not Associated with Return to Sport		
							Pre-Injury Level	Modified Level	Did Not Return	Knee Impairment or Functional	Psychological	Knee Impairment or Functional	Psychological	
		M/37% F)		83 HS		1 year							anterior knee laxity	
Lee DY et al.[6]	4 / High	64 (95% M/5% F)	24.8	64 HS	Competitive and recreational	5 years	43.8	26.5	29.7	-	-	-	-	-
Lee S et al.[67]	2 / High	42 (88% M/12% F)	30.3*	42 HS	NR	2 years	NR	NR	NR	-	-	-	-	-
Lentz et al.[69]	2 / High	94 (64% M/36% F)	22.4	PT and HS	At least recreational	1 year	55.0	NR	NR	Lower TSK score	Postoperative anterior knee laxity, postoperative knee extension and flexion ROM, LSI quadriceps strength	-	-	-
Mikkelsen et al.[70]	4 / High	44 (77% M/23% F)	24.1*	44 PT	Recreational (1 no participation)	2.5 years	38.6	52.3	9.1	-	-	-	-	-
Thoméé et al.[49]	2 / High	38 (66% M/34% F)	29.7	12 PT/26 HS	At least recreational	1 year	NR	NR	NR	Higher pre-operative K-SES	-	-	-	-
Tripp et al.[65]	2 / High	49 (55% M/45% F)	29.2	49 PT	At least recreational	1 year	NR	NR	NR	Lower TSK score	-	-	-	Negative affect, catastrophizing
Webster et al.[66]	2 / High	220 (56% M/44%F)	29.2	NR	At least recreational	1 year	39.5	29.1	31.4	Higher ACL-RSI	-	-	-	-

M = Male; F = Female; PT = patellar tendon; HS = hamstring tendon; NR = not reported; LSI = limb symmetry index; OKC = open kinetic chain; CKC = closed kinetic chain; IKDC = International Knee Documentation Committee; TSK = Tampa Scale of Kinesophobia; ACL-RSI = Anterior Cruciate Ligament-Return to Sport after Injury Scale; ERAIQ = Emotional Responses of Athletes to Injury Questionnaire; K-SES = Knee Self Efficacy Scale; IR = internal rotation; ER = external rotation;

Return to pre-injury sport defined as patients achieving the same activity level or same sport post-surgery as their pre-injury activity level. Modified sports activity defined as patients achieving a lesser activity level as compared to their pre-injury activity level. No return to sport defined as patients unable to participate in any athletic activity.

\* weighted mean age

‡The Overall 'NR' in the Graft Type column includes the 94 patients in the Lentz et al.[68] study, as specific numbers for patients with each graft type were not provided.

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TABLE 2

VARIABLES ASSOCIATED WITH RETURN TO SPORT

Strong Evidence [54] For Association With Return to Sport	None	
Moderate Evidence [54] For Association With Return to Sport	None	
Weak Evidence[54] For Association With Return to Sport	Pain	At 1 year post-surgery, patients returning to pre-injury level of sport reported less pain than those who did not return to sport (0.4 versus 1.0 on visual numeric pain scale where 0=no pain, 10=worst pain possible, p=0.05).[69] At 3 years post-surgery, 5 of 6 patients with effusion and pain had decreased sports participation level. [60]
	Post-operative quadriceps torque	At 1 year post-surgery, higher quadriceps torque-body weight ratio for patients returning to pre-injury level of sport than those who did not return to sport (81.5% vs. 73.9%, p=0.05).[69] At 5 years post-surgery, mean concentric quadriceps torque difference between surgical limb and nonsurgical limb lower in OKC+CKC group than CKC group at 30°/sec (34 Nm versus 60 Nm, p<0.01), 120°/sec (28 Nm versus 39 Nm, p<0.05), 240°/sec (18 Nm versus 27 Nm, p<0.07). Mean eccentric quadriceps torque difference between surgical limb and nonsurgical limb lower in OKC+CKC group than CKC group at 30°/sec (32 Nm versus 76 Nm, p<0.001), 120°/sec (40 Nm versus 65 Nm, p<0.01), and 240°/sec (38 Nm versus 60 Nm, p<0.02). 54.5% of OKC+CKC group returned to sport versus 22.7% of CKC group. [70] At mean 7.9 years post-surgery, difference in peak quadriceps torque between surgical leg and nonsurgical leg not different in group with return to pre-injury level of sport (205 Nm versus 226 Nm, p<0.05) but different in group participating in only non-cutting sports (200 Nm versus 241 Nm, p<0.01).[59]
	Knee effusion	At 1 year post-surgery, less effusion for patients returning to pre-injury level of sport than those who did not return to sport. [69] At 3 years post-surgery, 5 of 6 patients with effusion and pain had decreased sports participation level. [60]
	Post-operative tibial rotation range of motion	At 2 years post-surgery, higher Tegner activity score correlated with higher tibial internal rotation (r=0.44, p=0.02), higher tibial external rotation (r=0.39, p=0.04) and higher total tibial rotation (r=0.62, p<0.000).[67]
	Episodes of knee instability	At 1 year post-surgery, prevalence of knee instability in patients returning to pre-injury level of sport was less than in those who did not return to sport (44.2% versus 73.8%, p=0.004).[69]
	Marx Activity Score (0=lowest activity, 16=highest activity)	At 2 years post-surgery, higher Marx Activity Score for patients who did return to sport versus did not return to sport (15 versus 7.5, p<0.001).[62]
	Kinesiophobia (TSK score: 0=lowest fear, 51=highest fear) (TSK-11 score: 11=lowest fear, 44=highest fear)	At 1 year post-surgery, lower TSK-11 score for patients returning to pre-injury level of sport than those who did not return to sport (15.3 versus 19.6, p<0.01).[69]
		At 1 year post-surgery, higher TSK score associated with lower likelihood of resuming previous level of activity ( $\beta=-0.40$ ); Fear of re-injury unique predictor of return to sport ( $R^2=0.26$ ).[65]

<p>At 3-4 years post-surgery, lower TSK score for patients with return to pre-injury level of sport versus decreased or no sports activity (15 versus 20, p=0.01).[48]</p>	
<p><b>Athletic Confidence (ACL-RSI: 0=lowest confidence, 100=highest confidence)</b></p> <p>At 6 months post-surgery, higher ACL-RSI for groups with return to pre-injury level of sport than no return to sport (63.18 versus 51.80, p=0.005). At 1 year post-surgery, higher ACL-RSI for groups with full return to sport than no return to sport (72.05 versus 58.61, p=0.001).[68]</p> <p>At 1 year post-surgery, higher ACL-RSI for groups with return to pre-injury level of sport versus no return to sport (70 versus 46, p&lt;0.001).[66]</p>	
<p><b>Self-motivation (Psychovitality questionnaire: (Psychovitality questionnaire: (3=lowest motivation, 18=highest motivation)</b></p> <p>Higher pre-operative psychovitality score for group that did return to sport versus did not return to sport at 2 years post-surgery (16 versus 9, p&lt;0.001).[62]</p> <p>Higher pre-operative psychovitality score correlated with higher Tegner activity score at 3 years post-surgery (R<sup>2</sup> Linear=0.253).[63]</p>	
<p><b>Post-operative hamstring torque</b></p> <p>At 1.5-2 years post-surgery, higher hamstring torque correlated with higher Tegner activity score (r=0.52).[61]</p>	<p>Yes</p>
<p>At mean 7.9 years post-surgery, difference in max hamstring torque between surgical leg and nonsurgical leg not different in group with return to pre-injury level of sport (107 Nm), mild sports limitation (113 Nm), non-cutting sports (106 Nm), or no sports (104 Nm).[59]</p>	<p>No</p>
<p><b>Hop Testing / Functional Testing</b></p> <p>At 1 year post-surgery, patients with LSI &gt;85% on single leg hop for distance and crossover hop for distance more likely to have attempted pre-injury level of sport than patients with LSI &lt;85% (risk ratio, 2.5; 95% CI, 1.4-4.4).[58]</p> <p>At 1.5-2 years post-surgery, faster 6 meter shuttle run test correlated with higher Tegner activity score (r=0.57, p&lt;0.05).[61]</p>	<p>Yes</p>
<p>At 1 year post-surgery, no difference between groups with return to pre-injury level of sport and no return to sport in LSI on single hop for distance (91% versus 89%, p=0.371) or cross-over hop for distance (92% versus 92%, p=0.865).[68]</p>	
<p>At 1.5-2 years post-surgery, weak correlations between LSI on single hop for distance (r=0.13, p&lt;0.05), triple hop for distance (r=0.08, p&lt;0.05), cross-over hop for distance (r=0.27, p&lt;0.05), vertical jump test (r=0.15, p&lt;0.05), 10 step climb test (r=0.25, p&lt;0.05), step hop test (r=0.37, p&lt;0.05) and Tegner activity score.[61]</p>	<p>No</p>
<p><b>IKDC Subjective Form Score (0=lowest subjective rating, 100=highest rating)</b></p> <p>At 1 year post-surgery, higher IKDC subjective form score for patients returning to pre-injury level of sport than those who did not return to sport (93.8 versus 78.0, p&lt;0.001).[69]</p>	
<p>At 5 years post-surgery, higher IKDC subjective form score for patients returning to pre-injury level of sport (84.6) than those who did not return to sport due to fear of re-injury (73.5) or due to instability (60.1). (Between groups difference p&lt;0.001).[6]</p>	<p>Yes</p>
<p>At 2 years post-surgery, no difference between groups with return to pre-injury level of sport versus decreased sports activity level or no sports activity. [62]</p>	<p>No</p>
<p><b>IKDC Grade (A=normal, D=severely abnormal)</b></p> <p>At 5 years post-surgery, greater percentage of patients returning to pre-injury level of sport (89.3%) had IKDC Grade A&amp;B scores compared to those who did not return to sport due to fear of re-injury (77.7%) or due to instability (50%). (Between groups difference p=0.028).[6]</p>	<p>Yes</p>
<p>At 1 year post-surgery, no difference in return to sport outcomes between patients with IKDC Grade A and B (risk ratio, 1.5; 95% CI, 0.81-1.40). No difference in return to sport outcomes between patients with IKDC Grade A&amp;B and IKDC Grade C&amp;D (risk ratio 1.5; 95% CI, 0.86-2.50).[58]</p>	<p>No</p>
<p><b>Conflicting Evidence [54] For Association With Return to Sport</b></p>	

<p>At 2 years post-surgery no significant difference between groups with return to pre-injury level of sport versus decreased sports activity level or no sports activity. [62]</p>		
<p>At 5 years post-surgery, higher Lysholm Knee score for patients returning to pre-injury level of sport (88.5) than those who did not return to sport due to fear of re-injury (84) or due to instability (72). (Between groups difference p=0.001). [6]</p>	<p>Yes</p>	
<p>At 1.5-2 years post-surgery, no correlation with Tegner activity score. [61]</p>		
<p>At 2 years post-surgery, no difference between groups with return to pre-injury level of sport versus decreased sports activity level or no sports activity (p=0.38). [62]</p>		

OKC=open kinetic chain; CKC=closed kinetic chain; TSK=Tampa Scale of Kinesiophobia; ACL-RSI=Anterior Cruciate Ligament-Return to Sport after Injury Scale; LSI=limb symmetry index; IKDC = International Knee Documentation Committee