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SYSTEMATIC REVIEW

Kinesiophobia, Knee Self-Efficacy, and Fear Avoidance Beliefs in People with ACL Injury: A Systematic Review and Meta-Analysis

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Abstract

Background To improve the understanding of the psychological impacts of anterior cruciate ligament (ACL) injury, a systematic review synthesizing the evidence on knee self-efficacy, fear avoidance beliefs and kinesiophobia following ACL injury is needed.

Objective The aim of this systematic review was to investigate knee self-efficacy, fear avoidance beliefs and kinesiophobia following ACL injury, and compare these outcomes following management with rehabilitation alone, early and delayed ACL reconstruction (ACLR).

Methods Seven databases were searched from inception to April 14, 2022. Articles were included if they assessed Tampa Scale of Kinesiophobia (TSK), Knee Self-Efficacy Scale (KSES), or Fear Avoidance Beliefs Questionnaire (FABQ). Risk of bias (RoB) was assessed using domain-based RoB tools (ROBINS-1, RoB 2, RoBANS), and GRADE-assessed certainty of evidence. Random-effects meta-analyses pooled outcomes, stratified by time post-injury (pre-operative, 3–6 months, 7–12 months, > 1–2 years, > 2–5 years, > 5 years).

Results Seventy-three studies (70% high RoB) were included (study outcomes: TSK: 55; KSES: 22; FABQ: 5). Meta-analysis demonstrated worse kinesiophobia and self-efficacy pre-operatively (pooled mean [95% CI], TSK-11: 23.8 [22.2–25.3]; KSES: 5.0 [4.4–5.5]) compared with 3–6 months following ACLR (TSK-11: 19.6 [18.7–20.6]; KSES: 19.6 [18.6–20.6]). Meta-analysis suggests similar kinesiophobia > 3–6 months following early ACLR (19.8 [4.9]) versus delayed ACLR (17.2 [5.0]). Only one study assessed outcomes comparing ACLR with rehabilitation only.

Conclusions Knee self-efficacy and kinesiophobia improved from pre-ACLR to 3–6 months following ACLR, with similar outcomes after 6 months. Since the overall evidence was weak, there is a need for high-quality observational and intervention studies focusing on psychological outcomes following ACL injury.

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Key Points

A total of 70% of studies were rated as high risk of bias, with overall GRADE evidence rated as very low.

There was a distinct improvement in knee self-efficacy and kinesiophobia from pre-operative to 3–6 months following anterior cruciate ligament (ACL) reconstruction.

Similar kinesiophobia scores were observed at 3–6 months and 7–12 months following reconstruction, whereas removal of an outlier resulted in better knee self-efficacy at 7–12 months compared with 3–6 months post-surgery.

Only one study assessed outcomes after treatment with rehabilitation only.

There is a need for high-quality observational and intervention studies focusing on psychological outcomes following ACL injury.

1 Introduction

Anterior cruciate ligament (ACL) injuries are a devastating event sustained by active individuals [1–3], with impairments that reduce quality of life [4–6] and result in long-lasting knee difficulties [3, 4, 7, 8]. Historically, rehabilitation has focused on physical recovery; however, psychological factors such as confidence, self-efficacy, fear avoidance, and kinesiophobia are just as important given they affect all aspects of an individual's recovery process [5]. The construct kinesiophobia has been defined as "an excessive, irrational, and debilitating fear of physical movement and activity resulting from feeling of vulnerability due to painful injury or re-injury" [9], self-efficacy aims to assess patients' belief in their ability to perform specific tasks [10], and fear avoidance has been defined as the avoidance of specific movements or actions, conditioning negative reinforcement [11]. Previous research has determined that ACL-injured individuals commonly experience persistent fear of re-injury, due in part to a lack of confidence in their affected knee [12, 13]. Fear of re-injury and lack of confidence in the injured knee can effect kinesiophobia [13, 14] and knee self-efficacy [13]. Psychological measures may also differentiate between individuals who return to sport and those who do not more effectively than functional tasks such as hop testing [15, 16].

Early and delayed ACL reconstruction (ACLR) have resulted in similar long-term knee symptoms, physical activity, and knee function [17], but there is no current consensus on how these treatment strategies affect psychological recovery. Rehabilitation alone has demonstrated similar outcomes to early or delayed ACLR [18], with early rehabilitation reducing the occurrence of subsequent ACLR within these patients [19]. It cannot be assumed that physical and psychological outcomes are similar. Further, there may be an important interaction between worse psychological health and physical recovery [20–22], with only 15% of young athletes with high kinesiophobia meeting recommended isometric quadriceps strength limb symmetry values [21]. Additionally, modifiable treatment strategies may also play a role in an individual's early and late psychological recovery [20]. Of concern, young athletes who experience kinesiophobia [21], low psychological readiness [12], and altered knee confidence [23] are at increased risk of sustaining a second ACL injury. A second ACL injury is an important concern because it is associated with worse long-term knee function, lower quality of life, physical inactivity, and a higher likelihood of knee osteoarthritis compared with primary ACL injury [24].

Evidence supporting the relationship between psychological factors and poor ACL injury outcomes is derived from studies with heterogeneous methodology [6, 25–27]. Some studies have a high risk of bias, use different assessment time points, and a variety of research designs [14, 21, 26, 28]. This limits the interpretation and clinical applicability of these findings. There is a need to consolidate these data to better understand how an individual's psychological health progresses after ACL injury. Exploring potential differences in psychological outcomes following different treatment strategies for ACL injury may inform patient decision making regarding ACL treatment options. Therefore, the purpose of this systematic review was (i) to investigate knee self-efficacy, fear avoidance beliefs, and kinesiophobia following ACL injury; and (ii) to compare knee self-efficacy, fear avoidance beliefs and kinesiophobia following ACL injury between individuals managed with rehabilitation alone, early and delayed surgical approaches.

2 Methods

2.1 Study Design

This work is a systematic review with meta-analysis. This systematic review followed the Finding What Works in Health Care: Standards for Systematic Reviews Handbook [29] and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [30, 31]. This review was prospectively registered on the Open Science Framework (OSF), https://osf.io/2tezs/.

2.2 Information Sources

The databases searched comprised Medline (Ovid), Embase (Elsevier), CINAHL Complete (EBSCOhost), Web of Science Core Collection (Clarivate), Scopus (Elsevier), Cochrane Central Register of Controlled Trials (Cochrane Library), and SPORTDiscus with Full Text (EBSCOhost).

2.3 Search Strategy

The search was developed and conducted, with input from the other authors, by a professional medical librarian (LL) and included a mix of keywords and subject headings representing 'anterior cruciate ligament injuries,' 'fear,' 'confidence,' and 'kinesiophobia,' respectively. Search hedges or database filters were used to remove publication types such as systematic reviews, case studies, conference abstracts, editorials, letters, comments, and animal-only studies as was appropriate for each database. The original search was performed on July 17, 2020, with an updated search on April 14, 2022 and found 6192 citations. Bibliographies of selected studies were hand searched to identify relevant articles not found by the search strategies. The reference lists of the final included articles were reviewed and citation tracking in Web of Science or Scopus was used to identify relevant studies and those studies were added for full-text review. Complete reproducible search strategies, including date ranges and search filters, for all databases are detailed in the electronic supplementary materials (ESM), Appendix 1. After the search, all identified studies were uploaded into Covidence (Veritas Health Innovation, Melbourne, Australia), a software system for managing systematic reviews, and duplicates were removed by the software ($n = 3794$). A final set of 2398 citations were left to be screened in the title/abstract phase. Study selection was carried out independently by two authors.

2.4 Eligibility Criteria

ACL outcomes of interest included the Tampa Scale of Kinesiophobia (TSK), Knee Self-Efficacy Scale (KSES), and Fear Avoidance Beliefs Questionnaire (FABQ) (Table 1). These specific outcomes were chosen due to their frequency of use within research in ACL-injured populations, and previous research demonstrating that they are important constructs to measure in this population.

Inclusion criteria consisted of (i) studies that assessed an eligible outcome (TSK, KSES, or FABQ) in ACL-injured individuals (first or second ACL injury) at any time point; and (ii) articles written in English.

Exclusion criteria consisted of (i) studies that included patients with three or more concomitant ligament ruptures or knee dislocation on the involved knee; (ii) studies that included patients with a history of three or more ACL ruptures on the same knee; (iii) studies that included any synthetic or enhanced ligament grafting for ACLR (example: Ligament Advanced Reinforcement System [LARS] ligament/GORE-TEX enhanced, Leeds-Keio); (iv) systematic reviews, meta-analyses, qualitative studies, clinical commentaries, case reports, editorials, conference abstracts, or letters to the editor; (v) grey literature (i.e., abstracts theses, or dissertations).

2.5 Study Selection

Training for each reviewer was performed prior to screening, consisting of blinded screening of title, abstract, and full text of five studies, followed by group discussion of inclusion and exclusion of articles. Following training, title and

Table 1 A description of eligible outcome measures

Outcome	Alternative versions	Scale (range)	Interpretation	Psychometric properties
Tampa Scale of Kinesiophobia	11-Question (TSK-11) 13-Question (TSK-13) 17-Question (TSK-17)	TSK-11: 11–44 TSK-13: 13–52 TSK-17: 17–68	44 (TSK-11), 52 (TSK-13), or 68 (TSK-17) = severe kinesiophobia MCID = 4 points for both TSK-17 and TSK-11 [107]	Internal consistency: Chronbach's alpha: TSK-17: 0.76 TSK-11: 0.79 [107] Reliability: TSK-17: ICC: 0.82 (95% CI 0.72–0.88) TSK-11: ICC: 0.81 (95% CI 0.71–0.88) [107]
Knee Self-Efficacy Scale	None	0–11	11 = strong self-efficacy SEM = 0.1 [3, 16]	Internal consistency = 0.94 Reliability: ICC: 0.75 [3, 16]
Fear Avoidance Beliefs Questionnaire	None	0–24	24 = greater fear avoidance [116]	Internal consistency = 0.75 Reliability: ICC: 0.72–0.90 [117]

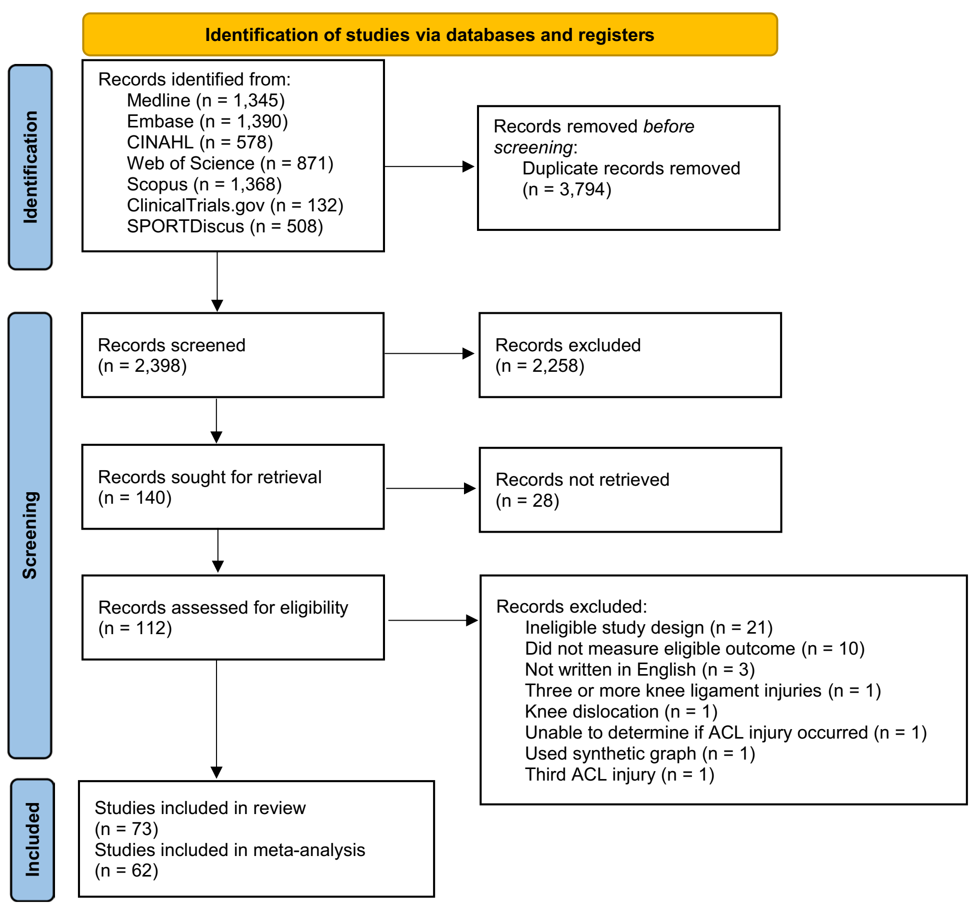
95% CI 95% confidence interval, *ICC* interclass correlation coefficient, *MCID* minimum clinically important difference, *SEM* standard error of the mean abstracts were randomly partitioned into five equal groups. These five equal groups were screened by five groups of two blinded independent reviewers (GB, RZ, CR, VK, HW, NM, CG, SD, AR, and TS) using pre-defined inclusion and exclusion criteria. Following abstract screening, the same two reviewers for each group then performed blinded (to each reviewer) full-text review of articles following title and abstract screening. If any duplicate cohort data were identified between papers or data was reported from more than one follow-up within the same time interval, data from the time point with the largest sample size was included in the meta-analysis. Any conflicts were first discussed between both reviewers; if a consensus could not be reached another reviewer (SF) was utilized to determine final study eligibility. Following full-text review, a hand search of eligible articles was performed for any studies missed within the initial search. The study selection process is presented by flowchart as per PRISMA guidelines (Fig. 1). For papers not published in English that met the inclusion criteria during the title/abstract screening, the abstracts were reviewed for usable data. Due to restrictions in funding, we chose not to have these papers translated and they were excluded at the full-text screening phase.

2.6 Data Extraction

Eligible articles were divided amongst five pairs of reviewers and data were extracted into customized Excel spreadsheets independently by each pair of reviewers (GB, RZ, CR, VK, HW, NM, CG, AR, SD, and SF). If consensus could not be reached for data extraction, a third reviewer (TS) resolved data discrepancies. If data were vague and further detail was needed, authors were contacted to provide clarification on two occasions, 2 weeks apart. If authors did not respond following second contact, specific data were considered not reported.

Data extraction included authors, journal, year published, study design, sample size, follow-up time points/length, injury/surgery history, concomitant injury and treatment, ACL injury treatment, psychological outcomes. Outcome measures were extracted as reported by each study. If outcome measures were reported at the subscale level, scores were calculated following data extraction.

Fig. 1 PRISMA flow diagram



2.7 Anterior Cruciate Ligament (ACL) Treatment Strategies

For the purposes of between-group comparisons, we established prior definitions of ACL treatment strategies. Early ACLR was defined as ACLR within a mean 6 months of ACL injury without trialing exercise therapy or following a period of 'pre-habilitation' with the intention of undergoing surgery on completion. Delayed ACLR was defined as ACLR following a trial of management with exercise therapy (i.e., rehabilitation alone). Patients may have 'crossed-over' to ACL surgery for a number of reasons including episodes of functional knee instability, patient choice, surgeon recommendations, and inability to meet strength/functional milestones.

2.8 Risk of Bias and Evidence Synthesis

Risk of bias (RoB) was assessed using domain-based RoB tools specific to study design, including the Cochrane Risk of Bias tool for randomized trials (RoB 2) for randomized control trials, Risk of Bias tool In Non-randomized Studies of Interventions (ROBINS-I) for pre-post and quasi-experimental studies, and the Risk of Bias Assessment tool for Nonrandomized Studies (RoBANS) for observational studies [32–34]. Two independent reviewers (GB, RZ, CR, VK, HW, NM, CG, AR) assessed each study for RoB. If consensus could not be reached for data extraction, a third reviewer (TS) resolved RoB discrepancies. The strength of the evidence for pooled data per outcome was derived based on RoB judgment of the individual studies according to methods adapted from Teirlinck et al. [35]. Specifically:

- Strong evidence: Data are provided by two or more studies in which 100% of the studies have a low risk of bias judgement in all assessed RoB domains.
- Moderate evidence: Data are provided by two or more studies in which $\leq$ 25% of the studies have a moderate, high or unclear risk of bias in one or more assessed RoB domain.
- Weak evidence: Data are provided by two or more studies in which > 25% of the studies have a moderate, high or unclear risk of bias in one or more assessed RoB domain.
- Limited evidence: Data are provided by one study irrespective of RoB judgment in all assessed RoB domains.

The Cochrane Grading of Recommendations, Assessment, Development and Evaluations (GRADE) scale was used to assess the certainty of the evidence for each meta-analysis estimate comparing overall, time and treatment groups of interest [36]. GRADE consists of six criteria (study design, risk of bias, inconsistency, indirectness, imprecision, publication bias, and upgrading factors), scored from − 2 to + 2. Quality of evidence scores are aggregated based on these criteria: very low, low, moderate, and high [36].

2.9 Deviation from Protocol

The original a priori protocol included the ACL Return to Sport (ACL-RSI) outcome measure. However, due to the large number of eligible studies reporting ACL-RSI outcomes, findings will be reported in a subsequent manuscript. Further, the protocol was designed to allow an additional meta-analysis using individual patient data (IPD) if IPD were received from at least 50% of studies. However, this threshold was not met so an aggregate meta-analysis was performed. Within the IPD meta-analysis, specific line items from the ACL quality-of-life outcome measure (ACL-QoL) addressing psychological constructs were designated for analyses. However, this required sharing of raw data and was not viable for an aggregate meta-analysis.

2.10 Statistical Analyses

Aggregated data were descriptively summarized using counts (percentages) and medians (ranges). If a study reported two subgroups for an outcome, the subgroup outcomes were combined using The Cochrane Handbook for Systematic Reviews of Interventions formula to obtain the mean and standard deviation estimates [37]. If a study only reported 95% confidence intervals without standard deviations, standard deviations were estimated using the square root of the sample size and corresponding t scores for the meta-analyses [37]. If a study reported median and quantiles, minimum and maximum, or interquartile range, outcome data were converted to mean and standard deviation through the method by McGrath et al. for the meta-analyses [38]. Time units (e.g., days, months, and years) were converted to the same unit for the meta-analyses.

A meta-analysis was performed using aggregate DerSimonian and Laird random effect models with inverse variance weighting stratified by time since ACL injury (e.g., pre-operative or prior to rehabilitation, 3–6 months, 7–12 months, > 1–2 years, > 2–5 years, > 5 years), and between group differences were assessed through a random effects Q-ANOVA. Specific time points were stratified based on typical rehabilitation recovery phases. Studies reporting TSK outcomes were stratified based on instrument version (i.e., TSK-11, TSK-13, TSK-17) for meta-analyses. Heterogeneity was assessed through overall Tau score, I^2 (heterogeneous: $\geq$ 50%), with a priori alpha of $p < 0.10$. As only four studies reported FABQ outcomes, with no overlap in time since ACL injury, FABQ outcomes were not included in the meta-analyses and were reported descriptively. Due to the low number of studies reporting TSK scores in specific treatment groups at a given follow-up time point, TSK comparisons between treatment groups were made descriptively. Meta-regressions were performed to investigate the explanation of variance of different confounders, which included ACL treatment group, percent female, mean age, and percent of participants with concomitant knee injuries. Only ACL treatment group and age were evaluated for KSES, due to the small number of studies reporting other potential confounders. Funnel plots were generated to assess for publication bias. Sensitivity meta-analyses excluding high RoB studies were performed. Following funnel plot analyses, one outlier was noted in the KSES analyses. Another sensitivity analysis was performed excluding the outlier. All analyses were performed in R version 4.02 (R Core Team [2013]. R: A language and environment for statistical computing) with the *meta* package used for all meta-analyses.

3 Results

A total of 2398 titles and abstracts were screened, with 73 studies [1, 3, 14–16, 20, 23, 39–103] included in the systematic review and 62 studies [1, 3, 15, 16, 20, 23, 39–42, 44–51, 53–56, 58–62, 64–67, 69, 70, 72–76, 81–83, 85–101, 103] included in the meta-analysis (Fig. 1). A total of 55 studies reported TSK scores (TSK-11 = 28; TSK-13 = 1; TSK-17 = 25; version not specified = 1), [1, 15, 20, 23, 39–42, 46–53, 55–57, 59–62, 64–79, 82, 83, 85–89, 93–96, 99–101, 103] 22 studies reported KSES scores [3, 14–16, 20, 41, 43–45, 52–54, 58, 80–82, 90–92, 97, 98, 104], and five studies reported FABQ scores [24, 56, 64, 102, 104]. A total of 44 studies were cross-sectional [1, 3, 20, 23, 39, 41, 43, 46, 47, 50, 54–56, 59, 60, 62, 63, 66–72, 75–78, 83–87, 90, 92–99, 101, 102], 14 studies were prospective cohorts [14, 15, 48, 49, 52, 53, 58, 61, 73, 74, 79–81, 88], seven were randomized controlled trials [57, 60, 82, 91, 100, 103, 104], four were case control [40, 45, 64, 92], three were retrospective cohorts [44, 51, 89], and two were case series [42, 65] (Table 2). A total of 7179 patients were included, with a percent female of 71% (range of 0–100%) and a mean age range of 16–46 years. Twelve (20%) studies were included in the delayed ACLR treatment group [14, 39, 40, 44, 49, 61, 68, 75, 81, 88, 97, 105].

3.1 Risk of Bias

Out of 64 observational cohort, case series, or cross-sectional studies [1, 3, 14, 15, 20, 23, 39–43, 45–51, 54–56, 58–81, 83–90, 92–99, 101, 102], 44 were high RoB [3, 14, 15, 39, 43, 45–50, 54–56, 58–68, 72, 73, 75, 76, 78–81, 87, 90, 92, 94, 97–99, 101, 102], and 20 were low RoB (Appendix 2A, see ESM) [1, 20, 23, 40–42, 51, 69–71, 74, 77, 83–86, 88, 89, 93, 95, 96]. Common sources of bias included inability to control for confounding, inadequate exposure measurement, and selective outcome reporting. Out of the two controlled intervention studies, both were high RoB [52, 53] (Appendix 2B, see ESM). Out of the seven randomized control trials [57, 82, 88, 91, 100, 103, 104], four were graded as high RoB [82, 88, 91, 104] and three were graded as low RoB [57, 100, 103]. Common sources of bias included allocation concealment, missing data reporting, and result reporting (Appendix 2C, see ESM). According to the Teirlinck et al. [35] strength of evidence, studies demonstrated weak evidence for TSK, KSES, and FABQ outcomes for all time points. The GRADE scale determined that the certainty of the pooled estimates for both TSK and KSES was very low, due to the high RoB of publications, inconsistency, and imprecision in reporting (Appendix 3, see ESM).

3.2 Tampa Scale of Kinesiophobia

TSK-17 meta-analyses demonstrated differences in scores between time points (pre-operative: 39.8 [95% CI 35.9–43.8]; 3–6 months: 34.6 [95% CI 31.0–38.2]; 7–12 months: 33.2 [95% CI 29.3–37.2]; > 1–2 years: 33.3 [95% CI 31.1–35.6]; > 2–5 years: 34.0 [95% CI 32.1–35.9]; > 5 years: 31.5 [95% CI 29.5–33.4]; $Q = 14.9$; $p = 0.011$) (Fig. 2a). Between pre-operative and 3–6 months, TSK-17 scores improved by a mean 5.3 points. Meta-regression of early and delayed ACLR and percent female demonstrated no explanation of meta-analysis variance ($R^2 = 0.0$). Meta-regression of ACL treatment group, percent female, age, and percent with concomitant knee injuries demonstrated over 50% explanation of meta-analysis variance ($R^2 = 0.83$). Funnel plots demonstrated no publication biases (Appendices 4–6, see ESM).

TSK-11 meta-analyses also demonstrated differences in scores between time points (pre-operative: 23.8 [95% CI 22.3–25.3]; 3–6 months: 19.6 [95% CI 18.6–20.7]; 7–12 months: 17.9 [95% CI 15.2–20.6]; > 2–5 years: 22.3 [95% CI 11.9–32.7]; $I^2 = 97.6\%$, $p < 0.001$; $Q = 22.8$, $p < 0.001$) (Fig. 2b). TSK-11 scores improved between pre-operative and 3–6-month follow-up by a mean of 4.1 points. Meta-regression of ACL treatment group and percent female demonstrated no explanation of meta-analysis variance ($R^2 = 0.0$). Meta-regression of ACL treatment group, percent female, age, and percent of concomitant knee injuries explained 0.73 (R^2) of meta-analysis variance. Funnel plots demonstrated no publication biases (see ESM).

3.3 Knee Self-Efficacy Scale

KSES meta-analyses demonstrated differences in pooled scores between follow-up time points (pre-operative: 5.0 [95% CI 4.4–5.5]; 3–6 months: 6.4 [95% CI 5.5–7.4]; 7–12 months: 7.5 [95% CI 6.8–8.2]; $Q = 32.0$; $p < 0.001$)

Table 2 Characteristics of included studies

Study	Year	Study design	Sample size	Sex (% F)	ACL graft type	ACL treatment	Outcome	Outcome stratified by follow-up timepoint, reported as mean (standard deviation)
Alswat et al. [39]	2020	Cross-sectional	93	1	NR	Delayed	TSK-11	5 years post-op: 27.6 (8.2)
Ardern et al. [40]	2013	Case control	187	34	Hamstring	Delayed	TSK-17	Pre-op: 36.3 (4.4) 4 weeks post-op: 36.3 (5.6)
Ardern et al. [20]	2014	Cross-sectional	162	40	NR	Early	TSK-17 KSES	3 years post-op: TSK: 35.6 (8.0) KSES: 6.9 (2.1)
Ardern et al. [42]	2015	Case series	122	35	NR	Early	TSK-17	1 year post-op: 34 (5.9)
Ardern et al. [41]	2016	Cross-sectional	170	41	NR	Early	TSK-17 KSES	1 year post-op: TSK: 35.2 (14.8) KSES: 7.3 (3.7)
Baez et al. [43]	2020	Cross-sectional	40	63	NR	Early	TSK-11 FABQ KSES	NR
Baez et al. [103]	2021	Randomized controlled trial	12	100	NR	Early	TSK-11	5 years post-op: 21.3 (4.9)
Barchek et al. [102]	2021	Cross-sectional	19	68	NR	Early	FABQ	5 years post-op: 8 (15)
Beischer et al. [44] (AJSM)	2019	Case control	528	48	NR	Delayed	KSES	8 months post-op: 8.2 (3.7) 1 year post-op: 8.9 (2.8)
Beischer et al. [45] (BMJO)	2019	Retrospective cohort	237	59	BTB Hamstring	Early	KSES	4 months post-op: 6.0 (1.6)
Burland et al. [46]	2020	Cross-sectional	21	52	BTB Hamstring	Early	TSK-17	3 years post-op: 31.7 (5.4)
Chen et al. [47]	2017	Cross-sectional	112	27		Early	TSK-17	1 year post-op: 41.3 (11.0)
Chmielewski et al. [49]	2011	Prospective cohort	77	47	Achilles BTB Hamstring Tibialis anterior Tibialis posterior	Delayed	TSK-11	Pre-op: 25.4 (5.9) 4 weeks post-op: 20.8 (6.0) 8 weeks post-op: 19.5 (5.9) 4 months post-op: 17.9 (5.9)
Chmielewski & George [48]	2019	Prospective cohort	75	40	Achilles BTB Hamstring Tibialis anterior Tibialis posterior	Early	TSK-11	1 week post-op: 25.8 (6.0) 4 weeks post-op: 24.6 (6.2) 4 months post-op: 18.9 (5.7)
Clifford et al. [50]	2017	Cross-sectional	45	36		Early	TSK-17	Pre-op: 41.2 (7.2)
Culvenor et al. [51]	2016	Retrospective cohort	110	31	Hamstring	Early	TSK-11	1 year post-op: 20.6 (4.5)
Coronado et al. [52]	2020	Prospective cohort	7	86	BTB	Early	TSK-13 KSES	Injury: TSK: 29; KSES: 2.7 6 months post-op: TSK: 23.8; KSES: 7.2
Courtot et al. [53]	2019	Prospective cohort	62	27	Quadricep	Early	TSK-17 KSES	Injury: TSK: 45.3 (7.4); KSES: 4.8 (1.8)

Table 2 (continued)

Study	Year	Study design	Sample size	Sex (% F)	ACL graft type	ACL treatment	Outcome	Outcome stratified by follow-up timepoint, reported as mean (standard deviation)
Ezzat et al. [54]	2021	Cross-sectional	115	NR	NR	Early	KSES	2 years post-op: 6.2 (2.9)
Faleide et al. [55]	2020	Cross-sectional	197	46	BTB Hamstring Quadricep	Early	TSK-11	1 year post-op: 24.3 (6.1)
Flosadottir et al. [15]	2018	Prospective cohort	89	28	BTB Hamstring	Early	KSES	10 months post-op: 7.8 (2.4)
Genoese et al. [56]	2020	Cross-sectional	20	75	NR	Early	FABQ	7 years post-op: 11.5 (16.7)
George et al. [105]	2012	Cross-sectional	289 Early: 105 Delayed: 184	38	NR	Early & delayed	TSK-11	Early: 2 months post-op: 59.5 (15.3) Late: 9 months post-injury: 83.4 (14.4)
Gholami et al. [57]	2020	Randomized controlled trial	20	10	NR	Early	TSK-17	6–12 months post-op: 43.4 (6.3)
Harput et al. [60]	2016	Randomized controlled trial	30	NR	Hamstring	Early	TSK-17	6 months post-op: 40.8 (3.6)
Harput et al. [59]	2017	Cross-sectional	93	5	BTB Hamstring	Early	TSK-17	1 year post-op: 37.7 (5.9)
Hartigan et al. [61]	2013	Prospective cohort	111	31	Hamstring	Delayed	TSK-11	Prior to surgery: 24.2 (5.0) Following surgery: 22.1 (5.1) 6 months post-op: 16.5 (4.1) 1 year post-op: 15.1 (3.7)
Hirohata et al. [62]	2020	Cross-sectional	93	55	NR	Early	TSK-17	3 months post-op: 36.0 (6.7)
Hoch et al. [64]	2018	Case control	20	75	NR	Early	TSK-11 FABQ	4 years post-op: TSK: 17.0 (4.2) FABQ: 10.5 (5.8)
Hoch et al. [63]	2020	Cross-sectional	30	70	NR	Early	FABQ	Return to sport: 10.5 (10.4)
Joreitz et al. [65]	2020	Case series	43		Achilles BTB Hamstring Quadricep Tibialis anterior	Early	TSK-11	Post-op: TSK: 21.1 (5.6); KSES: 21.7 (10.3) 6 months post-op: TSK: 18.1 (4.6); KSES: 61.4 (17.9) 8 months post-op: TSK: 17.0 (4.2); KSES: 73.7 (13.2) 9 months post-op: TSK: 15.5 (4.9); KSES: 87.0 (6.7) 1 year post-op: TSK: 15.5 (3.1); KSES: 92.6 (3.1)
Kuenze et al. [66]	2021	Cross-sectional	90	50	BTB Hamstring	Early	TSK-11	6 months post-op: 19.8 (4.8)

Table 2 (continued)

Study	Year	Study design	Sample size	Sex (% F)	ACL graft type	ACL treatment	Outcome	Outcome stratified by follow-up timepoint, reported as mean (standard deviation)
Kvist et al. [67]	2005	Cross-sectional	47	55	NR	Early	TSK-17	3–4 years post-op: 34 (4.6)
Kvist et al. [68]	2013	Cross-sectional	182	42	NR	Delayed	TSK-17	NR
Lentz et al. [69]	2009	Cross-sectional	58	34	Achilles BTB Hamstring Tibialis anterior	Early	TSK-11	9 months post-op: 18.0 (5.0)
Lentz et al. [70]	2012	Cross-sectional	94	36	Achilles BTB Hamstring Tibialis anterior	Early	TSK-11	1 year post-op: 10.3 (15.9)
Lentz et al. [1]	2015	Cross-sectional	73	38	Achilles BTB Gracillis Hamstring Tibialis anterior Tibialis posterior	Early	TSK-11	6 months post-op: 18.1 (9.2) 1 year post-op: 16.5 (10.1)
Levinger et al. [104]	2017	Randomized controlled trial	17	47	NR	Early	TSK-17 FABQ KSES	Injury: TSK: 42.9 (2.0) FABQ: 18.5 (6.9) KSES: 6.1 (2.2) 3 months post-op: TSK: 39.7 (4.9) FABQ: 16.1 (8.2) KSES: 6.2 (1.9)
Lisee et al. [71]	2020	Cross-sectional	25	52	BTB Hamstring	Early	TSK-11	4–12 months post-op: 19.8 (4.0)
Luc-Harkey et al. [72]	2018	Cross-sectional	30	70	BTB Hamstring	Early	TSK-11	6 months post-op: 21.9 (3.3)
Meierbachtol et al. [73]	2020	Prospective cohort	33	55	BTB Hamstring	Early	TSK-11	6 months post-op: 20.7 (4.6)
Müller et al. [74]	2015	Prospective cohort	39	46	Hamstring	Early	TSK-11	6 months post-op: 19.5 (4.8)
Norte et al. [75]	2018	Cross-sectional	64 Early: 34 Delayed: 30	57	BTB Hamstring	Early & delayed	TSK (not specified version)	2 years post-op: Early: 34.4 (5.7) Late: 32.1 (6.5)
Norte et al. [76]	2019	Cross-sectional	77	45	BTB Hamstring	Early	TSK-17	6 months post-op: 32.9 (6.0)
Ohji et al. [77]	2021	Cross-sectional	39	44	BTB Hamstring	Early	TSK-17	8–24 months post-op: 36.5 (4.7)
Paterno et al. [79]	2018	Prospective cohort	40	NR	NR	Early	TSK-11	High TSK (≥ 17) = 19 participants Low TSK (< 17) = 21 participants
Piussi et al. [14]	2020	Prospective cohort	328	63	BTB Hamstring	Delayed	KSES	10 weeks post-op: 4.0 4 months post-op: 5.9 8 months post-op: 7.8 1 year post-op: 8.5

Table 2 (continued)

Study	Year	Study design	Sample size	Sex (% F)	ACL graft type	ACL treatment	Outcome	Outcome stratified by follow-up timepoint, reported as mean (standard deviation)
Piussi et al. [80]	2020	Prospective cohort	117	33	BTB Hamstring	Early	KSES	NR
Pua et al. [81]	2021	Prospective cohort	595	24	BTB Hamstring	Delayed	KSES	2 months post-op: 18 (12) 3 months post-op: 34 (12) 6 months post-op: 43 (12)
Rhim et al. [82]	2020	Randomized control trial	32	16	Hamstring	Early	TSK-11 KSES	Injury: TSK: 25.1 (5.2); KSES: 3.5 (2.5) Hospitalization: TSK: 25.8 (5.0); KSES: 3.0 (2.0) 2 weeks post-op: TSK: 25.3 (5.3); KSES: 2.9 (1.7) 6 weeks post-op: TSK: 23.9 (5.3); KSES: 3.6 (1.9) 3 months post-op: TSK: 24.0 (4.9); KSES: 4.9 (1.9) 6 months post-op: TSK: 22.8 (5.4); KSES: 6.4 (2.1)
Roe et al. [83]	2021	Cross-sectional	66	53	BTB Hamstring	Early	TSK-11	6 months post-op: 21.0 (6.0)
Ross [84]	2010	Cross-sectional	48	29	BTB	Early	FABQ	1 year post-op: 12.9 (5.3)
Sala-Barat et al. [85]	2020	Cross-sectional	114	17	BTB	Early	TSK-11	9 months post-op: 22.5 (5.3)
Senorski et al. [58]	2017	Prospective cohort	157	49	NR	Early	KSES	10 months post-op: 6.4 (1.2)
Silva et al. [78]	2018	Cross-sectional	40	NR	BTB Hamstring	Delayed	TSK-11	NR
Slagers et al. [86]	2017	Cross-sectional	150	44	BTB Hamstring	Early	TSK-17	9 months post-op: 36.6 (16.0)
Tajdini et al. [87]	2021	Cross-sectional	28	0	Hamstring	Early	TSK-11	6 months post-op: 22.7 (4.6)
Tengman et al. [88]	2014	Prospective cohort	Total: 70 ACLR: 33 PT: 37	37	NR	Delayed & rehab alone	TSK-17	23 years post-op: ACLR: 33.0 (7) PT: 32.0 (7)
Theunissen et al. [89]	2020	Retrospective cohort	102	43	NR	Early	TSK-17	Injury: 38.3 (7.9) 3 months post-op: 36.5 (6.8) 12 months post-op: 35.6 (7.9)
Thomeé et al. [3]	2006	Cross-sectional	104	39	NR	Early	KSES	12 months post-op: 6.4 (2.3)
Thomeé et al. [92]	2007	Cross-sectional	38	34	BTB Hamstring	Early	KSES	Injury: 5.6 (2.3)

Table 2 (continued)

Study	Year	Study design	Sample size	Sex (% F)	ACL graft type	ACL treatment	Outcome	Outcome stratified by follow-up timepoint, reported as mean (standard deviation)
Thomeé et al. [16]	2007	Case control	63	44	NR	Early	KSES	1 month post-op: early: 5.0 (1.9); PT: 3.2 (1.6) 4 month post-op: early: 5.3 (2.6); PT: 6.2 (2.2) 6 month post-op: early: 7.0 (1.9); PT: 7.0 (2.1) 1 year post-op: early: 7.8 (1.6); PT: 7.9 (1.7)
Thomeé et al. [90]	2008	Cross-sectional	38	34	BTB Hamstring	Early	KSES	Injury: 5.6 (2.3)
Thomeé et al. [91]	2010	Randomized control trial	24	49	NR	Early	KSES	2 weeks post-injury: 3.0 (2.6) 1 year post-injury: 7.3 (2.5)
Tichonova et al. [23]	2016	Cross-sectional	22	23	NR	Early	TSK-11	Injury: 22.5 (0.9) 3 months post-op: 18.2 (0.7)
Tortoli et al. [93]	2020	Cross-sectional	129	27	BTB Hamstring	Early	TSK-17	9 months post-op: 23.2 (6.9)
Trigsted et al. [94]	2018	Cross-sectional	36	100	NR	Early	TSK-11	2 years post-op: 20.0 (4.5)
Tripp et al. [95]	2007	Cross-sectional	49	45	BTB	Early	TSK-17	1 year post-op: 27.4 (4.4)
Ueda et al. [101]	2021	Cross-sectional	97	NR	Hamstring	Early	TSK-11	1 year post-op: 17.2 (4.4)
Usen and Tolu [96]	2021	Cross-sectional	47	0	Hamstring	Early	TSK-17	1 year post-op: 28.0 (8.5)
Van Lankveld et al. [97]	2019	Cross-sectional	258	37	Hamstring	Delayed	KSES	Injury: 4.6 (2.3) 1 year post-op: 7.9 (2.0)
Van Melick et al. [98]	2021	Cross-sectional	144	31	Hamstring	Early	KSES	Injury: 5.3 (2.0)
Van Wyngaarden et al. [99]	2021	Cross-sectional	40	73	BTB Hamstring	Early	TSK-17	11 years post-op: 29.8 (5.6)
Zaffagnini et al. [100]	2013	Randomized control trial	106	20	Hamstring	Early	TSK-17	Injury: 33.9 (4.8) 3 months post-op: 30.1 (6.2)

Early ACL treatment was defined as performing surgery < 6 months following injury

Delayed ACL treatment was defined as performing surgery ≥ 6 months following injury

For studies with multiple groups reported, the Cochrane method was used to combine outcome measure scores

ACLR anterior cruciate ligament reconstruction, *BTB* bone patella bone, *FABQ* Fear-Avoidance Belief Questionnaire, *KSES* Knee Self-Efficacy Scale, *NR* data not reported, *PT* physical therapy only, *Post-Op* post-operative, *TSK* Tampa Scale for Kinesiophobia

(Fig. 3). KSES scores improved between pre-operative and 3–6-month follow-up by a mean of 1.5 points and between pre-operative and 7–12 months by 2.5 points. No studies included in the meta-analysis reported KSES scores > 12 months after ACLR. Meta-regression of ACL treatment group and percent female demonstrated no explanation of meta-analysis variance ($R^2 = 0.0$).

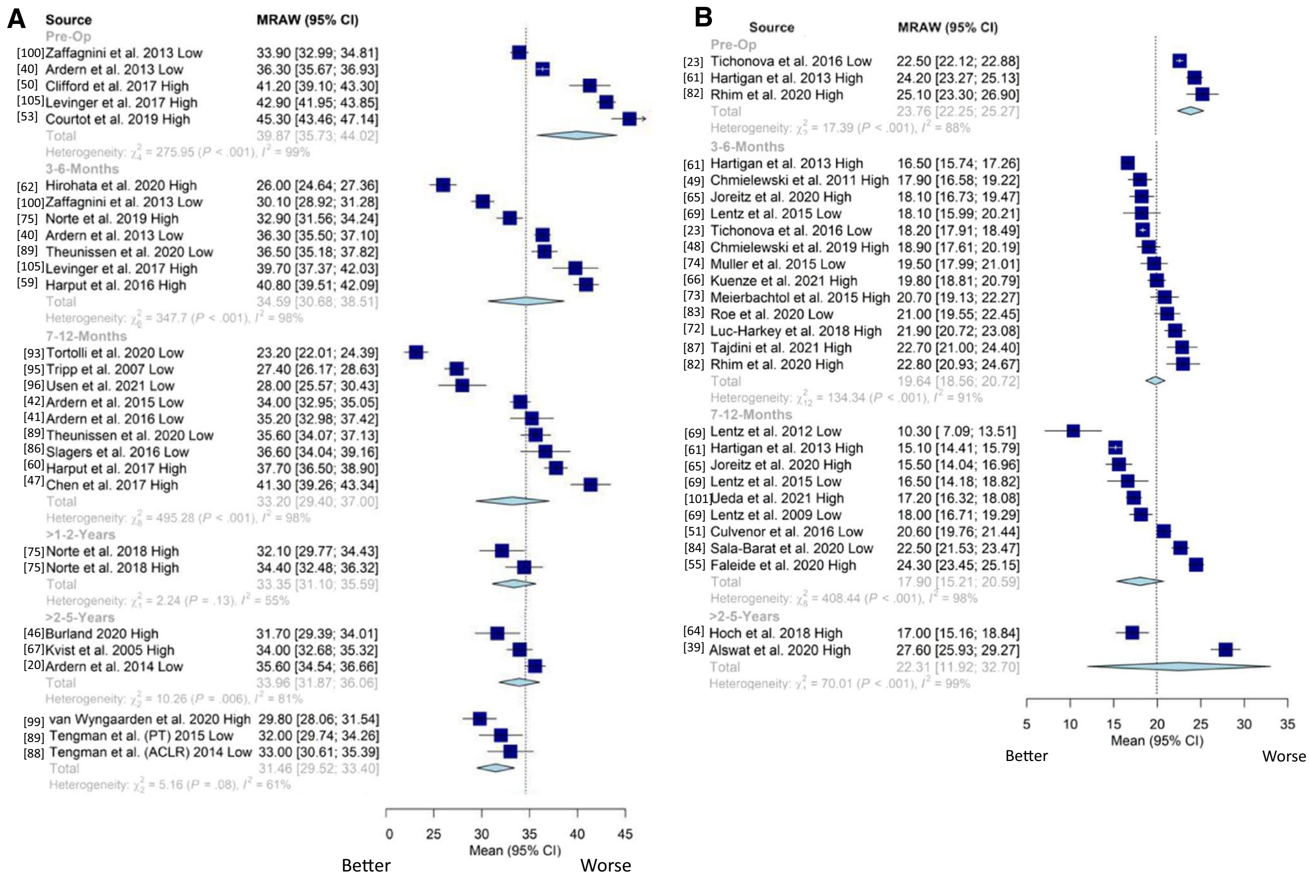


Fig. 2 Tampa Scale of Kinesiophobia forest plots stratified by time. **a** Tampa Scale of Kinesiophobia-17. **b** Tampa Scale of Kinesiophobia-11. *High* high risk of bias, *Low* low risk of bias, *MRAW* raw mean

3.4 Fear-Avoidance Belief Questionnaire

One study reported FABQ scores at injury (mean: 18.5 [SD 6.9]) and 3 months (mean: 16.1 [SD 8.2]) [104]. One study reported FABQ scores at 1 year post-injury (mean: 12.9 [SD 5.3]) [84]. At > 5 years following ACL injury, three studies reported FABQ scores ranging from median of 8.0 to 11.0 [56, 64, 102].

3.5 Early ACL Reconstruction (ACLR), Delayed ACLR, and Rehabilitation Alone

Only two TSK-11 studies could be summarized at any time points concerning delayed ACL treatment, which were for the 3–6-month time point [49, 61]. Participants in both studies performed exercise therapy for at least 10 sessions prior to delayed ACLR [49, 61]. The early ACL treatment group reported a median TSK-11 of 19.8 (4.9) and the delayed ACLR group a median of 17.2 (5.0) for the 3–6-month time point [49, 61]. Only one study reported outcomes (TSK-17) following treatment with rehabilitation only, and this was > 5 years following injury with a mean of 32 (SD 7) [88].

3.6 Sensitivity Analyses

Including only low RoB studies for the pooled TSK-17 and TSK-11 meta-analyses observed no differences in scores between follow-up time points. Excluding the outlier from the KSES meta-analyses demonstrated a reduced pooled score at 6 months post-injury (pre-operative: 5.0 [95% CI 4.4–5.5]; 3–6 months: 6.0 [95% CI 5.1–6.8]; 6–12 months: 7.5 [95% CI 6.8–8.2]; $I^2 = 97.4\%$, $p < 0.001$) compared with the primary meta-analysis. For further detail, please refer to Appendix 7 in the ESM.

4 Discussion

There was a distinct improvement in kinesiophobia and knee self-efficacy from pre-operative to 3–6 months following ACLR. The limited studies available suggest that FABQ may also improve from pre-operative to 3–6 months

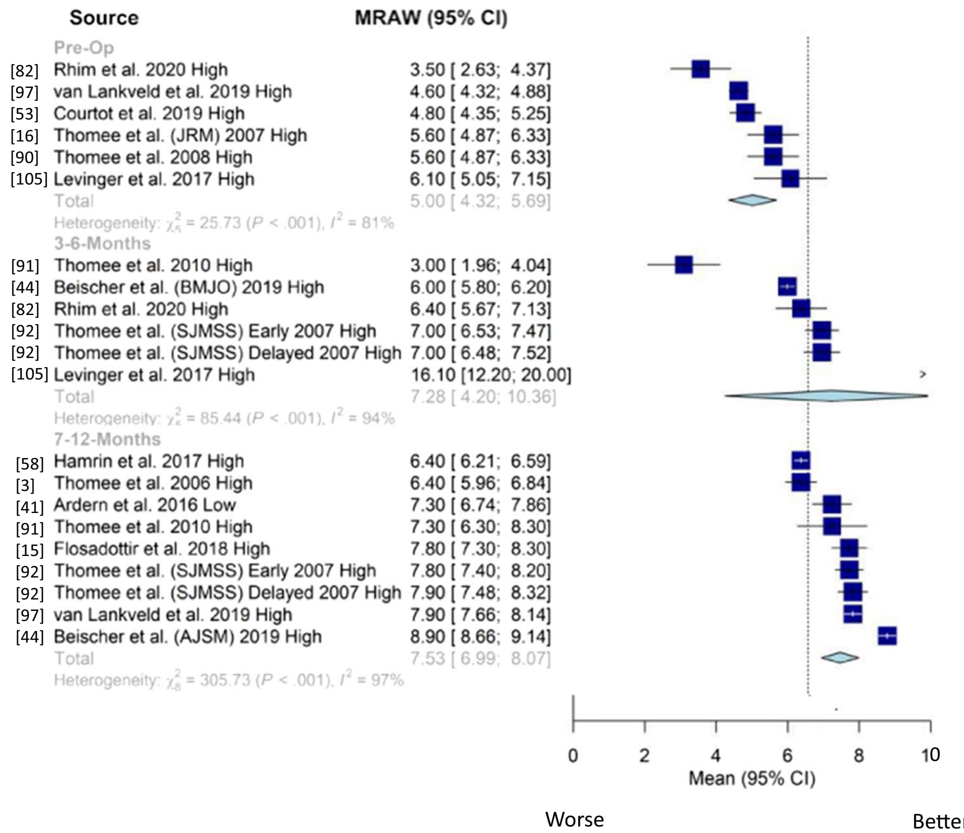


Fig. 3 Knee self-efficacy forest plot stratified by time. *High* high risk of bias, *Low* low risk of bias, *MRAW* raw mean

following ACLR. This improvement may be expected as patients progress from the acute postoperative phase to more advanced stages of rehabilitation. Similar scores were reported at 3–6 months and 7–12 months following ACLR for all outcomes. There is a need for further research on psychological outcomes following early ACLR, delayed ACLR, and rehabilitation only.

Both the TSK-17 and TSK-11 demonstrated a clinically significant (> 4-point change in TSK scores) [106] improvement in knee kinesiophobia from pre-operative to 3–6 months following ACLR. Similar kinesiophobia scores were observed between 3–6 months, 7–12 months, > 1–2 years, and > 2–5 years after ACLR. While only a single time interval could be compared between early and delayed ACLR patients, these groups demonstrated similar TSK scores at 6 months. Only two studies [1, 61] longitudinally followed ACL patients from injury to 1 year, which demonstrated similar scores between 3–6 months and 7–12 months. The plateau in kinesiophobia scores after a period of 3–6 months following injury is comparable to outcomes for shoulder dislocation [107] or Achilles tendon rupture [108]. These findings suggest that, on average, knee kinesiophobia is low and stabilized 6 months following ACLR, and remains similar over time. Another possible explanation is that once patients progress from the acute recovery phase, further improvements in kinesiophobia may require specific interventions. As rehabilitation does not traditionally target these psychological constructs, addressing psychological aspects of recovery may provide an opportunity to improve patient outcomes. Potential interventions to improve kinesiophobia include pre-operative education [109], knee bracing [110], or cognitive behavioral therapy [111]. The TSK meta-regression found that 73–83% of variance was explained by older age, increased kinesiophobia at ACL injury, and presence of concomitant injuries. These findings are similar to patients with knee osteoarthritis and patella dislocation [2, 112]. As there was high heterogeneity in the meta-analyses, this could be explained by different patient samples, including patients that were older at ACL injury and studies including a high prevalence of concomitant knee injuries. Increased age and concomitant knee injuries have previously been associated with increased kinesiophobia in ACL patient populations [113]. Increased kinesiophobia has been associated with worse knee quality of life and return to sport [113]. Older ACL-injured patients who have concomitant knee injuries may require targeted interventions to reduce kinesiophobia in the first 6 months following injury.

Twenty-one studies were included that evaluated knee self-efficacy with the KSES pre-operatively, at 3–6 months or 7–12 months after ACLR. All but one of the included studies were graded as high RoB. There was a 1.4-point decrease from pre-operative to 3–6 months and a 1.1-point decrease from 3–6 months to 7–12 months. These changes cannot be currently interpreted for clinical meaningfulness, but are statistically beyond the standard error of measurement [3, 16]. Self-efficacy refers to the patient's beliefs in performing specific movements, tasks, or actions [10]. As ACLR patients who return to sport are likely do so around 1 year following surgery, these findings may reflect increases in the patients' belief in their ability to perform sporting activities. Worse knee self-efficacy has been related to worse patient-reported outcomes and return to sport [14, 80]. On average, knee self-efficacy will improve after 3 months, so patients should be monitored for prolonged low levels of knee self-efficacy that exceed 3 months post-ACLR. Patients reporting low self-efficacy may require further rehabilitation time or specific psychological interventions prior to focusing on returning to sport [91].

Only five studies reported FABQ scores following ACL injury. There was a 6-point decrease in FABQ from pre-operative to 1 year following ACLR. A further 1-point decrease in FABQ was reported 5 years following ACLR. Currently, there is not an established minimal clinically important difference (MCID) for the FABQ outcome measure in knee-injured patients. However, a 6-point reduction may be clinically meaningful while a 1-point decrease is unlikely to be clinically relevant. While not validated in knee injury populations, FABQ scores > 14 in low back pain patients is associated with high levels of fear avoidance behavior [114]. Studies in our review did not report FABQ scores < 14 until after 6 months following injury, suggesting that fear avoidance may remain high in the first 6 months post-surgery.

The results from this systematic review necessitate future research. Over two-thirds of included studies were graded as high RoB, with overall weak evidence for all outcomes. Specific methodological domains with a high RoB prevalence included a lack of control of confounders for control intervention, a majority being observational studies, and poor reporting of missing data in all study designs. Given the recent identified importance of psychological recovery for ACL-injured athletes [40, 115], high-quality studies are needed to assess kinesiophobia, knee self-efficacy, and fear avoidance beliefs over time. The KSES and FABQ require studies to establish MCIDs within knee injury populations, to improve clinical outcome interpretation. The data did not allow comparisons between early and delayed ACL treatment and only one study assessed outcomes following treatment with rehabilitation alone. Further comparisons are needed between different ACL injury treatments and their effect on psychological recovery. Understanding the impact of psychological interventions is also needed for older patients with concomitant knee injuries prior to 6 months following ACL injury. Future research should focus on understanding the impacts of improving kinesiophobia, self-efficacy, and fear avoidance on other outcomes, such as health-related quality of life, anxiety and depression, sport and activity participation, and re-injury rates.

The results of this systematic review and meta-analysis have clinical implications. Patients should be monitored for kinesiophobia, knee self-efficacy, or fear avoidance following ACL injury and throughout the rehabilitation process. If kinesiophobia, knee self-efficacy, or fear avoidance does not improve and stabilize after 6 months following ACL injury and surgery, further examination and patient discussion is required to understand the causes underlying these patient-reported findings. While kinesiophobia, knee self-efficacy, and fear avoidance report different psychological constructs [9–11], only the TSK has established MCID [106] and therefore at this time it is recommended that the TSK should be administered.

We acknowledge a number of study limitations. The inclusion of only peer-reviewed published work excludes potential grey literature findings, which decreases the scope of these findings. Only studies written in English were included in this systematic review, decreasing the breadth of the included literature. The initial protocol involved performing an individual participant meta-analysis. Due to the paucity of individual participant data obtained, in accordance with the a priori protocol, only aggregated meta-analyses were performed. The initial protocol included further psychological knee outcomes. However, as a substantial number of studies were eligible, a separate systematic review was initiated. Knee injuries that involved three or more ligament ruptures were excluded from the review, which decreases the generalizability of these findings to all ACL injuries. Most included studies were cross-sectional; thus, ACLR longitudinal change and outcome responsiveness cannot be inferred from these results. Differences in outcomes by time points are not connected by longitudinal patient data, decreasing the clinical utility of these data. A large proportion of studies were graded as high RoB, decreasing the viability of these findings. Additionally, kinesiophobia was assessed with three different versions of the TSK, which decreased the precision in comparing time intervals, specifically concerning the meta-regressions and between early and delayed surgical groups. The TSK has not undergone English validation in ACL populations and these results should be interpreted with caution. The FABQ and KSES do not report MCID, which decreases the clinical interpretability of these findings. While all studies were included in the meta-analyses, sensitivity analyses were performed excluding high RoB studies, demonstrating similar results. The meta-analyses reported high heterogeneity, decreasing the weight of these inferences.

5 Conclusion

Knee self-efficacy and kinesiophobia improved from pre-ACLR to 3–6 months following ACLR, with the included limited studies suggesting that fear avoidance also improves during this time period. Knee self-efficacy and kinesiophobia remained relatively stable over the preceding year. Older age at injury and concomitant injuries, such as meniscus and medial collateral ligament injuries, may increase knee kinesiophobia and may benefit from targeted interventions prior to 6 months following injury. The high RoB, heterogeneity, and cross-sectional nature of these studies reduce the clinical weight of these findings. Sports medicine clinicians should consider monitor knee self-efficacy, kinesiophobia, and fear avoidance following ACLR. Patients that report poor knee self-efficacy, kinesiophobia, and fear avoidance following the acute stage of rehabilitation may benefit from targeted interventions to improve these psychological constructs. Since the overall evidence was weak, there is a need for high-quality observational and intervention studies focusing on psychological outcomes following ACL injury.

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Declarations

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Conflicts of interests and competing interests Garrett Scott Bullock, Tim Sell, Ryan Zerega, Charles Reiter, Victoria King, Hailey Wrona, Nilani Mills, Charlotte Ganderton, Steven Duhig, Anu Räisäsen, Leila Ledbetter, Gary S. Collins, Joanna Kvist and Stephanie R. Filbay declare that they have no conflicts of interest relevant to the content of this review.

Availability of data and material None.

Code availability Not applicable.

Authors' contributions GSB, TCS, JK, SRF conceived the study idea. GSB, TCS, GSC, LL, JK, SRF were involved in design and planning. GB, RZ, CR, VK, SD, HW, NM, CG, AR screened articles and assessed risk of bias. GB, RZ, CR, VK, HW, SD, NM, CG, AR performed data extraction. GSB, SRF wrote the first draft of the manuscript. GSB, TCS, RZ, CR, VK, HW, NM, CG, SD, AR, LL, GSC, JK, SRF critically revised the manuscript. GSB, TCS, RZ, CR, VK, HW, NM, CG, SD, AR, LL, GSC, JK, SRF approved the final version of the manuscript. All authors read and approved the final manuscript.

Ethics approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable.

Patient public involvement Five authors are researchers and clinicians who treat anterior cruciate ligament (ACL) injury patients, and four authors are researchers who have sustained ACL injuries and have undergone ACL rehabilitation and surgery. A series of symposiums are planned at various sports medicine conferences to help further educate clinicians on this topic.

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