Factors which influence return to sport following anterior cruciate ligament (ACL) reconstruction surgery: A narrative review

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Review article

Factors which influence return to sport following anterior cruciate ligament (ACL) reconstruction surgery: A narrative review

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Abstract

Objectives: To provide an evidence-based narrative review in accordance with the PRISMA guidelines of return to pre-injury sport levels following ACL reconstruction surgery. **Data sources:** Databases including: *Pubmed, MEDLINE, Embase, CINAHL, Web of Science* and *Google Scholar* were searched. Various combinations of the following keywords; 'ACL reconstruction', 'ACL surgery', 'sports', 'sports activity', and 'return to sports participation', were used in the searches. **Study selection:** Thirty-one studies were identified and included in this review. All studies documented a specific return to sport percentage after ACL reconstruction or reported a mean preoperative and postoperative activity score. **Data extraction:** Return-to-sport rates (RTS) following ACL reconstruction surgery and factors influencing these outcomes including: operative style, acute versus chronic ACL deficiency, prehabilitation/rehabilitation programmes, psychological factors, age/gender and competitive/elite athletes were compared between studies. **Data synthesis***:* RTS ranged from 20% to 100% depending on the cohort and sporting discipline. There was no leading graft choice or surgical technique that provided better RTS, however early reconstruction and early-return to sports had superior outcomes than late reconstruction and late-return to sports. There was some evidence to suggest that psychological status six months postoperatively could be crucial in terms of RTS. Higher RTS were observed in males and younger patients while the majority of professional athletes returned to pre-injury levels despite abnormal knee function. **Conclusion:** Return to pre-injury levels of sport following ACL reconstruction is multifactorial. To establish accurate return to pre-injury sport rates, future studies need to document pre-injury activity levels in addition to preoperative activity levels.
Keywords: anterior cruciate ligament reconstruction, lower extremity injury, return to play, sports re-entry, review

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Introduction

The anterior cruciate ligament (ACL) is the most commonly injured ligament in the body for which surgery is routinely performed [1]. It is difficult to ascertain definitive incidence rates for ACL tears because they are not always diagnosed [1] and not all ACL injuries require surgery [2]. Injury surveillance data collected by the National Collegiate Athletic Association (NCAA) for 15 sports, recorded a significant increase in the rate of ACL injuries with an average annual increase of 1.3% over a 16-year study period (1988-2004) [3]. In the United States alone, it is thought that over 200,000 ACL injuries occur annually, contributing to in excess of 100,000 ACL reconstruction surgeries [4], while an epidemiological study conducted in Australia documented 50187 ACL reconstructions over a 5-year study period (2003-2008) [2]. Consequently, ACL reconstruction is one of the most frequently performed orthopaedic surgeries [4] with estimated annual direct costs of $3 billion for the United States [5] and $75 million for Australia [2].

The primary objective of ACL reconstruction is to minimise morbidity, while enabling a safe and rapid return to a pre-injury level of function [6]. Debate regarding ACL injury management is on-going. Reconstructive surgery tends to be the most favoured treatment approach, particularly for those wishing to return to sports that involve cutting and pivoting [7]. However, emerging literature questions the efficacy of reconstructive surgery, especially in those patients who do not wish to return to competitive cutting or pivoting sports and whose functional instability is not a major problem [7].

Despite recent surgical advancements and accelerated rehabilitation programmes, the number of people returning to pre-injury levels of sport following reconstructive surgery varies significantly, with many even showing a decrease in activity level [8-10]. A return to pre-injury level of sport is considered the most robust assessment of a successful return-to-sport outcome [11]. ACL reconstruction surgery does not always guarantee a successful return

to pre-injury activity level [7]. Furthermore, some studies have shown that the numbers of non-operated patients that return to pre-injury activity levels are about the same as reconstructed patients [9, 12-14].

The most recent meta-analysis by Ardern and colleagues recorded a mean return to pre-injury sports rate of 63% (range 54% to 71%). This was based on the results of 30 studies, comprising of 1421 participants [15]. This return to pre-injury sport rate is relatively low considering that 90% of the subjects had achieved normal or near-normal knee function in impairment-based outcomes. The discrepancy between normal knee function and low return-to-sport rates highlights the need for further investigation into the different factors that influence return to sports after ACL reconstruction.

The primary aim of this paper is to provide an evidence-based review in accordance with PRISMA guidelines of return to pre-injury sport levels following ACL reconstruction surgery. A secondary objective is to identify intrinsic and extrinsic factors already documented in the literature that can influence these outcomes including: graft choice, rehabilitation, age, gender, competitive level of athlete and psychological factors.

Methods

Data sources and search strategy

The databases *PubMed MEDLINE, Embase, CINAHL, Web of Science* and *Google Scholar* were searched from the earliest entry up until March 2012. Search terms were mapped to subject headings or MeSH terms where possible. Various combinations of the following keywords; 'ACL reconstruction', 'ACL surgery', 'sports', 'sports activity', and 'return to sports participation', were used in the databases searches.

Inclusion criteria

Studies were limited to those published in English, involving human adults over the age of 18 years. The titles and abstracts of these studies were screened for review eligibility and the reference lists of major articles were searched for additional relevant articles. The inclusion criteria required either a specific return to sport figure after ACL reconstruction or a documented mean preoperative as well as a mean postoperative activity score. Papers with evidence ratings lower than level 3 (e.g. case reports, case series and expert opinion) were excluded from the review.

Data extraction

The following information was extracted from each study: study design, sample size, study objectives, return-to-sport rates, primary outcome measures used and inclusion/exclusion criteria. The extracted data from the reviewed studies is summarised in Tables 1-6. RTS was stratified for competitive and recreational athletes.

Table 1: Studies examining operative style on return to sport

Authors	Study design	*N*	Study objectives	Follow-up (mean)	Outcome measurements	Results
Mascarenhas et al. (2011)	Case control study	23 pairs	Investigate differences between BPTB and STG grafts.	4-5 years	IKDC, SAS, ADLS, SF-36 form, ROM, KT-1000 and hop tests.	**RTS: BPTB 57%, STG 44%.** STG demonstrated higher ADLS ($P < 0.01$), SAS ($P < 0.01$), better knee extension ($P < 0.05$) and less evidence of OA ($P < 0.05$).
Mascarenhas et al. (2010)	Case control study	19 pairs	Compare BPTB autografts with BPTB allografts.	3-14 years	IKDC, ADLS, SAS, SF-36, ROM, KT-1000, hop and vertical jump test.	**RTS: autograft 63.2%, allograft 57.9%.** Allografts had more episodes of instability.
Jones et al. (2007)	Retrospective study	50	Assess long-term outcome of ACL reconstruction with a Leeds-Keio Synthetic ligament.	11.9 years	IKDC, ROM, KT-1000, hop tests.	**RTS: 66% one year postoperatively and 40% maintained same level 10 years postoperatively**. 92% had excellent or good IKDC scores. ACL rupture occurred in 12%.
* Gobbi and Francisco (2006)	Prospective randomised study	100	Examine factors affecting RTS after ACL reconstruction using BPTB or STG grafts.	Preoperative, 3, 6, 12 and 24 months	IKDC, Lysholm, Noyes, Tegner, SANE, Marx, psychovitality questionnaire, Biodex and knee motion analysis.	**RTS: 65% same sports, changed sports 24%, quit sports 11%.** Significantly better Marx and psychovitality scores ($P = 0.001$) for those that returned to sport.
Ibrahim et al. (2005)	Prospective randomised study	85	Evaluate the clinical results of BPTB and STG grafts.	81 months	Lysholm, IKDC, KT-1000, ROM and Tegner.	**RTS: 77.6%, decreased activity levels 11.8% and gave up sport 10.6%.** Knee pain, crepitus, ROM deficits and early signs of degeneration occurred more frequently in BPTB.
Mastrokalos et al. (2005)	Retrospective nonrandomised cohort study	100	Investigate donor-site morbidity and RTS with ipsilateral and contralateral BPTB grafts.	39.2 months	Donor-site morbidity questionnaire, KT-2000, Cincinnati and Tegner.	**RTS: ipsilateral 32.3%, contralateral 27.6%.** Statistically significant differences in: knee pain and local tenderness between donor site knees and contralateral reconstructed knees.
Feller & Webster (2003)	Prospective randomised clinical trial	65	Identify differences in outcomes between BPTB and STG grafts.	4, 8, 12, 24 and 36 months.	Cincinnati, IKDC, ROM, KT-1000, VAS, Cybex and radiographs.	**RTS: BPTB 54%, STG 52%.** The BPTB had more postoperative complications than the STG group.
Webb et al. (1998)	Prospective study	82	Assess outcomes of ACL reconstruction using BPTB grafts.	24 months	IKDC, Lysholm, KT-1000 and radiographs.	**RTS: 56%.** Exceptional joint stability 90% and normal or near-normal knee function 86%.
O'Neill (1996)	Prospective randomised study	125	Investigate outcomes of three operative techniques (double-incision STG; double-incision BPTB; and single-incision BPTB).	2 years	IKDC, KT-2000, Biodex and radiographs.	**RTS: double-incision BPTB 95%, single-incision BPTB 89% and double-incision STG graft 88%.** Double-incision BPTB had significantly better KT-2000 scores.
Aglietti et al. (1994)	Prospective comparative study	60	Compare differences in outcomes between BPTB and STG grafts with chronic ACL tears.	28 months	IKDC, KT-2000, Cybex and ROM.	**RTS: BPTB 66%, STG 50%.** Significantly more BPTB (80%) returned to strenuous sports than STG (42%). BPTB grafts demonstrated better joint KT-2000 scores

*Webb et al. (1998) included in table 5. *Gobbi and Francisco (2006) included in table 4.

BPTB; Bone-patellar-tendon bone graft, STG; semitendinosus and gracilis graft, IKDC; International Knee Documentation Committee evaluation system, SAS; Sports Activity Scales from the Knee Outcome survey (KOS), ADLS; Activities of Daily living from the KOS, SF-36; short form 36, ROM; range of motion , SANE; Subjective Assessment Numeric evaluation, VAS; visual analogue scale RTS; return to sports rate, OA; osteoarthritis.

Table 2: Studies examining acute and chronic ACL deficiency on return to sport

Authors	Study design	*N*	Study objectives	Follow-up	Outcome measurements	Results
Noyes and Barber-Westin (1997)	Prospective study	53	Investigate outcomes of BPTB grafts in patients with advanced cartilaginous lesions.	27 months	Cincinnati Knee Rating System and KT-2000.	**RTS: 79% , quit sports because of knee 15%, gave up sports for reasons unrelated to knee 6%.** 66% increased activity levels, 6% maintained activity levels and 7% decreased activity levels. Cincinnati scores increased significantly (P = 0.0001)
Marcacci et al. (1995)	Prospective study	82	Examine differences in outcomes between early and late reconstruction surgery.	60 months	Lysholm, IKDC and KT-2000.	**RTS: early group 90%, late group 71%.** Early group demonstrated better clinical results, knee stability and returned to sports sooner. More meniscal lesions were seen in the later group.
Fitzgibbons and Shelbourne (1995)	Longitudinal study	189	Investigate outcomes of non-treatment of lateral meniscal tears during ACL reconstruction surgery.	2.6 years	Modified Noyes questionnaire, ROM and swelling.	**RTS: 100% to their "desired" sporting level**. Excellent knee stability and Noyes scores were recorded at follow-up.
Järvinen et al. (1995)	Cross-sectional study	30	Investigate outcomes of BPTB grafts in patients with chronic ACL deficiency.	2.2 years	KSS machine, Cybex and ROM.	**RTS: competitive athletes 53.3%.** Knee stability was good in 96.7% of cases and 73.3% had excellent or good objective Lysholm scores.

Table 3: Studies examining prehabilitation and rehabilitation protocols on return to sport

Authors	Study design	*N*	Study objectives	Follow-up	Outcome measurements	Results
Hartigan et al. (2010)	Randomised clinical trial	40	Compare preoperative prehabilitation programmes [(PERT = perturbation training and strengthening exercises) and (STR = strength-training exercises)] on RTS.	Preoperative, 3, 6 and 12 months	Global rating scale, KOS-ADLS, quadriceps strength index and hop tests.	**RTS: eligible 3 months postoperatively 5%, eligible 6 months postoperatively, 48% eligible 1 year postoperatively 78%.** The PERT achieved significantly better global rating scores 6 and 12 months postoperatively than STR.
Gerber et al. (2007)	Randomised pair-matched study	16 pairs	Compare a 12-week eccentric resistance-training programme (ECC) to traditional rehabilitation (TRAD).	Preoperative 3, 15 and 26 weeks	VAS, knee circumference, KT-1000, Kin-Com, KOS-ADLS, Tegner and hop test.	**ECC group had less significant decrease in activity levels 26 weeks postoperatively than TRAD group.** Significant group-by-time-interactions were seen for physical performance [(quadriceps peak torque; P < 0.04) and (hop distance; P < 0.01)] and self-reported activity levels (Tegner P=0.02).
Glasgow et al. (1993)	Retrospective analysis	64	Examine differences in outcomes between early-return and late-return to vigorous sporting activities.	46 months	Cincinnati Knee Rating Scores KT-1000, ROM and Cybex.	**RTS: early-return 74%, late-return 67%.** Early-return group restored full ROM sooner than the late-return group: [4.3; 5.4 months (P < 0.032)].

Table 4: Studies examining psychological influence on return to sport

Authors	Study design	*N*	Study objectives	Follow-up	Outcome measurements	Results
Langford et al. (2009)	Prospective longitudinal study	87	Examine influence of psychological factors on athletes' return to sport.	3, 6 and 12 months	ERAIQ, ACL-RSI, ROM, KT-1000, single hop and crossover hop.	**RTS: 51%, 12 months postoperatively.** Those who returned to sport 12 months postoperatively scored significantly higher in the ACL-RSI at both 6 and 12 months compared to those who did not return.
Lee et al. (2008)	Retrospective analysis	64	Investigate RTS in recreational athletes 5 years postoperatively.	5 years	IKDC, Lysholm, Tegner and KT-1000.	**RTS: 62.2%.** Fear of re-injury (20%) and knee instability/pain (17.8%) were attributed with being unable to return to the same sports level. Significant differences in IKDC and Lysholm scores between those who returned to pre-injury levels and those who did not.
Webster et al. (2008)	Cross-sectional study	220	Develop a scale to measure psychological impact of RTS.	8 and 22 months	ACL-RSI	**RTS: 40%.** Subjects that gave up sports had significantly lower ACL-RSI scores (*P* <0.001).
*Gobbi and Francisco (2006)	Prospective randomised study	100	Examine factors affecting RTS with BPTB or STG grafts.	Preoperative, 3, 6, 12 and 24 months	IKDC, Lysholm, Noyes, Tegner, SANE, Marx, psychovitality questionnaire, Biodex and knee motion analysis.	**RTS: 65% same sports, changed sports 24%, quit sports 11%.** Significantly better Marx and psychovitality scores (*P* =0.001) for those that returned to sport.
Kvist et al. (2005)	Retrospective study	62	Examine influence of kinesiophobia on RTS.	3-4 years	TSK, KOOS and activity levels questionnaire.	**RTS: 53%.** Those who did not return to pre-injury levels of sport had higher TSK scores.

* Gobbi and Francisco (2006) included in Table 1.

ERAIQ; Emotional Response of Athletes to Injury, ACL-RSI; ACL Return to Sport after Injury Scale, TSK; Tampa Scale of Kinesiophobia, KOOS; Knee Injury and Osteoarthritis Outcome Score.

Table 5: Studies examining age and gender influence on return to sport

Authors	Study design	*N*	Study objectives	Follow-up	Outcome measurements	Results
*Ardern et al. (2012)	Cross-sectional study	314	Examine age and gender influence on RTS after ACL reconstruction.	2-7 years	A self-report questionnaire	**RTS: 45%, same sport at a lower level 32%.** RTS by age: (<18 years = 49%), (18-25 years = 57%), (25-32 years = 44%) and (>32 years = 33%).
Dahm et al. (2008)	Retrospective study	34	Investigate outcomes of ACL reconstruction in subjects over 50 years.	72 months	Subjective IKDC, Lysholm, UCLA activity score, Tegner and ROM.	**RTS: 86% returned to pre-injury activity levels.** Significant improvements in postoperative IKDC and Lysholm scores ($P < 0.0001$). Graft failure rate was 8.6%.
*Webb et al. (1998)	Prospective study	82	Examine outcomes of ACL reconstruction with BPTB grafts.	24 months	IKDC, Lysholm, KT-1000 and radiographs.	**RTS: males 64%, females 56%.** 60% of males and 42% of females that reduced their activity levels attributed it to their knee. A larger proportion of females reduced their activity levels for reasons unrelated to their knee.
*Waldén et al. (2011)	Prospective three-cohort study	71	Examine incidence of ACL injury, gender differences and return to play in elite football players.	12 months	Time taken to return to training and to match play.	**RTS: 92% EUR males, 89% SWE males and 79% SWE females played a match within 12 months of surgery.** Mean age of injury lower in women than men. 58% non-contact injuries. Greater risk of injury in match play than training.

* Webb et al. (1998) included in table 1. * Ardern et al. (2012) included in table 7. * Waldén et al (2011) included in table 6.
UCLA activity score (University of California Los Angeles)

Table 6: Studies examining return to sport in competitive and elite athletes

Authors	Study design	*N*	Study objectives	Follow-up	Outcome measurements	Results
*Waldén et al. (2011)	Prospective three-cohort study	71	Examine incidence of ACL injury, gender differences and return to play in elite football players.	12 months	Time taken to return to training and to match play.	**RTS: 92% EUR males, 89% SWE males and 79% SWE females** played a match within 12 months of surgery. Mean age of injury lower in women than men.
Namdari et al. (2011)	Retrospective study	18	Investigate RTS in professional female basketball players.	11.8 months	Performance variables including: games played, points scored and steals per game.	**RTS: 78%.** Shooting percentage (P = 0.04) and steals per 40 minutes of play (P = 0.03) were significantly reduced after ACL reconstruction.
Carey et al. (2006)	Surveillance cohort study	31	Analyse RTS and NFL player performance after ACL reconstruction.	55.8 weeks	Power ratings (total yards divided by 10 plus touchdowns multiplied by 6).	**RTS: 79%.** Power ratings decreased significantly postoperatively from preoperative levels (P =0.002).
Fabbriciani et al. (2005)	Prospective study	18	Examine outcomes of ACL reconstruction in professional and recreational rugby players.	6 and 24 months	IKDC, Tegner, KT-1000 and Genu Plus II.	**RTS: 100%.** Mean postoperative and preoperative activity levels were similar. 11.1% had abnormal IKDC scores.
Myklebust et al. (2003)	Prospective cohort study	57	Investigate outcomes of ACL injury among competitive team handball players.	7.8 years	Lysholm, IKDC, KT-1000, Cybex 6000, single-jump, triple jump and stairs hopple test.	**RTS: 58% same level, 30% returned to a lower level, 12% quit handball** (46% attributed quitting to knee problems). Re-injury rate was 22%.
Jerre et al. (2001)	Retrospective study	275	Compare outcomes of ACL reconstruction between recreational and competitive athletes.	31.5 months	IKDC, Lysholm, Tegner, hop test, KT-1000, anterior knee pain scores.	**RTS: Recreational 59%, competitive 38%.** Activity levels decreased significantly more from pre-injury levels in the competitive group. No significant differences between groups in IKDC, Lysholm, hop test, KT-1000 or knee pain scores.
Nakayama et al. (2000)	Cross-sectional study	50	Investigate knee-functions and RTS after ACL reconstruction in competitive athletes.	1 year	IKDC, KT-2000 and Cybex.	**RTS: 92%,** reduced activity levels 2° knee issues 8%. 80% normal or near-normal IKDC scores. 92% subjectively rated their knee function as normal.
Roos et al. (1995)	Longitudinal study	310	Analyse incidence and risk factors of ACL injuries in Swedish soccer players.	7 years	Tegner, modified Lysholm and VAS.	**RTS: 20%.** ACL injuries occurred at a younger age in females than males.

* Waldén et al (2011) included in table 5.

WNBA; Women's National Basketball Association, NBA; National Basketball Association, NFL; National Football League, VAS; Visual Analogue Scale, EUR; European, SWE; Swedish.

Results

Identification of studies (see Figure 1)

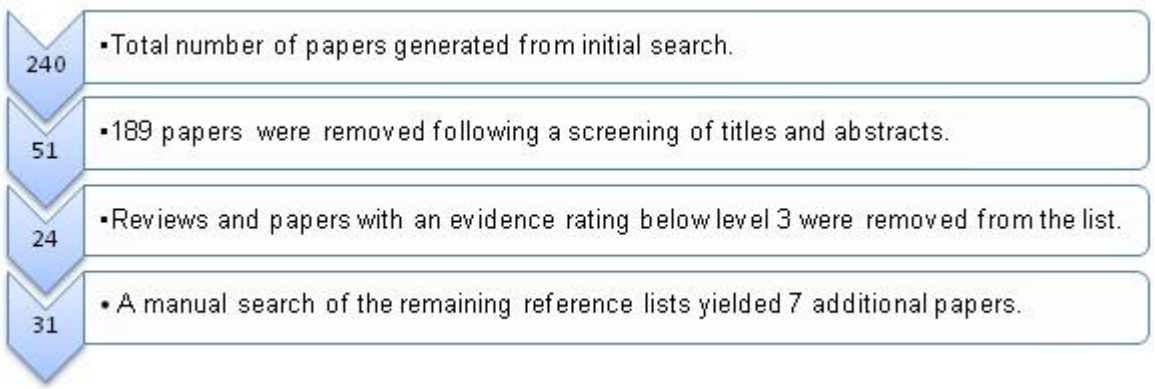

Figure 1: Breakdown of search results

Data synthesis

Following analysis, the 31 studies broadly fell under the following six categories:

- Operative style (10 studies)
- Acute versus chronic ACL deficiency and associated injuries (4 studies)
- Prehabilitation and rehabilitation programmes (3 studies)
- Psychological factors (5 studies)
- Age and gender influence (4 studies)
- Competitive and elite athletes (8 studies)

The studies are summarised and presented in Tables 1-6 in chronological order by category. Study designs varied between papers (retrospective, 9; case control, 2; cross-sectional, 4; prospective, 16), with the majority of studies being prospective in design, of which six were also randomised. The number of participants ranged from 18 to 314 [16, 17] and average follow-up assessments spanned from 26 weeks to 11.9 years postoperatively [18, 19]. RTS rates were documented in 29 studies. The primary outcome measures used most frequently are displayed in Figure 2.

Outcome measures	**Studies**
International Knee Documentation Committee (IKDC) score	16
KT1000 / KT2000 Arthrometer	16
Range of motion (ROM)	12
Isokinetics	8
Hop tests	8
Tegner Activity Scale	9
Lysholm Knee Scoring Scale	9

Figure 2: List of primary outcome measures

A breakdown of RTS for competitive and recreational athletes is displayed in Figure 3. Only one study[8] included in this review disclosed separate RTS figures for competitive and recreational athletes. Many studies did not document the athletic level of the cohort and combined RTS were reported in more than half of the studies.

Competitive Athletes	**RTS %**	**Recreational Athletes**	**RTS%**
Mascarenhas et al. (2011)	51	Dahm et al. (2008)	86
Waldén et al. (2011)	87	Gobbi and Francisco (2006)	65
Namdari et al. (2011)	78	Mastrokalos et al. (2005)	30
Mascarenhas et al. (2010)	61	Jerre et al. (2001)	59
Langford et al. (2009)	51	Noyes and Barber-Westin (1997)	79
Carey et al. (2006)	79		
Mykelbust et al. (2003)	53		
Jerre et al. (2001)	38		
Nakayama et al. (2000)	92		
Järvinen et al. (1995)	53		
Aglietti et al. (1994)	19		
Mean	**60**		**64**

Figure 3: Stratified RTS rates

Discussion

Operative style

The ideal graft should have structural properties that resemble those of the native ACL. The graft must permit speedy incorporation into the host bone, secure fixation and cause minimal donor site morbidity [20]. Ten studies included in this review examined various aspects of operative style taking: graft type, graft selection and surgical technique into consideration.

Graft type

Based on the findings of Mascarenhas and colleagues, Bone-Patellar Tendon-Bone (BPTB) allografts offer no additional benefits over the conventional BPTB autograft in terms of objective measurements and self-reported outcomes [6]. A larger proportion of the autograft group (63.2%) returned to their pre-injury sports level than the allograft group (57.9%). Both BPTB autografts and allografts were relatively successful in allowing athletes to return to strenuous sport (78.9%), but success rates of returning to pre-injury levels were lower for both groups. Recurrent episodes of instability were also seen more frequently in the allograft group. Only 37% of the allograft group were able to return to strenuous sport without symptoms of instability compared to 74% of the autograft group.

The results from Jones et al. support the use of synthetic ligaments as a feasible alternative to BPTB and semitendinosus-gracilis (STG) grafts [19]. Synthetic grafts demonstrated long-term knee stability and facilitated return to pre-injury level sport in 66% of cases, while 40% were able to maintain the same pre-injury level of sport 10 years postoperatively. Of those who lowered their activity levels only six percent attributed it to knee instability. International Knee Documentation Committee (IKDC) scores were excellent or good for 92% of the sample. However, the graft failure rate was 12%, which should be taken into account.

Graft selection

Mastrokalos et al. found no obvious advantage in using a contralateral graft as an alternative to an ipsilateral graft [21]. It did not improve the likelihood of returning to pre-injury activity levels and donor site morbidity problems were transferred to the previously unaffected leg. The returns to pre-injury activity levels were

low in both groups: 32.3% (ipsilateral) and 27.6% (contralateral) respectively.

Five studies compared the most popular grafts currently in use; BPTB and STG autografts. There were no significant differences found between grafts in terms of return to pre-injury sport rates. There was, however, an obvious trend towards BPTB grafts having higher return to pre-injury sport rates [22-25].

Better objective knee stability was achieved with BPTB grafts than with STG grafts [22, 23]. Extension deficits were recurrently observed in BPTB grafts [22-24]. BPTB grafts cannot be held entirely responsible for these extension deficits because rehabilitation protocols also play vital part in recovery. Mascarenhas et al. used a rehabilitation protocol that focused on preserving knee ROM and as a result, all BPTB sujects had knee ROM within 2° of their contralateral unaffected leg [6], thus emphasising the influence of a postoperative rehabilitation protocol that focuses on preserving knee ROM.

STG grafts resulted in reported lower figures returning to pre-injury level sports, but they also demonstrated fewer donor-site morbidity problems such as knee crepitus, kneeling pain and degenerative changes [22, 24, 25]. The recent surge in popularity for STG grafts might be a reflection of the lower donor-site morbidity incidence rates associated with the graft [26].

Surgical technique

The numbers who returned to pre-injury sport levels following a double-incision BPTB graft, as reported by Webb et al., were much lower (56pre-injury%) [27] than those reported by O'Neill in 1996 (95%) [28] for the same graft. Excellent stability and normal or near-normal IKDC scores were documented in most cases, suggesting that the lower return rate to pre-injury sport might be unrelated to the surgical procedure.

Similar to graft selection, there was no definitive leading surgical technique. Greater joint stability and return to pre-injury activity levels were observed in both single-incision and double-incision BPTB grafts than double-incision STG grafts [28]. The double-incision BPBT graft had better outcomes than single-incision BPTB in terms of return to pre-injury activity rates, joint stability and quadriceps strength. But, double-incision techniques, whether BPTB or STG grafts, were also associated with hamstring strength deficits, as a result of the posterolateral dissection involved in this technique.

Acute versus chronic ACL deficiency and associated injuries

The degree of knee instability in the acute phase of an ACL tear is often concealed by muscle spasm and pain. It is quite common for a partial tear to develop into a complete tear, leading to chronic ACL deficiency [29]. Treatment options for ACL injuries depend on several factors, such as the extent of knee instability, acuteness of injury, grade of tear, and the existence of other lesions or associated injuries. Early reconstruction is believed to reduce the risk of cartilage or meniscal lesions that contribute to the acceleration of joint degeneration, while delaying reconstruction is thought to prevent postsurgical stiffness [30]. The following four studies examine early and late ACL reconstruction surgery, along with chronic ACL deficiency and concomitant injuries.

ACL reconstruction surgery produced successful results in patients with chronic deficiency and facilitated the return to sports in over half (53.3%) of competitive athletes who had previously ceased sporting activity [29, 31]. ACL reconstruction also demonstrated successful outcomes in chronic ACL deficient patients with advanced cartilage damage. There were no definitions provided for chronic ACL deficiency; however the mean period from original knee injury to ACL reconstruction in Noyes et al., was 90 months [31]. Significant improvements were achieved in Cincinnati scores at follow-up and preoperative symptoms of pain and swelling were significantly reduced. Activity levels increased from preoperative levels in 66% of the subjects and the total return to sport rate was 79% [31].

Severe cartilage damage has often been considered as a relative contraindication for reconstruction, because pain and swelling are more likely to be primary symptoms than instability [31]. ACL deficient patients with advanced cartilage damage commonly modify their activity levels to minimise pain and swelling, rather than undergo surgery. As a result of reduced activity levels, fewer episodes of instability are usually experienced. This helps to explain the large increase in activity levels seen postoperatively in Noyes et al., as most subjects probably had relatively low preoperative activity levels to begin with [31].

Early ACL reconstruction is more favourable than late reconstruction in terms of knee stability, return to pre-injury sport rates and time taken to return to pre-injury activity levels [30, 32]. Delaying reconstruction in an ACL deficient patient can speed up degenerative changes. Marcacci et al. found a greater number of meniscal lesions, at the time of surgery in the late-reconstruction group than in the early-reconstruction group [30].

The return to sport rates documented in the four studies were not specific to pre-injury sport levels and are therefore misleading. For example, Fitzgibbons & Shelbourne, stated that all subjects returned to their "desired level" of sports after ACL reconstruction [33], implying a return to sport success rate of 100%. This is high, considering that all subjects also had untreated lateral meniscal tears. It might be reasonable to presume that subjects' preoperative activity levels were considerably lower than their pre-injury levels because most subjects had chronic ACL tears with concomitant injuries in some cases. This would account for the high return to sport rates recorded in these studies.

Prehabilitation and rehabilitation programmes

ACL reconstruction alone does not guarantee return to pre-injury activity levels; inappropriate rehabilitation protocols can injure healing graft tissue and surrounding structures, which in some cases may lead to ACL reconstruction failure [18, 34]. Suitable rehabilitation programmes are therefore fundamental in facilitating return to sport after surgery. The primary objectives of rehabilitation are to restore muscle strength and performance, while maintaining the recently restored knee stability [18]. Three studies included in this review examine the effect of prehabilitation and rehabilitation programmes on return to pre-injury sports after ACL reconstruction surgery.

Quadriceps strengthening is often a common component of prehabilitation and rehabilitation programmes because quadriceps strength has been shown to influence functional outcomes after ACL injury [35]. Neuromuscular interventions like perturbation training can also be included in these programmes to increase neuromuscular awareness and dynamic stability in the injured or operated lower limb [36]. No additional advantage was achieved in functional outcomes by incorporating perturbation training into a standard quadriceps strengthening prehabilitation programme [37]. After ten prehabilitation sessions, close to 50% had passed strict return-to-sports criteria six months postoperatively and this figure increased to 78% one year postoperatively. These figures were high, considering that the sample consisted entirely of "non-copers" (subjects who had the worst functional status after acute ACL rupture and were surgical candidates according to the University of Delaware's protocol) [37]. Preoperative quadriceps strength deficits are known to have significant negative consequences on long term functional outcomes after ACL reconstruction [38]. The findings by Hartigan et al. would indicate that prehabilitation strengthening sessions were in some way responsible for the successful results [37]. However, the absence of a control group in this study makes it difficult to draw a definite conclusion about the efficacy of prehabilitation strengthening programmes.

More than one-fifth of all subjects that had taken part in prehabilitation programmes failed to achieve a score of 90% or more in standard return-to-sport physical function tests 12 months postoperatively and, as a result, they were not cleared to return to sport [37]. Taking this failure rate of 22% in functional tests alone helps to provide some insight into the low return to pre-injury sport rates reported in other studies, especially since return to sport is known to be multidimensional and is not solely dependent on performance in physical tests.

Progressive, eccentric resistance exercises proved superior to traditional, postoperative rehabilitation, demonstrating promising results in both physical performance and return to preoperative activity levels[18]. The lack of significant differences between the eccentric (ECC) and traditional (TRAD) strengthening groups in terms of pain, swelling and stability scores would suggest that eccentric training, when progressed gradually, is as safe as traditional rehabilitation programmes and it is also more successful at restoring strength, physical performance and resumption of activities.

Early return to sports activity should be encouraged and based on the results of Glasgow et al., return to vigorous activities as early as two to six months postoperatively does not place subjects at any greater risk of reinjury or produce poorer clinical results three to four years postoperatively [32]. Glasgow et al. even documented that fewer subjects in the

"early return" group had decreased their activity levels 46 months postoperatively and of those who reduced their activity; none of the "early-return" group attributed it to the knee problems, as opposed to 9% of the "late-return" group [32].

Psychological factors

The numbers returning to pre-injury sport levels are low, despite successful physical recovery and restoration of knee stability. This observation has stimulated a convergence of theories, based on psychological models suggesting that cognitive and emotional factors play a part in return to pre-injury sport outcomes after ACL reconstruction surgery [39]. Five of the studies reviewed concentrate specifically on the influence of psychological factors on return to pre-injury sport levels.

In most of the studies, subjects had been given medical clearance to return to sport or had achieved normal or near-normal IKDC scores, yet the numbers that actually returned to pre-injury sport were lower than expected, ranging between 40%–62.2%[40-43]. Fear of re-injury and negative feelings towards returning to sport were the dominant psychological factors examined in these studies. Fear of re-injury has been considered as a predictor of postoperative confidence in sporting ability and activity levels [39]. Subjects who did not return to pre-injury sport levels had a greater fear of re-injury [42], with one-fifth of subjects attributing this to their inability to return to pre-injury levels [40]. A theory has been proposed to help to explain athletes' fear of re-injury and suggests that individuals can develop inaccurate beliefs about their ability to function in order to prevent future structural damage [42].

The ACL Return to Sport after Injury Scale (ACL-RSI) was used in two of the studies to gauge subjects' feelings about returning to sport after surgery [41, 43]. Subjects who returned to full competition had significantly higher ACL-RSI scores in both studies, indicating a more positive attitude to returning to sport. These scores increased significantly over time and high scores were documented from as early as six months postoperatively. High ACL-RSI scores at six months were also coupled with a return to full competition 12 months postoperatively [43]. The six-month time point might be crucial in identifying individuals who would benefit from psychological intervention and therefore improve their chances of returning to pre-injury levels of sport.

Greater attempts need to be made by clinicians to identify and predict individuals who would benefit from psychological intervention, in conjunction with routine physical rehabilitation. This could be accomplished through psychological questionnaires (e.g. ACL-RSI) at critical time points suggested by Webster et al.: preoperatively, three-months postoperatively; when individuals return to sport-specific drills, and six months postoperatively; when athletes return to training [41].

Age and gender influence

In the past, ACL reconstruction surgery was not routinely offered to ACL-deficient patients over 40 years of age. Non-operative treatment such as: physiotherapy, activity modifications and functional bracing, were preferred for older patients, while ACL reconstruction surgery was reserved for younger and highly-active patients [44].

Dahm et al. assessed return to pre-injury levels in an older patient cohort (> 50 years) and found that the majority (86%) were able to return to their pre-injury activity level [44]. This was considerably high in comparison to other similar studies where a younger cohort was examined. However, the older patient cohort was not very active in sports prior to injury, recording a mean pre-injury Tegner activity score of (4.4). This was very low considering the minimum Tegner activity score for recreational sports is 5. As a result it was quite easy for such a large proportion (86%) to return to their pre-injury activity levels.

Age certainly appeared to significantly influence return to pre-injury sport rates, as found by Ardern et al. [17]. The sample was divided into four distinct age groups and the return to pre-injury sport rates were as follows: (<18 years = 49%), (18-25 years = 57%), (25-32 years = 44%) and (>32 years = 33%). The highest return to pre-injury sport rates was recorded in the (18-25 years) group, while lowest return rates were seen in the (>32 years) group. It has been suggested that people under 25 years of age have a greater opportunity to participate in sports because teams are often linked to their educational institutions, whereas those over 25 years of age have more competing interests, including employment, family commitments and less opportunity to take part in sport [17]. It might be more accurate to attribute lifestyle changes associated with increasing age as having an influence on return to pre-injury rates.

Females are known to have a greater predisposition towards ACL injuries than males [45] but it is unclear whether similar gender differences exist in terms of return to pre-injury sport rates. Ardern et al. found no differences between genders in terms of return to pre-injury sport rates [17], in contrast to Webb et al. and Waldén et al. [27, 46]. Males exceeded females in return to pre-injury sports rates in both studies (64% vs. 46%; 89% vs. 79%) [27, 46]. Males also associated their reduction in activity to knee-related problems, while females attributed their decrease in activity levels to reasons unrelated to their knee [27]. It was surprising that very few studies reported separate return to sport rates for males and females, especially considering the extensively documented gender differences in ACL injury incidence rates.

Competitive and elite athletes

Professional athletes might be expected to have greater success rates in returning to pre-injury levels of sport than recreational athletes considering that they have a more favourable physical status preoperatively, a shorter wait between injury and surgery, unlimited resources to access top quality rehabilitation and are mentally prepared to return to sport [47]. Eight studies included in this review investigated return to pre-injury levels of sport in competitive and professional athletes.

The proportion of professional athletes that returned to pre-injury sport levels varied greatly between sporting disciplines, from 20-89% in soccer [12, 46] to 100% in rugby [48]. However, the cohort of soccer players analysed by Roos et al. ranged in sporting level from professional to amateur players [12], whereas the soccer players and rugby players assessed by Waldén et al. and Fabbriciani et al. were all playing at a professional level [46, 48]. Advancements in operative techniques and evolution of rehabilitation protocols made over time might also explain the large discrepancies between studies.

Many athletes returned to pre-injury levels of sport, despite having abnormal IKDC knee scores [48]. Some of the highest returns to pre-injury sport levels were documented in more physically demanding contact sports such as American football (79%) and professional rugby (100%). Rugby players have been described as “knee-abusers” because of their high tolerance for pain and swelling, relative to the general sporting population [27]. This theory provides a reasonable explanation for the high return to pre-injury rugby (100%) and NFL (79%) recorded by Carey et al. and Fabbriciani et al. compared to other sports [48, 49].

The number of professional athletes that returned to pre-injury levels of basketball after ACL reconstruction was 78%. This was based on a study of eighteen female WNBA players [16]. Two of the seven studies had strict criteria for return to pre-injury levels of sport due to their study design; they did not include any players that returned to same level of sport in an alternative equivalent league [16, 49]. This could have potentially underestimated the results of those who returned to pre-injury levels of sport. The wide range in figures seen in these studies certainly suggests that the type of sport and of professional athlete (e.g. “knee-abuser”) can influence return to pre-injury rates.

It was difficult to stratify RTS for competitive athletes and non-competitive athletes because the figures documented in most studies included combined RTS. The average RTS for competitive athletes was (60%; range 19-92%), slightly lower than recreational athletes (64%; range 30-86%). However, these figures were only based on the results of 15 studies and consequently, may not provide an accurate reflection of RTS.

Conclusion

In summary, this review collates previously documented return to pre-injury sport rates after ACL reconstruction surgery and comprehensively discusses the different factors identified in the literature that influence return to sport outcomes. The factors discussed included: operative style, acute or chronic injury, prehabilitation and rehabilitation programmes, psychological factors, age and gender influence and competitive and elite athletes.

In terms of operative style, there was no definitive leading graft choice or surgical technique. However, when considering return to pre-injury levels of sport, there was a positive trend towards BPTB grafts and a double-incision surgical technique. Early reconstruction was preferable to late reconstruction just as an early-return to sports was more favourable than late-return to sports. Rehabilitation programmes incorporating progressive eccentric strengthening exercises achieved superior results to traditional strengthening protocols.

There was some evidence to suggest that; physical recovery and psychological readiness to return to sport do not always coincide, especially at the six month postoperative stage [43].

In terms of age and gender influence, there were no definitive findings. A larger proportion of younger subjects (< 25 years) returned to their pre-injury activity levels although this might have been more attributed to lifestyle factors rather than their age. There was some evidence to suggest that males demonstrated better return to pre-injury activity levels than females. The majority of professional athletes returned to their pre-injury levels with some of the highest figures documented in contact sports.

Return-to-sport rates after ACL reconstruction varied significantly between studies. It was difficult to compare studies because pre-injury activity levels were not consistently documented and data was often retrospective in nature. Some studies recorded return to pre-injury levels, while others reported on return to preoperative levels. In order to evaluate the success of ACL reconstruction in future studies, return to pre-injury activity levels should be recorded each time to provide the most accurate result.

Further investigation of specific RTS for competitive and non-competitive athletes would be useful to examine the influence of the sporting environment on patient outcomes. This information would be of particular interest to physiotherapists who manage a broad range of patients, from recreational athletes to professional and elite athletes, following ACL reconstruction surgery.

Return to pre-injury level sport following ACL reconstruction is multifactorial. Clinicians need to be aware of the various factors so that, potential barriers (e.g. poor psychological status) can be identified at crucial time points during patients' recovery and treatment, or rehabilitation modifications can be made accordingly to improve the success of ACL reconstruction outcomes.

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