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Eighty-three per cent of elite athletes return to preinjury sport after anterior cruciate ligament reconstruction: a systematic review with meta-analysis of return to sport rates, graft rupture rates and performance outcomes

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ABSTRACT

Objectives The primary objective was to calculate the rate of return to sport (RTS) following anterior cruciate ligament (ACL) reconstruction in elite athletes. Secondary objectives were to estimate the time taken to RTS, calculate rates of ACL graft rupture, evaluate postsurgical athletic performance and identify determinants of RTS.

Design Pooled RTS and graft rupture rates were calculated using random effects proportion meta-analysis. Time to RTS, performance data and determinants of RTS were synthesised descriptively.

Data sources MEDLINE, EMBASE, AMED, CINAHL, AMI, PEDro, SPORTDiscus and The Cochrane Library were searched from inception to 19 January 2016. Hand searching of 10 sports medicine journals and reference checking were also performed.

Eligibility criteria for selecting studies Studies were included if they reported the ratio of elite athletes who returned to their preinjury level of sport following ACL reconstruction. Twenty-four studies were included.

Results The pooled RTS rate was 83% (95% CI 77% to 88%). The mean time to RTS ranged from 6 to 13 months. The pooled graft rupture rate was 5.2% (95% CI 2.8% to 8.3%). Six out of nine studies that included a noninjured control group found no significant deterioration in athletic performance following ACL reconstruction. Indicators of greater athletic skill or value to the team were associated with RTS.

Summary and conclusions Eighty-three per cent of elite athletes returned to sport following ACL reconstruction, while 5.2% sustained a graft rupture. Most athletes who returned to sport performed comparably with matched, uninjured controls. This information may assist in guiding expectations of athletes and clinicians following ACL reconstruction.

INTRODUCTION

Athletes who sustain an anterior cruciate ligament (ACL) rupture often undergo surgical reconstruction to facilitate their return to sport.[1–3] However, a previous systematic review reported that only 60% of nonelite athletes returned to their preinjury level of sport after ACL reconstruction.[4] Elite athletes were analysed as a subgroup rather than being the focus of that systematic review, and additional studies of elite athletes who have undergone ACL reconstruction have since been published. Important physical,[5–8] psychological[9] and social[10] differences between elite and nonelite athletes might give elite athletes a greater chance of returning to sport following ACL reconstruction compared with nonelite athletes.

The primary aim of this systematic review and meta-analysis was to determine the rate of return to the preinjury level of sport following ACL reconstruction among elite athletes. The secondary aims were to assess how long elite athletes took to return to sport, determine the rate of ACL graft rupture among the elite athlete cohort, evaluate athletic performance after ACL reconstruction and identify potential determinants of returning to sport. Further understanding of these outcomes may assist athletes and clinicians to form realistic goals and expectations following ACL reconstruction.

METHODS

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[11] were followed in preparing, conducting and reporting this systematic review.

Search strategy

The electronic databases MEDLINE, EMBASE, AMED, CINAHL, AMI, PEDro, SPORTDiscus and The Cochrane Library were searched from inception to 19 January 2016. Search terms were entered under two concepts; terms within each concept were combined with the OR Boolean operator, and the two concepts were combined with the AND Boolean operator. Where possible, terms were mapped to medical subject headings and searched using keywords. Examples of terms in concept 1 included 'anterior cruciate ligament', 'anterior cruciate ligament reconstruction' and 'ACL'. Examples of terms in concept 2 included 'sport', 'athlete', 'physical activity', 'return to sport' and 'sport re-entry'. An example of a database search as applied to MEDLINE is provided in Supplementary file 1.

To supplement the database searches, we hand searched the online contents pages and 'Articles in Press' lists of *The American Journal of Sports Medicine*; *British Journal of Sports Medicine*; *Arthroscopy*; *The Knee*; *Knee Surgery, Sports Traumatology, Arthroscopy*; *The Journal of Orthopaedic and Sports Physical Therapy*; *Journal of Science and Medicine in Sport*; *Sports Health*; *Orthopaedic*

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Journal of Sports Medicine; and *Open Access Journal of Sports Medicine*. Studies in the reference lists of the included studies were also screened.

Selection criteria

Studies of interventional or observational design were included if they reported, in English language, the number or ratio of participants who returned to their preinjury level of sport, in a consecutively recruited cohort of at least 10 elite athletes who had undergone ACL reconstruction. Elite athletes were defined as people playing sport professionally, or at the highest possible competitive level for their sport, or in Division I of the National Collegiate Athletic Association.

Conference proceedings and review studies were excluded because of the risk of duplicating data. Studies that included only participants who had undergone revision ACL reconstruction or ACL reconstruction combined with high tibial osteotomy were also excluded.

Two reviewers independently applied the selection criteria to the studies. The reviewers first screened the titles and abstracts of studies identified by the search strategy. Studies that either clearly did not meet the inclusion criteria or had at least one exclusion criterion were excluded. The full-text versions of the remaining studies were then retrieved, and the selection criteria were applied independently by the reviewers. Any discrepancies were discussed, and a third reviewer was consulted if consensus could not be reached. If additional information was required to decide whether a study should be included, attempts were made to contact the authors of the study.

Risk of bias assessment

A six-item checklist[12] was used to assess the risk of bias in included studies for this systematic review. The items assessed were selection criteria described, representative population selected, participants' preinjury sports participation level reported, data collected prospectively, demographic data reported and postoperative sports participation level compared with preinjury level. In addition, the level of evidence for each study in addressing the primary aim of this review was graded.[13] For each included study, two reviewers independently assessed and recorded the number of checklist items fulfilled and the level of evidence. Any discrepancies were resolved through discussion; a third reviewer was consulted if consensus could not be reached. The risk of bias assessment was not used in weighting for meta-analysis.

Data extraction and synthesis

Two reviewers independently extracted data from each study. Any discrepancies were resolved by consensus. If further clarification of data was required, contact with the authors of the respective studies was attempted.

'Return to sport' was treated as a dichotomous outcome and defined as playing at least one match or competing in at least one event following ACL reconstruction at the preinjury or higher level of competition. The return to sport rate was calculated from the number of elite athletes who returned to sport, out of the number of elite athletes who underwent ACL reconstruction, and expressed as a percentage. If a study defined 'return to sport' or derived a return to sport rate in a different manner, and if enough data were available, the return to sport rate was recalculated to meet the definition used in this review.

Where available, rates of ACL graft rupture were calculated from the number of elite athletes who sustained ACL graft rupture out of the number of elite athletes who initially underwent ACL reconstruction, and expressed as a percentage.

The sports and competitions played by participants were extracted from each study. Where three or more studies of the same sport reported return to sport rates or graft rupture rates, subgroup analyses were performed for those sports.

Further data that were extracted from each study included the mean time taken for athletes to return to sport following ACL reconstruction, athletic performance measures of elite athletes who had undergone ACL reconstruction and matched control groups of elite athletes without ACL injury, and determinants of returning to sport following ACL reconstruction. These data were synthesised descriptively.

Pooled rates of return to sport and ACL graft rupture were calculated using random effects proportion meta-analysis (StatsDirect, V.2.8; Altrincham, UK). Heterogeneity was assessed using the I^2 statistic[14] and interpreted according to the guidelines published by The Cochrane Collaboration.[15] Funnel plots were used to evaluate bias in the results of the meta-analyses, and funnel plot asymmetry was quantified with the Harbord test.[16]

RESULTS

Study selection

The literature search identified 2844 potentially eligible studies for screening; 2502 were excluded after reviewing the titles and abstracts. The full-text versions of the remaining 342 studies were obtained, of which 318 were subsequently excluded. The remaining 24 studies, which included 1272 elite athletes, met the inclusion criteria for this systematic review and meta-analysis (figure 1).

Risk of bias assessment

Of the 24 studies, 21 (88%) clearly described the selection criteria,[17–37] 17 (71%) identified the source population,[17 18 20 23 25–31 33 34 36–39] and 23 (96%) clearly reported participants' preinjury level of sports participation.[17–25 27–40] Six studies (25%) collected data prospectively,[20 26 28 34 35 40] and demographic data were reported in 15 studies (63%).[18 19 22–24 27 28 32–39] All of the studies compared postoperative activity levels with preinjury levels. With respect to addressing the primary aim of this systematic review, all of the included studies were graded as level 4 evidence (table 1).

Sports studied

Eighteen studies reported on a cohort of elite athletes from a single sport. Nine of these studies included football players of various codes: four were of soccer players,[23 34 35 39] four were of American football players[19 21 33 38] and one was of rugby players.[40] Three studies were of basketball players,[18 27 32] and two studies were of ice hockey players.[22 37] Two studies included snow sports athletes: one study was of alpine skiers,[36] and one study was of freestyle skiers and snowboarders.[24] One study was of baseball players,[25] and one study was of handball players.[31] Three studies included participants from various sports,[17 28 29] while three studies did not report which sports participants played[20 26 30] (table 1).

Return to sport rates

The pooled rate of return to sport following ACL reconstruction in elite athletes (n=1272) was 83% (95% CI 77% to 88%; I^2=86%; Harbord test=−1.98, 92.5% CI −4.76 to 0.80; figure 2). Among elite soccer players (n=220), the return to sport rate was 85% (95% CI 78% to 90%; I^2=36%; Harbord

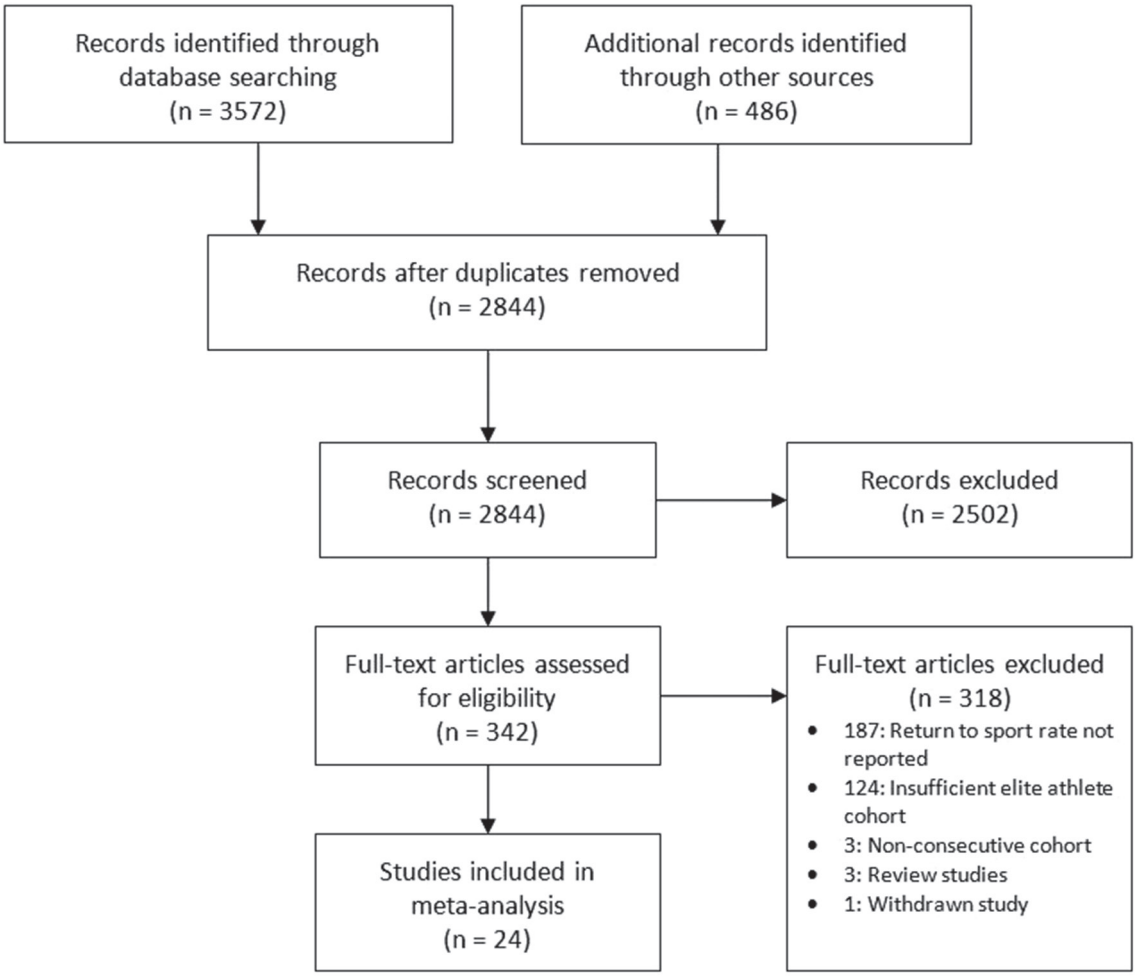

Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram.

test=1.93, 92.5% CI −9.40 to 13.27; Supplementary file 2). Among elite American football players (n=279), the return to sport rate was 78% (95% CI 67% to 87%; I^2=65%; Harbord test=−0.54, 92.5% CI −8.95 to 7.87; Supplementary file 3). Among elite basketball players (n=103), the return to sport rate was 82% (95% CI 74% to 89%; I^2=0%; Harbord test=−2.47, 92.5% CI −9.97 to 5.04; Supplementary file 4).

Time taken to return to sport

Fifteen studies provided data on the duration taken for athletes to return to their preinjury level of sport (table 1). One study reported that all participants returned to sport within 6 months.[40] Six studies reported mean times of 6–9 months,[20–22 34 35 39] six studies reported mean times of 9–12 months,[18 23 27 32 33 37] and two studies reported mean times of 12–13 months.[19 38]

On average, soccer players returned to sport between 6 and 10.2 months postoperatively,[23 34 35 39] American football players returned to sport between 8.2 and 13 months postoperatively[19 21 33 38] and rugby players returned to sport within 6 months of ACL reconstruction.[40] Basketball players returned to sport, on average, between 10.7 and 11.8 months postoperatively.[18 27 32] Ice hockey players returned to sport, on average, between 7.8 and 9.8 months postoperatively.[22 37]

Graft rupture rates

Fourteen of the included studies reported a graft rupture rate (table 1). The pooled graft rupture rate was 5.2% (95% CI 2.8% to 8.3%; I^2=51%; Harbord test=0.58, 92.5% CI −3.85 to 2.70; figure 3). Three studies of elite soccer players reported graft rupture rates. The pooled graft rupture rate in elite soccer players was 5.6% (95% CI 2.5% to 9.9%; I^2=0%; Harbord test=0.64, 92.5% CI −23.16 to 24.44; Supplementary file 5). Only two studies of American football players and two studies of elite basketball players provided graft rupture rates, so subgroup analyses were not performed.

Athletic performance on return to sport

Eleven studies compared athletes' preinjury and postsurgery performances (table 2). Seven of these studies measured overall athletic performance using the following: the number of competition medals won by alpine skiers[36] and freestyle skiers and snowboarders,[24] International Ski Federation (FIS) rankings and points for alpine skiers,[36] the number of All-Star team selections for National Basketball Association (NBA)[27] and National Hockey League (NHL)[37] players and formulated ratings for players in the NBA[18] and the National Football League (NFL).[19 38] Eight studies measured performance with various individual statistics, including games played per season,[18 22 23 25 27 32 37 38] touchdown passes made by NFL quarterbacks,[38] goals scored by soccer[23] and ice hockey players,[22 37] home runs scored by baseball players[25] and shooting percentages among basketball players.[18 27 32] Nine of the 11 studies selected a control group of elite athletes who had not sustained an ACL injury but were matched to the ACL reconstruction study group on characteristics, including

Table 1 Characteristics of included studies

Author (year)	Sport Population Recruitment source	Focus of study	RBA[12] LOE[13]	RTS rate (%) Months to RTS*	Graft rupture rate (%)
Ardern *et al* (2014)[17]	Multiple sports Elite athletes Medical records	Psychological factors	4 items met Level 4	10/24 (42%) NR	NR
Busfield *et al* (2009)[18]	Basketball NBA Competition database	RTS and performance	5 items met Level 4	21/27 (78%) 10.7±2.7 (6.7–15.3)	NR
Carey *et al* (2006)[19]	American football NFL (RB and WR) Public domain	RTS and performance	4 items met Level 4	26/33 (79%) 12.8 (9.2–43)	NR
Colombet *et al* (2002)[20]	Not reported Not reported Medical records	Surgical factors (graft and fixation)	5 items met Level 4	98/113 (87%) 7.7 (3–10)	NR
Daruwalla *et al* (2014)[21]	American football NCAA Division I Medical records	Determinants of RTS	3 items met Level 4	151/184 (82%) 8.2	NR
Erickson *et al* (2013)[23]	Soccer (association football) MLS Public domain	RTS and performance	5 items met Level 4	40/52 (77%) 10.2±2.8	4/52 (7.7%)
Erickson *et al* (2013)[24]	Freestyle skiing/snowboarding X-Games Public domain	RTS and performance	4 items met Level 4	20/25 (80%) NR	1/25 (4.0%)
Erickson *et al* (2014)[22]	Ice hockey NHL Public domain	RTS and performance	4 items met Level 4	35/36 (97%) 7.8±2.4	1/36 (2.8%)
Erickson *et al* (2014)[38]	American football NFL (Quarterbacks) Public domain	RTS and performance	4 items met Level 4	12/13 (92%) 13±3.9	1/13 (7.7%)
Fabbriciani *et al* (2005)[40]	Rugby (union) Professional athletes Medical records	Surgical factors (graft and fixation)	3 items met Level 4	12/12 (100%) ≤6	0/12 (0%)
Fabricant *et al* (2015)[25]	Baseball MLB Public domain	RTS and performance	4 items met Level 4	27/33 (82%) NR	NR
Franceschi *et al* (2013)[26]	Not reported Not reported Medical records	Surgical factors (tunnel drilling)	4 items met Level 4	29/43 (67%) NR	NR
Haida *et al* (2016)[36]	Alpine skiing French national team Competition database	RTS and performance	5 items met Level 4	148/148 (100%) NR	NR
Harris *et al* (2013)[27]	Basketball NBA Public domain	RTS and performance	5 items met Level 4	50/58 (86%) 11.6±4.1	2/58 (3.4%)
Howard *et al* (2016)[39]	Soccer (association football) NCAA Division I Females Medical records	Determinants of RTS	4 items met Level 4	66/78 (85%) 6.5±1.2	NR
Ibrahim *et al* (2015)[28]	Multiple sports Professional athletes Medical records	Surgical factors (graft and fixation)	6 items met Level 4	61/66 (92%) NR	0/66 (0%)
Kamath *et al* (2014)[29]	Multiple sports NCAA Division I Medical records	RTS and reinjury	4 items met Level 4	38/43 (88%) NR	1/54 (1.9%)
Marcacci *et al* (1995)[30]	Not reported Not reported Medical records	Surgical factors (timing of surgery)	4 items met Level 4	16/23 (70%) NR	0/23 (0%)
Myklebust *et al* (2003)[31]	Handball Norwegian top 3 divisions Competition database	Operative vs nonoperative management	4 items met Level 4	33/57 (58%) NR	11/57 (19.3%)
Namdari *et al* (2011)[32]	Basketball WNBA Public domain	RTS and performance	4 items met Level 4	14/18 (78%) 11.8 (8.1–22.5)	1/18 (5.6%)

Continued

Table 1 Continued

Shah *et al* (2010)[33]	American football NFL Medical records	Determinants of RTS	5 items met Level 4	31/49 (63%) 10.8	NR
Sikka *et al* (2016)[37]	Ice hockey NHL Competition database	RTS and performance	5 items met Level 4	42/47 (89%) 9.8 (6–21)	4/47 (8.5%)
Walden *et al* (2011)[34]	Soccer (Association football) European first leagues Medical records	Injury incidence and risk factors	6 items met Level 4	61/69 (88%) 7.8±2.5	2/69 (2.9%)
Zaffagnini *et al* (2014)[35]	Soccer (Association football) Italian main divisions Medical records	Surgical factors (graft and fixation)	5 items met Level 4	20/21 (95%) 6.0±1.7	1/21 (4.8%)

ACL, anterior cruciate ligament; LOE, level of evidence; MLB, Major League Baseball; MLS, Major League Soccer; NBA, National Basketball Association; NCAA, National Collegiate Athletic Association; NFL, National Football League; NHL, National Hockey League; NR, not reported; RB, running backs; RBA, risk of bias assessment; RTS, return to sport; WNBA, Women's National Basketball Association; WR, wide receivers. *Months to RTS, where reported, given in the following format: mean ± SD (range).

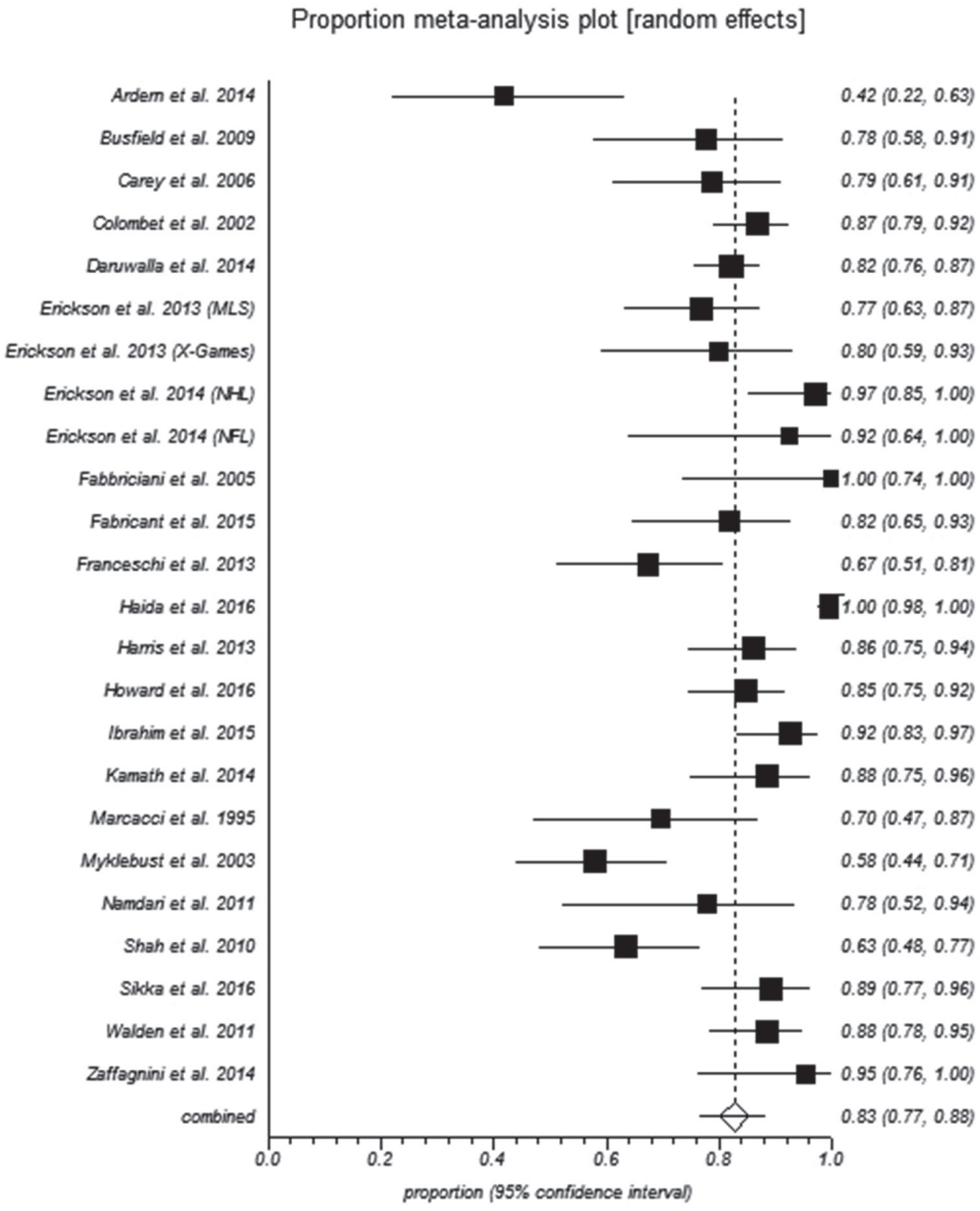

Figure 2 Forest plot of return to sport rates (MLS, Major League Soccer; NFL, National Football League; NHL, National Hockey League).

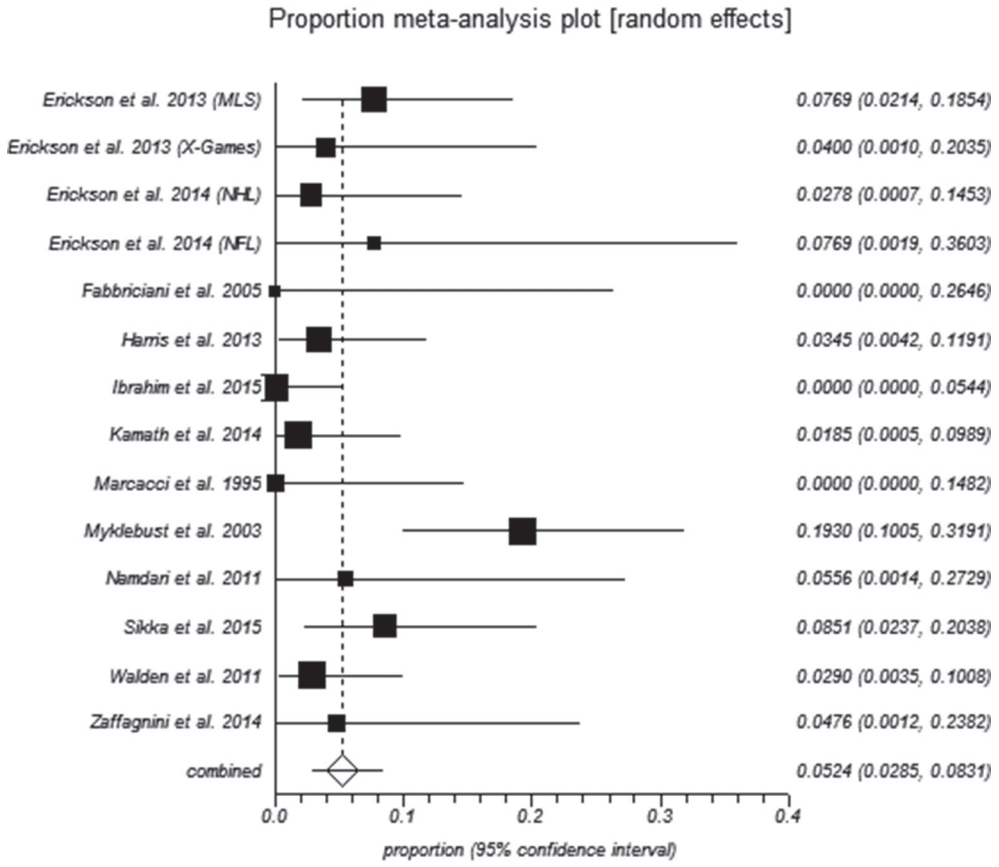

Figure 3 Forest plot of graft rupture rates (MLS, Major League Soccer; NFL, National Football League; NHL, National Hockey League).

age, body mass index and amount of playing experience[18 22 23 27 32 37 38]; national team selection[36]; preinjury playing performance[18 22 23 37 38]; and playing position.[22 23 27 32 38]

Erickson *et al*[23] reported that the performance of Major League Soccer (MLS) players did not deteriorate significantly following ACL reconstruction, while they attempted more shots at goal and made more assists per season than matched controls. Among NFL players, the study of running backs and wide receivers found that those returning after ACL reconstruction had lower power ratings compared with their preinjury levels and those of matched controls,[19] while the study of quarterbacks did not report any significant deterioration in performance post-surgery compared with either their preinjury performance or the performance of matched controls.[38]

The three studies of elite basketball players each reported that players' postsurgery performance deteriorated compared with preinjury performance on measures including player efficiency rating,[18] number of All-Star selections,[27] games played per season,[18 27] shooting percentage,[18 27 32] points and rebounds per game[27] and steals per game.[32] However, elite basketball players' performance did not decline significantly compared with those of matched controls,[18 32] except Harris *et al*[27] reported that players returning from ACL reconstruction played fewer games per season.

The two studies of NHL players had conflicting results. Sikka *et al*[37] found that forwards and wings who underwent ACL reconstruction did not return to their preinjury level of performance and did not perform as well as players in the control group, while defenders improved their plus-minus rating in their second season after returning to sport and performed comparably with players in the control group. Erickson *et al*[22] reported that performance did not deteriorate after ACL reconstruction, and some performance measures improved compared with those of the control group.

As a cohort, X-Games freestyle skiers and snowboarders won more medals after surgery than they did preinjury.[24] Members of the French national alpine skiing team who underwent ACL reconstruction won more medals per race and improved their FIS rankings and points after surgery.[36] After ACL reconstruction, elite baseball players played fewer games per season compared with their preinjury levels.[25]

Determinants of returning to sport and preinjury performance

Six studies analysed player-related factors possibly associated with a return to sport and preinjury levels of performance. Surrogate measures indicative of greater levels of athletic skill or value to an elite sporting team, including being selected earlier in the NFL draft,[33] being on a college sporting scholarship[21 39] or having a higher depth chart position (players who started games on field were positioned highest and players who rarely played games were positioned lowest),[21] were associated with higher rates of return to sport. NHL players with more goals or assists in the season preceding ACL injury were more likely to return to their previous level of performance.[37]

Two studies found that more preinjury playing experience was associated with a higher rate of return to sport.[21 33] However, college athletes injured during their fourth or fifth years at college were less likely to return to sport,[21 39] and NHL players injured after turning 30 years of age were less likely to return to play at least one full season.[37] French alpine skiers who were younger at the time of injury were more likely to improve their performance after returning to sport.[36] Playing position was not a significant determinant of returning to sport in American football,[33] women's

Table 2 Studies comparing athletic performance following ACL reconstruction with preinjury performance and control group performance

Author (year)	Population	Performance measures	Performance compared with preinjury	Performance compared with control group
Soccer (association football)				
Erickson *et al* (2013)[23]	MLS	Individual	No significant difference	More shots at goal and assists per season
American football				
Carey *et al* (2006)[19]	NFL (RB and WR)	Overall (power rating)	Power rating decreased	Power rating decreased
Erickson *et al* (2014)[38]	NFL (QB)	Overall (passer rating) and individual	No significant difference	No significant difference
Basketball				
Busfield *et al* (2009)[18]	NBA	Overall (PER) and individual	12/21 players decreased PER Fewer games per season Lower shooting percentage Fewer turnovers conceded Several other individual measures decreased but not statistically significant	No significant difference
Harris *et al* (2013)[27]	NBA	Overall (All-Star selection) and individual	Fewer All-Star selections Fewer games per season Fewer points and rebounds per game Lower shooting percentage	Fewer games per season
Namdari *et al* (2011)[32]	WNBA	Individual	Fewer steals per game Lower shooting percentage Several other individual measures decreased but not statistically significant	No significant difference
Ice hockey				
Erickson *et al* (2014)[22]	NHL	Individual	No significant difference	More goals and shots at goal per season Higher shooting percentage
Sikka *et al* (2016)[37]	NHL	Overall (All-Star selection) and individual	3/8 All-Stars reselected as All-Stars Forwards and wings: fewer games, goals and assists per season Defenders: improved plus-minus rating	Shorter careers Forwards and wings: fewer goals and assists per game Defenders: no significant difference
Snow sports (Alpine skiing, Freestyle skiing and snowboarding)				
Erickson *et al* (2013)[24]	X-Games	Overall (medals won)	More medals won	No control group
Haida *et al* (2016)[36]	French national team	Overall (medals won, FIS points and rankings)	More medals won per race Improved FIS points and rankings	Longer careers but no increase in number of events competed in
Baseball				
Fabricant *et al* (2015)[25]	MLB	Individual	Fewer games per season Lower batting average if rear knee injured	No control group

FIS, International Ski Federation; MLB, Major League Baseball; MLS, Major League Soccer; NBA, National Basketball Association; NFL, National Football League; NHL, National Hockey League; PER, player efficiency rating; QB, quarterbacks; RB, running backs; WNBA, Women's National Basketball Association; WR, wide receivers.

basketball[32] or women's college soccer,[39] but Sikka *et al*[37] found that NHL defenders were more likely to return to their previous level of performance than forwards and wings.

Nine studies reported on the influence of surgical factors on return to sport. Concomitant injuries to menisci were associated with shorter careers among NHL players,[37] but no other studies found that concomitant injuries significantly affected return to sport rates.[18 21 29 39] Daruwalla *et al*[21] found that autografts were associated with higher rates of return to sport than allografts, but two other studies did not find any significant association between graft types and return to sport rates[39] or postsurgery performance.[37] Among elite baseball players, ACL reconstruction to the rear batting leg was associated with decreased batting average on return to sport.[25] The timing of surgery,[30] tunnel drilling technique[21 26 39] or graft fixation method[21 28 39] did not significantly affect return to sport rates among elite athletes.

DISCUSSION

Return to sport rates

In this systematic review and meta-analysis, we found that 83% of elite athletes returned to their preinjury level of sport following ACL reconstruction. This finding is consistent with previously published rates[4] and incorporates additional data from 11 recent studies. It confirms that rates of return to the preinjury level of sport following ACL reconstruction are higher among elite athletes (83%, 95% CI 77% to 88%) than among nonelite athletes (60%, 95% CI 53% to 67%).[4] A combination of factors, including elite athletes having superior athletic skill,[5] levels of physical fitness[7] and knee proprioception,[6 8] different psychological profiles,[9] ready access to high-quality healthcare[10] and greater financial incentives to play than nonelite athletes might help to explain why elite athletes have a higher rate of return to sport.

Conversely, nearly one out of every five elite athletes who undergo ACL reconstruction does not return to sport, which remains below the expectations of patients undergoing ACL reconstruction[41] and their clinicians.[42] Our results may help elite athletes who undergo ACL reconstruction, and clinicians who work with elite athletes, to have realistic expectations and goals for surgery and rehabilitation.

Time taken to return to sport

Rehabilitation following ACL reconstruction surgery is a complicated process, and the time from surgery should not be the only factor used to determine when a return to sport should be allowed.[43 44] The average time between ACL reconstruction and return to sport may, however, help to guide goal setting for elite athletes and clinicians. Among the 15 studies that reported these data, only two studies of American football players[19 38] reported that elite athletes took longer than 12 months on average to return to sport. Two other studies of American football players included in this review reported mean times of 8.2 months[21] and 10.8 months[21] to return to sport. There are currently insufficient data to confirm whether or not elite athletes from different sports take substantially different amounts of time to return to sport.

The majority of studies in this review reported that elite athletes returned to sport on average within 12 months. This is considerably shorter than what has previously been reported in the nonelite population.[45] In our review, it was not possible to determine whether there was any correlation between the amount of time taken to return to sport and graft rupture rates. Although elite athletes appear to return to sport earlier than nonelite athletes,[45] whether this approach is safe remains uncertain.

Graft rupture rates

ACL graft rupture is a traumatic and career-threatening event for elite athletes. Elite athletes and clinicians should be aware of the rate of ACL graft rupture when considering the risks and benefits of returning to sport. The pooled graft rupture rate was 5.2% (95% CI 2.8% to 8.3%), which is comparable with a previous meta-analysis of six primary studies of nonelite athletes that reported a graft rupture rate of 5.8%.[46] It is important to recognise that the graft rupture rate in this review may be underestimated though, as six of the 14 studies that reported graft rupture rates gathered data from the public domain,[22–24 27 32 38] and not all athletes were followed up for the duration of their careers. This graft rupture rate was calculated from studies that met the inclusion criteria for this systematic review, so there may be studies of elite athletes following ACL reconstruction that did not report return to sport rates but did report graft rupture rates. Any such studies have not been included in this meta-analysis. In addition, we were not able to calculate an annualised graft rupture rate because the majority of included studies that reported graft rupture rates did not report the average duration of follow-up.

Athletic performance on return to sport

Feucht *et al* reported that 94% of patients who were about to undergo primary ACL reconstruction expected to return to sport with only slight or no restrictions.[41] It is reasonable to speculate that most elite athletes who undergo ACL reconstruction would expect to return not only to their preinjury level of sport but also to their preinjury level of performance. Returning to preinjury levels of performance can be considered as a further stage of progress following a return to playing at the preinjury level of sport.[47] The concept of studying athletic performance on returning to sport from ACL reconstruction is relatively new and under-researched. Eleven studies in this systematic review attempted to compare preinjury and postsurgery athletic performance, and all of them have been published since 2006.

We found conflicting results regarding elite athletes' performance on their return to sport. Five studies reported that postsurgery performance was unchanged[22 23 38] or improved[24 36] compared with preinjury performance, while six studies reported that performance deteriorated after surgery.[18 19 25 27 32 37] Differing methods of identifying participants might account for some of these discrepancies: for example, Erickson *et al*[22] used data that were available in the public domain, while Sikka *et al*[37] accessed a competition-wide injury surveillance system. Even though the studies that used data available in the public domain described thorough search strategies for identifying elite athletes who underwent ACL reconstruction, accessing a database of injuries prospectively collated and maintained by the sporting organisation is likely to be a more reliable source of injury data.

To control for the dynamic nature of elite sport and the progression of time, nine studies used a matched control group with which to compare the study groups' performances. Encouragingly, six of the nine studies did not demonstrate any significant deterioration in postsurgery performances when compared with the control groups' performances.[18 22 23 32 34 38] In many cases, deterioration in athletic performance following ACL reconstruction may be explained by the progression of time, rather than the result of ACL reconstruction.

Due to the limited number of studies available for each sport, the wide variety of methods used to measure athletic performance and the conflicting results between some studies, the synthesis of athletic performance data was challenging. As further studies explore the concept of returning to preinjury performance following ACL reconstruction, it may become possible to reach stronger conclusions to assist athletes and clinicians. It would be useful for future studies to assess the longevity of elite athletes' careers following ACL reconstruction. In addition, the increasing use of global positioning systems in sport may offer an avenue to measure performance and load in elite athletes following ACL reconstruction.[47]

Determinants of returning to sport and preinjury performance

Several studies identified that indicators of greater athletic skill or value to an elite sporting team were determinants of returning to sport. The findings on age and experience were less consistent, but it is possible that even if elite athletes with greater experience are more likely to return to sport, younger elite athletes who return to sport may be more likely to sustain improved athletic performance after ACL reconstruction.

While only one of the included studies found that the presence of concomitant injuries was associated with shortened career length, this may be explained by inadequate power contained within each study. The use of autografts was associated with higher rates of return to sport than the use of allografts in one study,[21] but no other surgical factors were associated with different rates of return to sport. This corroborates previous systematic reviews that have not found substantial differences in clinical outcomes following the use of autografts compared with allografts.[48–50] There does not appear to be enough evidence to suggest that any one graft choice would increase return to sport rates among elite athletes.

Positive psychological responses to injuries,[51] including ACL injuries,[52 53] are determinants of returning to sport in the general athletic population. None of the studies included in this systematic review focused on the psychological determinants of returning to sport among elite athletes, and this may be an avenue for further research.

General limitations

The overall return to sport rate of 83% should be interpreted with some caution. There was substantial statistical heterogeneity across the studies (I^2=86%), which may be explained by several factors. There was a broad time frame covered across the studies, with elite athletes from as early as 1975 through to 2013 being included. Various methods of identifying and recruiting elite athletes were used across studies, and the rate of return to sport may be affected by the type of sport played. The inconsistent lengths of follow-up across studies may have affected the calculations of pooled return to sport and graft rupture rates. Therefore, it is important that future studies specify the duration of follow-up.

There was also a risk of bias identified in several studies. Nine studies did not report the demographic characteristics of included athletes, which may limit the external validity and generalisability of this meta-analysis. Only six of the included studies collected data prospectively, which introduces a risk of recall bias. However, this risk is expected to be low given that return to sport is usually a highly anticipated and memorable event following major injury. Eight studies collected data exclusively from the public domain,[19 22–25 27 32 38] and although the described search methods were comprehensive, it is likely that some ACL injury and return to sport data may have been missed. Although the risk of bias assessment checklist used in this study has been used in previous systematic reviews,[4 12] it has not been validated as a mechanism to weight studies in meta-analysis.

All of the studies included in this review were level 4 evidence. We expect that that the majority of future studies in the elite athlete population will also be of observational design. While the quality of findings from this review may be weakened by the lack of interventional studies on elite athletes who sustain ACL rupture, this review does address the aims of the study as best as possible in the elite athlete context.

Publication bias[54] may have led to overestimation of return to sport rates and underestimation of graft rupture rates. However, none of the Harbord tests performed were statistically significant at the 92.5% CI. This indicates that publication bias may not have been a significant issue in this meta-analysis, although the substantial heterogeneity present between individual studies limits the interpretation of the Harbord tests.[15]

There is a relative paucity of research on return to sport rates in the elite female athlete population following ACL reconstruction, even though female athletes face a greater risk of ACL rupture when participating in the same sports as male athletes.[55 56] Only two studies included in our review reported on a female-only cohort,[32 39] while 13 studies reported on a male-only cohort of elite athletes[18 19 21–23 25 27 28 33 35 37 38 40] and most of the remaining studies did not detail the number of male and female elite athletes who returned to sport. These factors meant that we could not determine whether outcomes differed between male and female elite athletes who underwent ACL reconstruction. Our results should not be generalised to elite athletes who have had revision ACL reconstruction, as studies of revision ACL reconstruction were excluded from this meta-analysis, and the outcomes of revision ACL reconstruction, including return to sport rates, are generally inferior compared with primary ACL reconstruction.[57 58] However, our meta-analysis does represent the best available estimate of return to sport rates in elite athletes who undergo ACL reconstruction, given that it is based on 1272 elite athletes across 24 studies.

CONCLUSION

The rate of return to preinjury level of sport following ACL reconstruction among elite athletes was 83%, and most of those who returned to sport played their first game between 6 and 13 months after surgery. Elite athletes with greater levels of athletic skill may be more likely to return to their preinjury level of sport. Five per cent of elite athletes who underwent ACL reconstruction sustained a graft rupture. The performance of elite athletes who returned to sport following ACL reconstruction was comparable with the performance of matched cohorts of elite athletes who had not undergone ACL reconstruction. These results may be used by athletes and their treating clinicians to guide realistic expectations regarding return to sport following ACL reconstruction.

Contributors All authors contributed to the conception and design of the review. CCHL and CLA applied the search strategy, applied the selection criteria and completed the risk of bias assessment. CCHL and KEW extracted and synthesised the data. All authors contributed to the analysis and interpretation of data. CCHL wrote the manuscript. CLA, JAF and KEW critically revised the manuscript for important intellectual content. CCHL is responsible for the overall content as guarantor. All authors approved of the final version published.

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Eighty-three per cent of elite athletes return to preinjury sport after anterior cruciate ligament reconstruction: a systematic review with meta-analysis of return to sport rates, graft rupture rates and performance outcomes

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