Quality of life in anterior cruciate ligament-deficient individuals: a systematic review and meta-analysis

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ABSTRACT

Background Physical and psychological impairments impacting quality of life (QOL) are common following ACL reconstruction. Rehabilitation alone is an effective alternative to reconstruction for some patients, warranting the investigation of QOL in ACL-deficient individuals.

Purpose To report and compare QOL in ACL-deficient individuals with population norms and ACL-reconstructed groups, and investigate relationships between participant characteristics and QOL.

Study design Systematic review and meta-analysis.

Methods We systematically identified and methodologically appraised all studies reporting QOL in ACL-deficient individuals ≥5 years following ACL rupture. Knee-related and health-related QOL scores in ACL-deficient cohorts were compared to ACL-reconstructed groups using a random-effects meta-analysis. Descriptive comparisons were made with population norms.

Results Eleven studies reported QOL in 473 ACL-deficient individuals, a mean of 10 (range 5–23) years following ACL rupture. Eight studies reported knee-related QOL using the Knee injury and Osteoarthritis Outcome Score QOL subscale (KOOS-QOL); scores (mean ±SD) ranging from 54±17 to 77±22 were impaired compared to population norms. Health-related QOL, measured with the SF-36 domain scores in five studies, was similar to population norms, but impaired compared to physically active populations. Meta-analysis revealed no significant differences in KOOS-QOL (mean difference (95% CI) 2.9 (−3.3 to 9.1)) and SF-36 scores (for all SF-36 domains except Vitality) between ACL-deficient and ACL-reconstructed groups.

Conclusions This systematic review found impaired knee-related QOL in ACL-deficient individuals ≥5 years after ACL rupture, compared to population norms. Meta-analysis revealed similar knee-related QOL in ACL-deficient and ACL-reconstructed groups, and no difference in health-related QOL scores for seven of the eight SF-36 domains.

INTRODUCTION

Over 127 000 ACL reconstructive surgeries are performed annually in the USA,[1] most commonly in active adolescents and young adults. Rationales for performing an ACL reconstruction include facilitating a return to competitive sport[2 3] and minimising the risk of post-traumatic knee osteoarthritis (OA).[4] However, many ACL reconstructed individuals cease sports participation,[5] develop accelerated knee osteoarthritis (OA),[6] or experience ongoing fear of re-injury[7] and poor knee-related quality of life (QOL).[8] This highlights the need to explore longer term outcomes following non-operative management of ACL rupture. Rehabilitation alone may be a successful alternative to ACL reconstruction for many individuals.[9 10]

A recent meta-analysis found that the rate of return to non-elite competitive sport following ACL reconstruction was surprisingly low (42%).[5] Emerging evidence suggests that this rate is no higher than that achieved by individuals managed with rehabilitation alone.[10–12] Several systematic reviews have also revealed either no significant difference in radiographic OA rates between groups of ACL reconstructed and non-operatively managed individuals,[13] or a slightly higher prevalence of OA following ACL reconstruction.[12 14 15] The low return to sport rates and presence of OA following ACL reconstruction may contribute to the impaired knee-related QOL we identified in this population (compared to general population norms) 5–20 years after ACL rupture.[8] However, little is known about the long-term QOL of individuals following non-operative management of an ACL rupture, and how this compares with the QOL of individuals who undergo ACL reconstruction.

This systematic review is the first to investigate QOL in ACL-deficient individuals, enabling QOL comparisons between management approaches. Undergoing knee surgery may expose an individual to additional physical and psychological trauma, which could facilitate fear avoidance behaviours,[16] impact future participation in desired activities[5] and impair QOL. On the other hand, individuals who choose not to undergo surgery for ACL rupture may be more likely to experience limitations due to increased passive knee laxity.[11 12] Considering the increasing frequency of ACL reconstruction procedures,[17 18] reported knee-related QOL impairments 5–20 years after surgery,[8] and the ongoing debate regarding the optimal management of an ACL-ruptured knee, investigation into long-term QOL in ACL-deficient individuals is warranted.

Specific factors (revision surgery, concomitant meniscus surgery, subsequent injury, and severe OA) have been associated with poor longer term QOL in individuals who choose to undergo ACL reconstruction.[8] However, it is not known whether such factors are associated with QOL outcomes in individuals who remain ACL deficient. Exploring potential predictors of low QOL in ACL-deficient people may assist clinical decision-making by helping to identify patient subgroups most likely to benefit from non-operative management. This will also facilitate the development of evidence-based treatment guidelines and recommendations.

The *primary aim* of this study was to report QOL outcomes in ACL-deficient individuals, 5–25 years following ACL rupture. The *secondary aims* were

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to: (1) compare QOL in ACL-deficient individuals with published population norms; (2) compare QOL in ACL-deficient and ACL-reconstructed populations; and (3) investigate relationships between relevant participant characteristics and QOL outcomes in ACL-deficient individuals.

METHODS

This systematic review used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines for conducting and reporting systematic reviews,[19] and the protocol for this review was prospectively registered on PROSPERO (CRD42014007499, 21 February 2014).

Search strategy

We searched seven electronic databases in January 2014 to retrieve all relevant articles: Scopus, MEDLINE, Web of Knowledge (Web of Science), The Cochrane Library, PubMed, CINAHL and SPORTDiscus. The search strategy retrieved articles that contained the term 'anterior cruciate ligament' or the abbreviation 'ACL' in the title or abstract, as well as at least one key word relevant to QOL outcomes (see appendix 1 for full search strategy). This search was undertaken independently by two of the authors (SRF, AGC), who screened titles and abstracts for eligibility, and reviewed the references of relevant articles for any additional publications. If eligibility could not be ascertained from the abstract, the full text was retrieved. Any contrasting opinions in determining eligibility were resolved by an independent researcher (KMC). The searches were repeated in June 2014 to identify any further publications of relevance.

Selection criteria

Articles were considered eligible for inclusion in the review if these met the following criteria:

1. Study participants completed a health-related QOL or knee-related QOL outcome measure on average 5–25 years following ACL rupture;
2. All participants or a subgroup of participants had not received an ACL reconstruction, repair or augmentation at the time of follow-up;
3. Participants had a mean age between 18 and 55 years at the time of follow-up.

Articles including participants with partial ACL rupture, and articles published in languages other than English were excluded. Articles including both ACL-deficient and ACL-reconstructed participants were included only if these reported separate knee-related QOL or health-related QOL outcomes for non-operative participants, or if the authors provided this data on request. We did not exclude studies that reported data from participants who sustained a concomitant or subsequent meniscal or collateral ligament injury; were aged less than 18 years at the time of ACL injury; or had radiographic or clinical signs of OA as these were identified as variables with a potential to impact on QOL. If multiple publications featuring data from the same study cohort were retrieved, the article reporting outcomes of interest for the greatest number of eligible participants was included in the review.

Methodological appraisal

A modified version of the Downs and Black's Checklist for the Assessment of Methodological Quality of Randomised and Non-Randomised Studies[20] was used to appraise the quality of eligible articles. This tool is appropriate for methodological appraisal of a variety of study designs; however, some items were not applicable as per the aims of this review and were consequently excluded or modified. In total, six items were excluded and additional items were modified or clarified, which resulted in modified Downs and Black criteria as we have described previously.[8] The methodological score ranged from 0 (lowest methodological quality) to 21 (highest quality), where randomised and prospective studies score more highly then retrospective or case studies. As studies of low methodological quality may be subject to greater bias,[21] articles achieving less than 50% of the total possible methodological appraisal score were excluded from the review.

Patient-reported outcomes

Self-administered questionnaires are commonly used to assess knee-related QOL and overall health-related QOL. Knee-related QOL refers to the impact of one's knee status on their well-being and life satisfaction, and is commonly assessed in ACL-ruptured populations using questionnaires containing a knee-specific QOL subscale, such as the Knee injury and Osteoarthritis Outcome Score (KOOS).[22] The KOOS contains a subscale addressing QOL, in addition to Pain, Symptoms, Activity of Daily Living, and Sport/Recreation subscales. Knee-related QOL can also be assessed using an ACL-specific questionnaire devised with the primary purpose of assessing QOL in an ACL-ruptured population. The only measure developed to date with this intention is the Anterior Cruciate Ligament Quality of Life questionnaire (ACL-QOL).[23] The ACL-QOL contains 31 items, across 5 subscales (symptoms and physical symptoms, work-related concerns, sports/recreation, lifestyle, social and emotional).

Health-related QOL refers to the influence of one's health status on their well-being and life satisfaction, and has been described as the discordance between an individual's expectations of health and their current health experience.[24] Health-related QOL can be assessed with non-disease-specific patient-reported outcomes, such as the Short-Form 36 (SF-36),[25] which is commonly used in studies of ACL ruptured individuals[8] and assesses the influence of an individual's health status on their overall life quality. The SF-36 is comprised of eight domains (Bodily Pain (BP); General Health (GH); Mental Health (MH); Physical Function (PF); Role Emotional (RE); Role Physical (RP); Social Function (SF); and Vitality (V)). All three measures (SF-36, KOOS, ACL-QOL) are valid for use in ACL-ruptured individuals[23 26 27] and are measured on 0 to 100 scales, where 0 represents the poorest possible outcome, and 100 represents the best possible score. Separate scores can be calculated for individual domains or subscales, in addition to an overall score for each measure.

Data extraction

Study characteristics and participant demographics were extracted independently by two of the authors (SRF, AGC). These data were cross-checked and any discrepancies resolved through discussion. Data extracted included knee-related QOL and health-related QOL scores, participant characteristics (age, body mass index (BMI), sex, time since ACL injury, proportion undergoing a delayed ACL reconstruction), as well as factors that could potentially influence QOL outcomes (concomitant and subsequent injuries, prevalence of tibiofemoral and patellofemoral OA, activity levels and return to sport data).

Statistical analysis

Primary outcomes included all knee-related QOL and health-related QOL scores. The two-tailed Spearman rank correlation coefficient (r) was used to explore potential relationships between knee-related QOL scores, participant demographics and

study characteristics (follow-up duration, sex (% female), quality appraisal score, mean age), as well as relationships between subscales of the primary knee-related outcome measure. Random-effects meta-analysis was used to produce forest plots for primary outcomes displaying mean differences and 95% CIs between ACL-deficient and ACL-reconstructed subgroups from individual studies, and pooled mean differences (95% CIs) for combined studies. Where only domain scores were presented for a given outcome measure, component scores were calculated using reported mean values from each domain. Where only 95% CIs were reported for a primary outcome, SDs were estimated using the square root of the sample size and corresponding t scores.[28] If population norms were reported separately for males and females[29 30] or for two separate age groups within a more appropriate age range,[31] then the two groups were combined using a formula from *The Cochrane Handbook for Systematic Reviews of Interventions*[28] to obtain mean and SD estimates for the combined groups.

RESULTS

Literature search

The systematic search yielded a total of 1172 studies. After removal of 549 duplicate articles, a further 555 papers were excluded through screening of titles and abstracts, resulting in the full text retrieval of 68 studies. Of these, 56 papers did not meet our eligibility criteria and were excluded (figure 1). We requested additional data from the authors of six papers with insufficient reporting of outcomes for the purposes of this review. Five authors provided data required to meet our eligibility criteria[10 32–35] and one study was subsequently excluded as no further data was provided by the authors.[36] Eleven papers were included in the initial appraisal of methodological quality, and an additional eligible paper was identified in the June 2014 searches.[31]

Quality appraisal

Quality appraisal scores for the reviewed studies ranged from 4 to 21. The study with the lowest quality was excluded due to satisfying less than 10 (4 of 21) of the quality appraisal criteria.[37] The quality appraisal scores for the remaining 11 studies are presented in table 1.

Study and participant characteristics

QOL outcomes were reported for a total of 473 ACL-deficient participants from 11 studies at a mean of 10 years (range 5–23 years) following ACL rupture. Study and participant characteristics are presented in table 1. Knee-related QOL was measured with the KOOS-QOL subscale in eight studies[10 31 32 35 38–40] and the ACL-QOL in one study.[41] Health-related QOL was measured with the SF-36 in five studies,[10 32 33 40 42] and three studies included both a knee-related QOL and a health-related QOL measure.[10 32 40] Six studies used a prospective study design; however, only one was a randomised controlled trial.[10] Nine studies reported outcomes for both ACL-deficient and ACL-reconstructed subgroups, or provided these data on request.

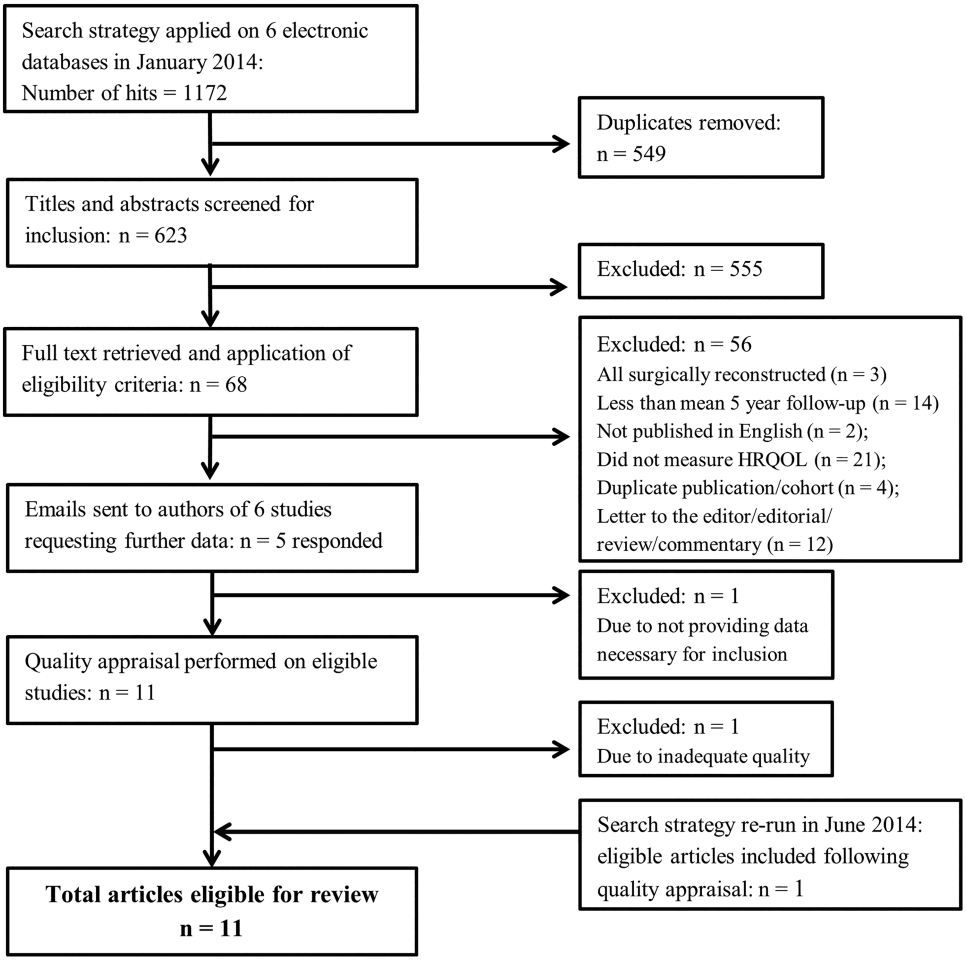

Figure 1 Search strategy. N, sample size; HRQOL, Health-related quality of life.

Table 1 Study and participant characteristics

Study	Quality*	Country	n=(ACLD/ ACLR)†	Follow-up (years)	BMI (kg/m^2)	Mean age at follow-up (years)	Sex (% women)	Study design	QOL measure(s)
Fithian *et al*[42]	13	America	113/96‡	7 (3–10)	NR	45±11, 38±14, 37 ±14§	54, 61, 46§	Prosp	SF-36
Frobell *et al*[10]	21	Sweden	29/59	5	24±3¶	31±5¶	31	RCT	KOOS, SF-36
Hartwick *et al*[41]	11	Canada	17/0	12 (1–26)	27	40±8	47	CS	ACL-QOL
Lohmander *et al*[32]	15	Sweden	32/52	12	23 (18–40)	31 (26–40)	100	Retro	KOOS, SF-36
Meunier *et al*[35]	13	Sweden	36/0**	15±1	NR	36 (29–45)‡¶	38	Prosp	KOOS
Michalitsis *et al*[38]	14	Greece	32††/0	5±5	26	30	11	CS	KOOS
Neuman *et al*[34]	18	Sweden	71/22‡‡	16±1‡	26±4‡	42±7‡	39‡	Prosp	KOOS
Potter *et al*[33]	12	America	7/12††	7–11	NR	42±10¶	77	Prosp	SF-36
Swirtun and Renström[39]	13	Sweden	24/22	6±1	NR	32±8‡¶	48	Prosp	KOOS
Tengman *et al*[31]	11	Sweden	37/33	23±1	29±5	48±6	38	CS	KOOS
von Porat *et al*[40]	14	Sweden	65/89	14	26±2	40±6	0	CS	KOOS, SF-36

All data are reported as range only, mean only, mean±SD, or mean (range).
*Quality appraisal scores range from 0 to 21 (worst to best quality).
†Number of eligible participants for which QOL outcomes were reported.
‡Included delayed ACL-reconstructed patients.
§Data reported separately for ACL-deficient patients grouped by risk level (low, moderate and high) based on baseline knee stability and sports participation.
¶Estimated using mean age from baseline and mean follow-up.
**n=42 had a surgical ACL repair, as opposed to ACL reconstruction.
††QOL data provided for a portion of total sample with >5-year follow-up.
‡‡All n=22 were delayed ACL reconstruction.
ACLD, anterior cruciate ligament deficient; ACLR, anterior cruciate ligament reconstructed; BMI, body mass index; QOL, quality of life; NR, not reported; Prosp, prospective; RCT, randomised controlled trial; CS, cross-sectional; Retro, retrospective; KOOS, Knee injury and Osteoarthritis Score; SF-36, Short-Form 36.

Knee-related QOL

Knee-related QOL in ACL-deficient individuals

A total of five studies reported KOOS-QOL data for ACL-deficient participants[10 31 35 39 40] and a further three studies provided these data on request.[32 34 38] Mean KOOS-QOL values ranged from 54[32 38] to 77[39] out of a maximum of 100 (best possible score) (figure 2). Strong positive relationships were identified between KOOS-QOL and all subscales of the KOOS (Pain r=0.86, p=0.01; Symptoms r=0.79, p=0.02; ADL r=0.79, p=0.02; and Sport/Rec r=0.74, p=0.04).[10 31 32 35 38–40] KOOS-QOL scores were not significantly related to follow-up duration (r=0.25, p=0.55), sex (r=0.28, p=0.51), age (r=0.42, p=0.31), sample size (r=0.35, p=0.40) or quality appraisal scores (r=0.13, p=0.76).

Only one study used the ACL-QOL to report knee-related QOL in ACL-deficient individuals.[41] This study evaluated knee-related QOL in 17 people with knee OA at an average of 9 years following ACL rupture. These participants reported a mean±SD ACL-QOL score of 39±19 indicating very low QOL (score of 100 indicates optimal QOL). Total ACL-QOL scores were correlated to the level of pain reported during isometric knee extension (Pearson's r=−0.56; p=0.016).

Comparison to normative populations

KOOS-QOL scores in ACL-deficient individuals ranged from 54 ±17[32] to 77±22[39] (mean±SD); these were impaired compared to Swedish general population norms (81±24),[29] Swedish amateur soccer players with minor (14%), severe (23%) or no history (63%) of knee injury (88±17),[43] and a population of US military recruits (92±28).[30] The other KOOS subscale scores reported by ACL-deficient groups were similar to those reported by the general Swedish population.[43] In contrast, all ACL-

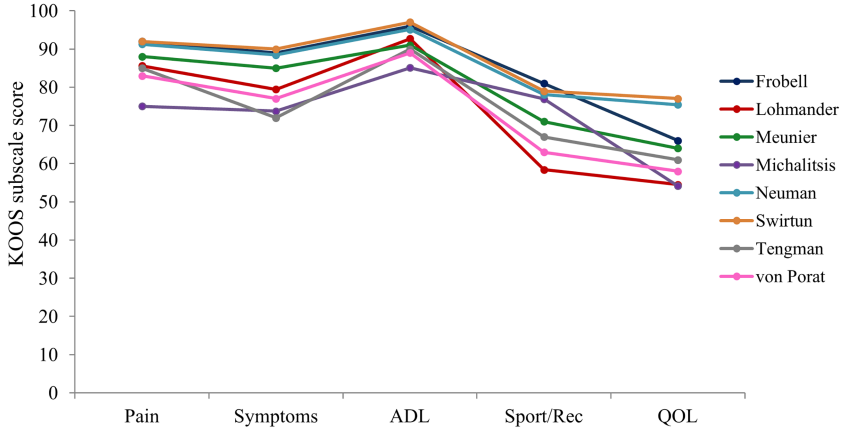

Figure 2 Knee injury and Osteoarthritis Outcome Score (KOOS) values for individual studies from anterior cruciate ligament-deficient cohorts. All subscale scores represent means; a lower score indicates poorer outcomes in all subscales. ADL, activities of daily living; Sport/Rec, function in sport and recreation; QOL, quality of life; KOOS, Knee injury and Osteoarthritis Outcome Score.

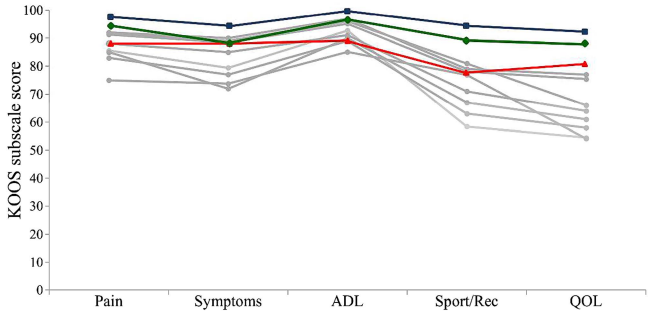

Figure 3 Knee injury and Osteoarthritis Outcome Score (KOOS) values of anterior cruciate ligament-deficient cohorts for individual studies (grey lines) compared with population norms. Blue squares: mean values from US military recruits with no history of knee ligament injury (aged 19±1 years, n=1005)[30]; Green diamonds: mean values from amateur Swedish soccer players with minor (14%), severe (23%), or no (63%) history of knee injury (aged 22±4 years; n=188)[43]; Red triangles: mean values from the Swedish general population (aged 18 to 54 years; n=291)[29]; All normative populations include men and women; a lower score indicates poorer outcomes in all subscales. ADL, activities of daily living; Sport/Rec, function in sport and recreation; QOL, quality of life; KOOS, Knee injury and Osteoarthritis Outcome Score.

deficient groups reported more knee pain and worse function in sport and recreation compared to amateur soccer players and military recruits (figure 3).

Knee-related QOL comparisons between ACL-deficient and ACL-reconstructed groups

Pooling of KOOS-QOL data extracted from the studies reporting separate scores for ACL-deficient and ACL-reconstructed groups[10 32 31 34 39 40] revealed no significant difference in knee-related QOL between groups (mean difference (95% CI) 2.9 (−3.3 to 9.1; figure 4). Of these studies, three found no difference in KOOS-QOL between ACL-deficient and ACL-reconstructed groups at 5, 12 and 14-year follow-up,[10 32 40] or no difference in KOOS-QOL between ACL-deficient and delayed ACL-reconstructed groups (all ACL-reconstructed individuals in this study initially received non-operative management).[34] The remaining two studies reported better KOOS-QOL scores in ACL-deficient participants at 6 and 23-year follow-up, respectively.[31 39] Meunier

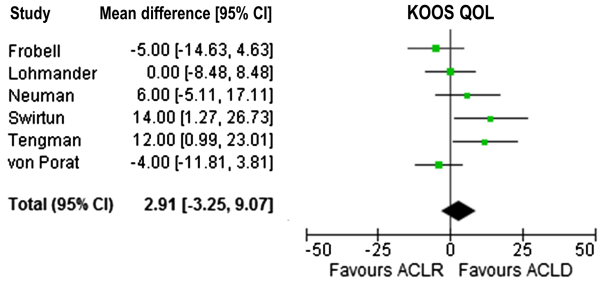

Figure 4 Forest plot of random-effects meta-analysis of Knee injury and Osteoarthritis Outcome Score-Quality of life (KOOS-QOL) scores. Mean differences (boxes) and 95% CIs (whiskers) are presented for individual studies reporting data for anterior cruciate ligament (ACL)-deficient and ACL-reconstructed subgroups; The pooled mean difference and 95% CI are represented by the diamond; A negative mean difference indicates a favourable knee-related QOL outcome for ACL-reconstructed participants. ACLR, anterior cruciate ligament reconstruction; ACLD, anterior cruciate ligament deficient.

et al[35] initially allocated participants to surgical repair (not reconstruction) of the torn ACL or non-operative management, and reported no between-group differences in KOOS-QOL scores.

Health-related QOL

Health-related QOL in ACL-deficient individuals

The only health-related QOL measure used in the included studies was the SF-36. Two studies reported SF-36 scores for all domains for ACL-deficient participants,[40 42] and a further two studies provided these data on request.[10 32] One additional study provided SF-36 physical and mental component scores, but did not report data for individual SF-36 domains.[33] Comparison of SF-36 domain scores revealed similarities in reported mean values across all studies, with the exception of the low Bodily Pain domain score reported by Fithian *et al*,[42] and the low physical and mental component scores reported by Potter *et al*[33] (figure 5).

Comparison to normative populations

Health-related QOL scores, measured with the SF-36, were similar or slightly higher in ACL-deficient individuals compared to a population-based sample from Norway (n=2323; aged 45 ±17 years)[44] (figure 6). Specifically, similar scores were reported for the four physical health domains (PF, RP, BP and GH) addressing activity limitations due to physical health, bodily pain, self-rated health and future health expectations. The four SF-36 mental health domain scores reported by ACL-deficient groups in each study were similar or higher than those reported from Norwegian population norms (figure 6).[44] These four domains (V, SF, RE and MH) address energy and fatigue, the influence of emotional health on activity participation and social activities, anxiety and depression. Considering ACL rupture commonly occurs during participation in competitive sport, we compared SF-36 scores in ACL-deficient groups with norms available from a more active population of 696 US college athletes (n=696: mean age 19, range 17–23 years),[45] and over half of these athletes reported previous sporting injuries. Lower mean SF-36 scores were observed for all ACL-deficient groups compared with this active population (figure 6).

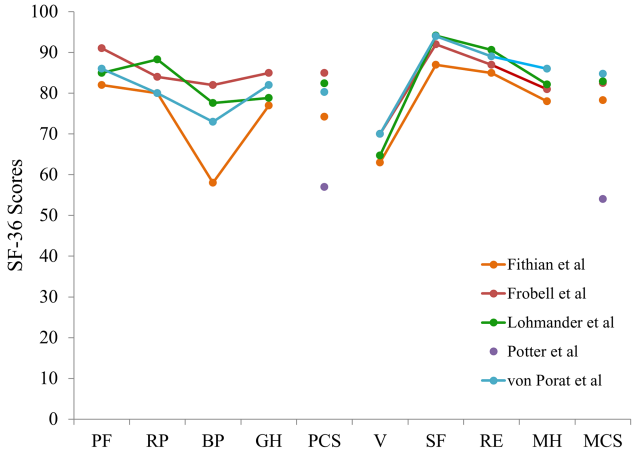

Figure 5 Short Form-36 (SF-36) results for individual studies. All scores represent mean values; a lower SF-36 score indicates poorer outcome on each domain. PF, Physical Function; RP, Role Physical; BP, Bodily Pain; GH, General Health; PCS, Physical Component Score (the aggregate mean score of PF, RP, BP and GH domains); V, Vitality; SF, Social Function; RE, Role Emotional; MH, Mental Health; MCS, Mental Component Score (the aggregate mean score of V, SF, RE and MH domains); only component scores were reported by Potter *et al*.[33]

Health-related QOL comparisons between ACL-deficient and ACL-reconstructed groups

Pooling of mean SF-36 domain scores from individual studies identified no significant differences between ACL-deficient and ACL-reconstructed groups for seven of the eight domains (figures 7 and 8). However, there was a significant difference for the SF-36 Vitality domain, favouring the ACL-reconstructed group (mean difference (95% CI) −4.3 (−7.6 to −1.0); figure 8). Three out of four studies reporting SF-36 scores found no differences between ACL-deficient and ACL-reconstructed groups.[10 33 40] The only study to report between-group differences in SF-36 scores reported increased PF, RP, BP, V, SF and RE scores in participants who underwent ACL reconstruction.[42]

Factors that may influence QOL

Tibiofemoral OA and cartilage pathology

Three studies reported no difference in knee-related QOL between individuals with tibiofemoral radiographic OA and those without OA.[32 35 40] However, only one study reported knee-related QOL scores separately for ACL-deficient and ACL-reconstructed participants with and without tibiofemoral OA.[31] This study reported higher KOOS-QOL scores in ACL-deficient individuals with OA (Kellgren and Lawrence > grade 2; n=25; KOOS-QOL 59±27) compared with ACL-reconstructed individuals with OA (n=26; mean KOOS-QOL 48±22). However, a between-group statistical analysis was not reported. No studies investigated differences in QOL based on the presence of tibiofemoral cartilage pathology.

Patellofemoral OA and cartilage pathology

Four studies reported rates of patellofemoral OA or patellofemoral cartilage lesions in ACL-deficient participants with more than 5 years following ACL rupture.[10 32 38 42] These studies found lower rates of patellofemoral degenerative changes (58% vs 76%, p=0.02),[42] lower rates of patellofemoral OA (28% vs 61%, p=0.01, OR 5.8)[32] or a trend toward less patellofemoral OA (p=0.08)[10] in ACL-deficient participants compared with those managed with ACL reconstruction. The fourth study included only ACL-deficient participants, and found no patellofemoral cartilage lesions among the sample at an average of 5 years after ACL rupture.[38] However, the relationship between patellofemoral changes and QOL scores was not investigated.[38]

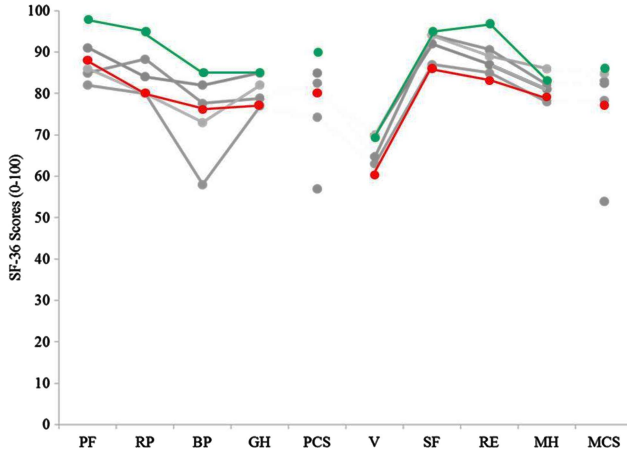

Figure 6 Short-Form 36 (SF-36) scores for individual studies (grey lines) compared with sporting and general population-based normative data. Green line: mean scores from US college athletes (n=696: mean age 19, range 17–23 years)[45]; Red line: normative data from the Norwegian general population (n=2323; aged 45±17 years)[44]; All scores are mean values; a lower SF-36 score indicates poorer outcomes in all domains. PF, Physical Function; RP, Role Physical; BP, Bodily Pain; GH, General Health; PCS, Physical Component Score (the aggregate mean score of PF, RP, BP and GH domains); V, Vitality; SF, Social Function; RE, Role Emotional; MH, Mental Health; MCS, Mental Component Score (the aggregate mean score of V, SF, RE and MH domains); only component scores were reported by Potter *et al*.[33]

Concomitant and subsequent injuries

Two studies found that subsequent meniscus injury[38] and meniscal repair[40] were not related to KOOS-QOL or SF-36 outcomes at an average of 5 and 14 years after ACL rupture. In contrast, Swirtun and Renström[39] reported a relationship between subsequent trauma (described as subsequent meniscus, cartilage or medial collateral ligament injury, patella subluxation or fracture or arthroscopic debridement) to the ACL injured knee and poorer KOOS-QOL scores (p=0.002). While increased rates of OA were reported in those with baseline meniscectomy or meniscal repair,[32 34 35] the influence of meniscus surgery or subsequent trauma on QOL outcomes was not evaluated specifically for ACL-deficient individuals.

Delayed ACL reconstruction

Three studies reported no significant difference in KOOS-QOL scores between ACL-deficient participants and those who were initially managed non-operatively, but had a delayed ACL reconstruction prior to 5, 15 and 16-year follow-up.[10 34 35] The proportion of participants deciding to have an ACL reconstruction despite undergoing initial non-operative management ranged from 23%[42] to 51%[10] across the included studies. Participants in the study by Michalitsis *et al*[38] differed from those in other studies in that all participants completed questionnaires 1 day prior to undergoing a delayed ACL reconstruction, at a mean of 5 years postinjury. These participants reported the poorest knee-related QOL (figure 2).

Activity level

Five studies compared return to sport rates or activity level between ACL-deficient and ACL-reconstructed groups. There were no reported differences in return to preinjury sport or activity level at follow-up between non-surgical and surgical groups.[10 32 35 39 42] No study compared QOL between those who returned to the same level of sport and those who did not in ACL-deficient individuals more than 5 years following ACL rupture.

DISCUSSION

This systematic review shows that knee-related QOL is impaired 5–25 years following ACL rupture in ACL-deficient individuals, compared to population-based normative data. Meta-analyses using pooled data from multiple studies revealed no difference in knee-related QOL between patients who underwent ACL reconstruction and those who did not. All of the included studies reported similar[10 32 40] or better[31 39] knee-related QOL 5–25 years following ACL rupture in people who remain ACL-deficient, compared to those managed with surgical reconstruction. In contrast, health-related QOL in ACL-deficient groups was similar to general population norms but impaired compared to more active populations. Data pooling revealed no health-related QOL differences between ACL-deficient and ACL-reconstructed groups for seven of the eight SF-36 domains.

Knee-related QOL

Knee-related QOL scores in ACL-deficient individuals were impaired compared to general population norms.[29] Greater

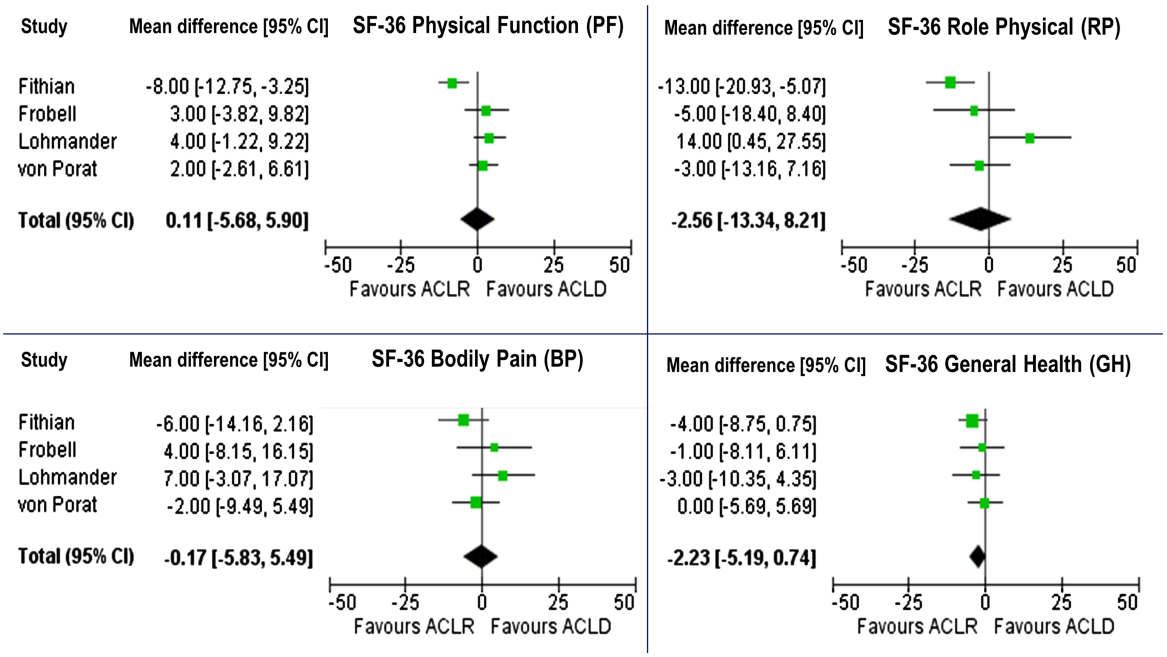

Figure 7 Forest plot of random-effects meta-analysis of SF-36 domains contributing to the Physical Component Score. Mean differences (boxes) and 95% CIs (whiskers) are presented for individual studies reporting data for anterior cruciate ligament (ACL)-deficient and ACL-reconstructed subgroups, in addition to the pooled mean difference and 95% CI (diamond); A negative mean difference indicates a favourable QOL outcome for ACL-reconstructed participants; Data from Potter *et al*[33] was not included in this meta-analysis as SF-36 domain scores were not reported. ACLR, anterior cruciate ligament reconstruction; ACLD, anterior cruciate ligament deficient; Short-Form 36 (SF-36).

knee-related QOL impairments were observed when ACL-deficient patients were compared to Swedish amateur soccer players[43] and US military recruits[30]; these populations are likely to be more active than the general population. The magnitude of difference is consistent with the minimal clinically important change (the smallest change required for an effect to be considered clinically relevant) for the KOOS (8–10 points).[22] Notably, ACL ruptured individuals are typically active in competitive sports at the time of injury[46] and may have a higher pre-injury QOL compared with the general population. This should be considered when making QOL comparisons following ACL rupture. Two of the lowest KOOS-QOL scores were reported in

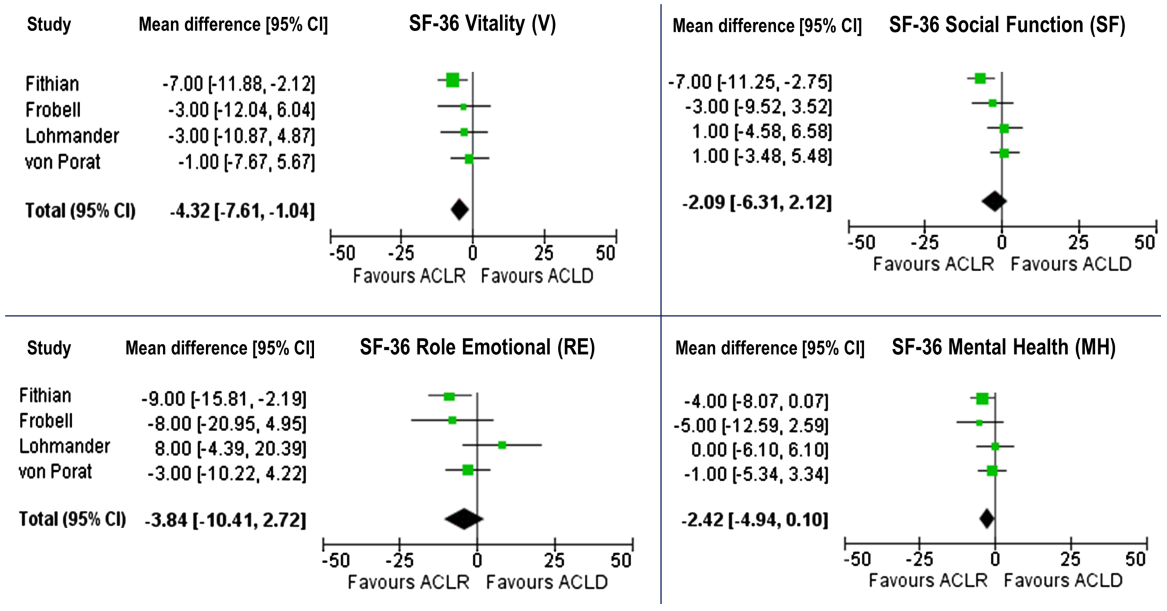

Figure 8 Forest plot of random-effects meta-analysis of SF-36 domains contributing to the Mental Component Score. Mean differences (boxes) and 95% CIs (whiskers) are presented for individual studies reporting data for anterior cruciate ligament (ACL)-deficient and ACL-reconstructed subgroups, in addition to the pooled mean difference and 95% CI (diamond); A negative mean difference indicates a favourable QOL outcome for ACL-reconstructed participants; Data from Potter *et al*[33] was not included in this meta-analysis as SF-36 domain scores were not reported. ACLR, anterior cruciate ligament reconstruction; ACLD, anterior cruciate ligament deficient; Short-Form 36 (SF-36).

studies including all male[40] and all female[32] Swedish soccer players at a mean of 12 years and 14 years following ACL rupture, respectively. These ACL-deficient groups reported markedly impaired KOOS-QOL scores in contrast to a comparable sample of Swedish amateur male and female soccer players.[43] The KOOS-QOL subscale is comprised of four questions, one of these questions addresses knee-related lifestyle modifications. This may partly explain the impaired KOOS-QOL scores reported in ACL-deficient soccer players (30% of male soccer players reported severe lifestyle change[40] and 50% of female soccer players reported lifestyle changes).[32] ACL-deficient individuals may benefit from targeted support to return to their desired activity level, or encouragement to adopt an active lifestyle if ceasing sport participation.

Our meta-analyses revealed similar knee-related QOL between individuals who received an ACL reconstruction and those who remained ACL-deficient. Notably, the highest quality paper and the only RCT included in meta-analysis found no difference in KOOS-QOL scores between treatment groups.[10] There is also substantial overlap between the knee-related QOL scores reported in ACL-deficient populations (ranging from 54±17 to 77±22) and those reported in our recent systematic review looking at health-related QOL in ACL-reconstructed individuals 5–20 years after surgery (range of KOOS-QOL scores for ACL-reconstructed populations 63±22 to 83±18; pooled mean (95% CI) 75 (68 to 81)).[8] The results of both systematic reviews, therefore, suggest that ACL-ruptured individuals are at risk of long-term QOL impairments, irrespective of surgical or non-surgical management. Strategies to improve knee-related QOL following ACL rupture are important to incorporate into standard rehabilitation regimes. Such approaches could address knee confidence and assist individuals to make healthy lifestyle modifications or resume preinjury activities. Most importantly, an individualised approach is required, as QOL is an individual construct[47] and should be taken in the context of one's goals, expectations, standards and concerns.[48] To our knowledge, no studies have trialled interventions targeting QOL impairments after ACL rupture; this review indicates that such research is warranted.

Health-related QOL

Health-related QOL measured with the SF-36 was similar or better compared with data from the Norwegian general population,[44] but worse compared to US college athletes.[45] The study of college athletes reported significantly higher health-related QOL scores for athletes compared to an age-matched general population cohort. Additionally, higher QOL was observed in athletes without a history of injury, compared to those with a history of injury.[45] This highlights the importance of considering preinjury activity levels when evaluating health-related QOL. We found no significant pooled mean difference between ACL-deficient and ACL-reconstructed subgroups for seven of the eight SF-36 domains.

There was a significant between-group difference for the SF-36 Vitality domain (which assesses levels of energy and fatigue), where ACL-reconstructed individuals demonstrated more favourable outcomes. However, this difference of four SF-36 points is smaller than the estimated minimal detectable change of 5 points,[49] and largely attributable to results from one larger, moderate quality study[42] (figure 8). The other three studies reporting SF-36 Vitality scores (including the only high-quality RCT) found no significant difference between groups. Importantly, the observed pooled mean difference for the SF-36 Vitality domain is unlikely to be of clinical significance.

Concomitant injuries and OA

No studies investigated associations between concomitant or subsequent meniscal and cartilage injury or surgery on QOL outcomes for ACL-deficient participants specifically. Although our previous systematic review identified relationships between concomitant meniscal surgery at the time of ACL reconstruction and poorer KOOS-QOL and SF-36 scores more than 10 years following surgery,[50 51] we were not able to perform similar analyses for ACL-deficient cohorts.

Limited research has shown that radiographic OA severity is associated with knee-related QOL 14 years following ACL reconstruction.[52] The only study reporting KOOS-QOL scores according to OA severity and treatment groups found better knee-related QOL in ACL-deficient participants with OA compared to ACL-reconstructed participants with OA (mean 59 vs 48).[31] This difference is greater than the minimal clinically important change for the KOOS[22] and is likely to be of clinical relevance.

While studies identified differences in rates of patellofemoral OA[32] or degenerative changes[42] between ACL-deficient and ACL-reconstructed groups, the influence of patellofemoral changes on QOL in ACL-deficient individuals was not explored in the included studies. Patellofemoral OA may contribute to pain, symptoms and activity restrictions following ACL rupture.[53]

Considerations for QOL comparisons between ACL-deficient and ACL-reconstructed groups

A range of potential biases were identified in the included studies that could result in the underestimation or overestimation of QOL in these patient populations. These include advice regarding activity modification, study designs that may result in surgical bias, and the surgical treatment of baseline meniscal injuries in non-reconstructed individuals. Several studies purposefully selected individuals with a low preinjury activity level for non-operative management or strongly advised non-operatively managed participants against returning to high-impact sports.[31 33 34 39 42] This could potentially influence KOOS-QOL scores, where one of four questions addresses lifestyle modifications. Advice to patients that ACL reconstruction is required for return to sport may result in a surgical bias, and could increase the likelihood of ACL-deficient participants adopting a less active lifestyle, or experiencing reduced confidence for taking part in future activities. Increased lifestyle modifications and reduced knee confidence is likely to translate into a poor KOOS-QOL score.

The impact of meniscal injury and subsequent surgery on QOL in ACL-deficient participants is difficult to determine. Meniscal injuries occurring at the time of ACL rupture may go undiagnosed in non-operatively managed patients who do not receive an MRI or diagnostic arthroscopy. This may result in the mislabelling of some concomitant meniscal injuries as new subsequent meniscal injuries in ACL-deficient groups, making interpretation of the influence of concomitant and subsequent meniscal injuries on QOL in these individuals more difficult than ACL-reconstructed groups. Where studies did perform baseline MRI or diagnostic arthroscopies, baseline meniscal surgery was frequently performed in patients managed without ACL reconstruction. Undergoing any form of knee surgery may have psychological consequences, such as increased fear of reinjury and poor knee confidence, potentially negatively impacting QOL.

Limitations and strengths

An ACL-specific QOL instrument (ACL-QOL) was only used in one study, precluding between-study comparisons for this

measure. As most studies did not evaluate QOL as their primary objective, potential influences on QOL were rarely explored for ACL-deficient participants, limiting conclusions about factors impacting on QOL. Furthermore, patient-reported QOL measures often fail to address patient-perceived important and relevant factors.[47] The KOOS-QOL is a valid measure of knee-related QOL and the most commonly used QOL measure 5–20 years after ACL reconstruction.[8] However, specific items (knee-related lifestyle modification and knee awareness) may not accurately reflect QOL in ACL-ruptured individuals. Heightened knee awareness has the potential to facilitate positive lifestyle modifications that result in a satisfactory QOL.[54] We recommend that future studies measuring knee-related QOL as a primary outcome in ACL-deficient participants include the ACL-QOL questionnaire. We also recommend comparisons with active reference groups to enhance interpretability of findings.

Rehabilitation has potential to improve quality of life, but only four studies included in this review described a standardised rehabilitation programme for non-operative patients.[10 31 34 42] Rehabilitation strategies varied between studies (physiotherapist supervised neuromuscular training or a strategy of self-monitored training that commonly resulted in poor joint mobility and muscle atrophy;[34] a goal oriented physiotherapist led progressive programme focusing on functional stability training and activity modification;[31] an unmonitored rehabilitation programme consisting of non-impact closed chain strengthening and range of motion exercises;[42] and a standardised evidence-based goal oriented rehabilitation programme described in great detail)[10]. Consequently, we were unable to investigate the influence of specific rehabilitation strategies on QOL outcomes. Long-term QOL outcomes reported by participants in other studies may have been influenced by ineffective postinjury management and better outcomes might have been obtained from evidence-based rehabilitation programmes.

Additionally, ACL reconstruction studies with long-term follow-up may have used surgical procedures that are now outdated and not comparable to modern day techniques. There is also a need for high-quality RCTs investigating longer term QOL as a primary outcome between ACL-reconstructed and ACL-deficient groups, since other study designs are more susceptible to bias. Finally, we only included articles published in English; 7 of 11 eligible studies were performed in Sweden and 2 were performed in the USA. This potentially limits the generalisability of findings to other populations. The main strengths of this review were the systematic approach to literature searching, study selection and data extraction; the inclusion of both knee-specific QOL and health-related QOL data; and access to unpublished data that enabled us to pool key outcomes for meta-analysis. The availability of normative QOL data enhanced the interpretation of results and enabled us to evaluate the findings within a broader population context.

SUMMARY AND CONCLUSION

This systematic review has shown that knee-related QOL is impaired 5–25 years following ACL rupture in ACL-deficient individuals compared to population norms, and to an even greater degree when compared to young, active adults. Meta-analysis identified no significant differences in knee-related QOL between ACL-deficient and ACL-reconstructed groups. Average health-related QOL scores in ACL-deficient people were similar to those reported in a general population, but impaired compared to more active populations. The only difference between ACL-deficient and ACL-reconstructed groups for health-related QOL outcomes was a favourable SF-36 Vitality score for ACL-reconstructed participants; however, this is unlikely to be of clinical significance. These findings indicate that longer term impairments in knee-related QOL are evident after ACL rupture, irrespective of operative or non-operative management.

What are the new findings?

- Knee-related quality of life (QOL) is commonly impaired 5–25 years after ACL rupture, irrespective of management strategy.
- QOL outcomes are similar between ACL-deficient and ACL-reconstructed groups.
- A range of biases may impact interpretation of QOL in ACL-deficient individuals.
- Strategies are needed to improve longer term QOL after ACL rupture.

How might it impact on clinical practice in the near future?

- Clinicians should consider educating ACL-ruptured patients about potential long-term outcomes—unrealistic patient beliefs, such as 'ACL reconstruction prevents osteoarthritis', should be addressed at initial consultations.
- Clinicians may use this information to highlight similarities in longer term QOL outcomes between ACL reconstructed and conservatively managed groups when discussing management options.

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Contributors SRF made a substantial contribution to the design of the study; performed the literature search; applied the eligibility criteria; methodologically appraised the articles; extracted, analysed and interpreted the data; produced the figures and graphs; drafted, critically revised and wrote the manuscript. AGC made a substantial contribution to the design of the study; performed the literature search; applied the eligibility criteria; methodologically appraised the articles; extracted the data; assisted with data analysis; critically revised the manuscript. IA contributed to and critically commented on the design of the study; assisted with analysis and interpretation of data; critically revised the article. TGR critically commented on the design of the study; assisted with interpretation of data; critically revised the article. KMC contributed to and critically commented on the design of the study; assisted with analysis and interpretation of data; critically revised the article.

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