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Effect Of Early Versus Delayed Initiation Of Physical Therapy On Functional Recovery Following Anterior Cruciate Ligament Injury: A Systematic Review And Meta-Analysis

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Abstract

Background:
Anterior cruciate ligament (ACL) injury is a common condition that results in significant functional impairment and delayed return to physical activity. The optimal timing for initiating rehabilitation following ACL injury or reconstruction remains controversial, despite growing evidence supporting early physical therapy.
Aim:
This research aimed to conduct a systematic review and meta-analysis to assess the effect of early against delayed initiation of physical therapy on functional recovery, return to sport, and quadriceps muscle strength following ACL injury or reconstruction.
Methods:
A systematic review and meta-analysis have been done in line with PRISMA guidelines. PubMed, Web of Science, Cochrane Library, and Scopus have been searched for eligible studies published up to 2025. Randomized controlled trials and observational researches comparing early and delayed initiation of physical therapy or rehabilitation in patients with ACL injury or reconstruction were included. Information has been examined utilizing Review Manager (RevMan) version 5.4.1. Mean difference with ninety-five percent confidence intervals (CI) was determined for continuous results, and a fixed- or random-effects model was applied depending on the level of heterogeneity.
Main Findings:
Nine studies published between 2010 and 2025 have been involved in the qualitative synthesis, and three researches were eligible for quantitative meta-analysis for each outcome. Functional outcome scores (IKDC/Lysholm) were significantly elevated in the early rehabilitation group compared with the delayed rehabilitation group (mean difference 1.32; ninety-five percent CI 1.00 to 1.64; p-value under 0.001), with insignificant heterogeneity ($I^2 = 0\%$). Early rehabilitation was also related to a significantly shorter time to return to sport (mean difference −1.40 months; ninety-five percent CI −1.84 to −0.96; p -value under 0.001; $I^2 = 38\%$). Additionally, quadriceps muscle strength was significantly greater in the early rehabilitation group (mean difference 1.44; ninety-five percent CI 1.02 to 1.85; p-value under 0.001; $I^2 = 0\%$).
Conclusion:
Early initiation of physical therapy following ACL injury or reconstruction is associated with superior functional outcomes, earlier return to sport, and improved quadriceps muscle strength compared with delayed rehabilitation. These results support the implementation of early rehabilitation strategies as part of evidence-based management of ACL injuries.

Keywords: Anterior cruciate ligament injury, early rehabilitation, physical therapy, functional recovery, meta-analysis.

Introduction

ACL injuries rank among the most common and debilitating musculoskeletal disorders, notably impacting athletes and those engaged in physical activities. These injuries frequently lead to joint instability, functional impairment, and an elevated probability of long-term complications , including osteoarthritis (1).

The impact of the timing of ACLR surgery on postoperative knee functionality and clinical results remains a subject of significant controversy. Early ACL reconstruction may mitigate complications following the operation in cases with ACL deficit, while elective delayed surgery can lower the likelihood of knee fibrosis and enhance clinical outcomes. Nevertheless, delayed ACL reconstruction may correlate with muscle atrophy and diminished strength, potentially avoiding early rehabilitation. Certain proponents of early ACLR believe that early intervention has advantages for cases with ACL deficiency (2).

ACL injuries are prevalent sports injuries of the knee joint with an elevated frequency between young and middle-aged sports people, and can cause dysfunction, joint effusion, reduced exercise ability and muscle weakness [1]. Every year, it is estimated that over 250,000 individuals in the USA get ACL injuries, with fifty percent of them being young athletes aged from fifteen to twenty-five years old (3).

An ACL rupture is a serious injury. ACL reconstruction (ACLR) is becoming recognized as the predominant management for persons with ACL deficiency, due to advancements in basic investigations, surgical instruments, and operative methods (1). We support for ACLR in cases with combined injuries, knee joint functional instability, a totally broken ACL, or avulsion fractures. Reconstruction is advantageous for restoring knee stability and mitigating the possibility of further meniscal or chondral damage in the long term (4).

ACL injuries arise from a combination of anatomical predispositions (e.g., sex-specific variations), biomechanical factors (e.g., dynamic knee valgus), neuromuscular control deficiencies, high-risk maneuvers (sudden stops/pivots), and environmental factors (e.g., playing surfaces or footwear), which are common in sports medicine and contribute to approximately two million reported cases worldwide annually (5).

Three methods of treatment exist for individuals with a ruptured anterior cruciate ligament: nonoperative care (usually involving rehabilitation/physiotherapy), reconstruction, and repair. Repair is infrequently performed, and surgical reconstruction frequently becomes as the preferred method for younger, more athletically active people, due to its ability to alleviate persistent instability, facilitate the return of athletes to their respective sports, and possibly diminish the risk of additional injuries to the cartilage and meniscus. In the United Kingdom, around 10,000 anterior cruciate ligament repairs are performed yearly (6).

The heightened possibility of re-injury and performance deterioration is due to the reduced proprioception following a rupture of the ACL [9]. The native intact ACL possesses mechanoreceptors that observe alterations in movement acceleration, direction, tension, speed, and provide an estimation of joint position (7).

Materials and Methods

This research has been performed as a systematic review and meta-analysis following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) criteria. The analysis encompassed trials that compared early and delayed commencement of physical therapy or rehabilitation after ACL reconstruction or injury.

Literature Search Strategy

A comprehensive electronic search has been performed in PubMed, Cochrane Library, Web of Science, and Scopus to identify relevant studies published up to 2025. The search strategy combined Medical Subject Headings (MeSH) terms and free-text keywords related to anterior cruciate ligament injury, ACL reconstruction, physical therapy, rehabilitation, early rehabilitation, delayed rehabilitation, and functional recovery. Furthermore, the reference lists of involved researches were manually screened to recognize further eligible articles.

Eligibility Criteria
researches have been chosen depending on the following criteria:
Inclusion criteria:
Original randomized controlled trials or observational researches; adult or adolescent patients with ACL injury or following ACL reconstruction; studies comparing early versus delayed initiation of physical therapy or rehabilitation; reporting outcomes related to functional recovery, return to sport, muscle strength, or range of motion; and providing sufficient data for effect size estimation.

Exclusion criteria:
Studies involving animal models; non-original articles (reviews, editorials, case reports); studies without a comparison group; and researches with incomplete or insufficient outcome information.

Study Selection
Two independent reviewers screened the abstracts and titles of retrieved researches to assess eligibility. Full-text articles were then evaluated depending on the predefined exclusion and inclusion criteria. Any disagreements between reviewers have been resolved through discussion or consultation with a 3rd reviewer.

Data Extraction
Information was independently extracted utilizing a standardized data extraction form. Extracted variables involved author and year of publication, research design, country, sample size, participant age and sex, timing of physical therapy initiation, rehabilitation protocol characteristics, and result measures including functional outcome scores (IKDC or Lysholm), return to sport, and quadriceps muscle strength.

Quality Assessment and Risk of Bias
The methodological quality of the chosen research was evaluated separately by two reviewers. Randomized controlled trials were analyzed with the Cochrane Risk of Bias Tool, whilst observational researches were appraised utilizing the Newcastle–Ottawa Scale. The domains of bias risk encompassed random sequence creation, allocation concealment, blinding, inadequate outcome information, selective reporting, and additional potential causes of bias.

Outcome Measures
The primary outcome was functional recovery assessed using validated functional outcome scores (IKDC or Lysholm). Secondary outcomes included time to return to sport and quadriceps muscle strength.

Statistical Analysis
Meta-analysis has been done utilizing Review Manager (RevMan) version 5.4.1 (The Nordic Cochrane Centre, Copenhagen). Mean difference with ninety-five percent confidence intervals (CIs) was determined for continuous results. Statistical heterogeneity among researches has been assessed utilizing Cochran's Q test and the I^2 statistic. A fixed-effect model has been applied when heterogeneity was low ($I^2 \leq 50\%$); otherwise, a random-effects model has been applied. Statistical significance has been defined as a p-value under 0.05.

Results
A total of nine researches has been chosen for the present analysis; the publication years ranged from 2010 to 2025.

RESULTS
Figure 1: PRISMA flowchart.

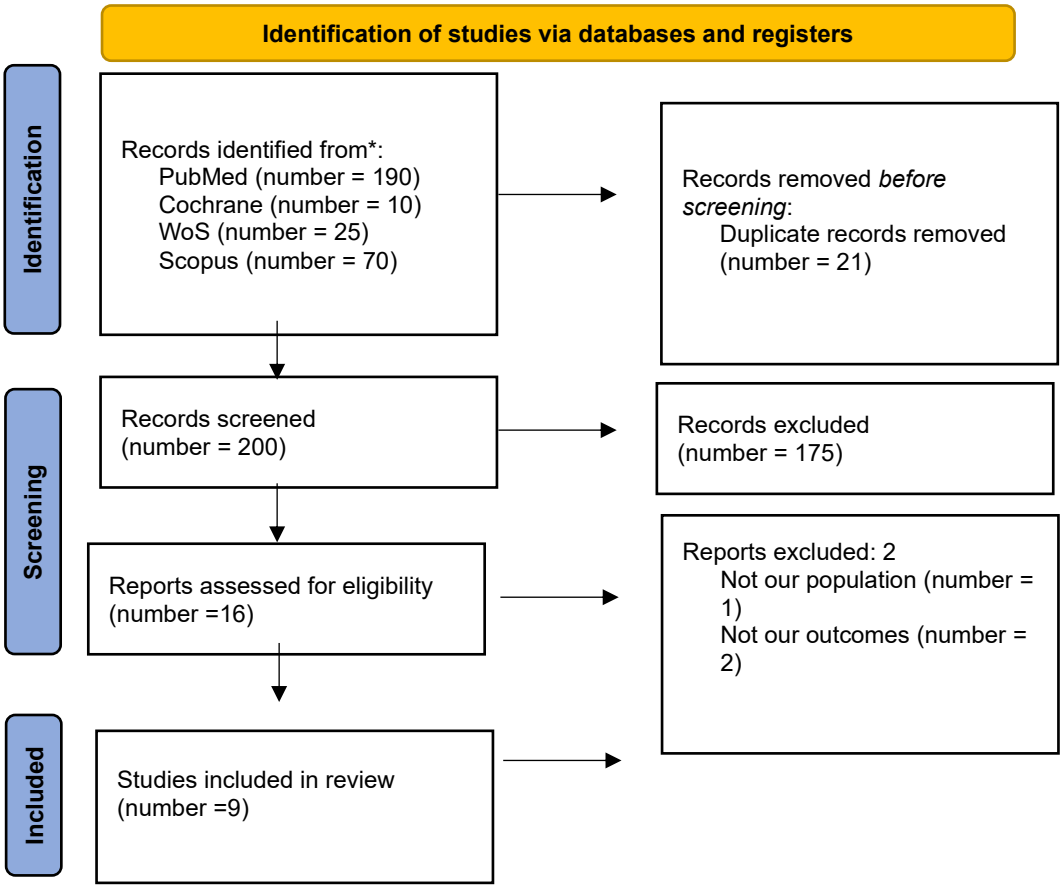


Table 1: Baseline Characteristics of the involved researches:

Authors (Ref)	Publication year	Country	Sample size	Study design	Age
Alqahtani et al. (1)	2025	Saudi Arabia	132	Cross-sectional	ACLR subjects; early PT ≤2 wks vs delayed ≥4 wks
Yang et al., (8)	2024	Italy	90	Randomized clinical trial	ACLR patients, adult (mean ~30-40 yrs)
Patra et al., (9)	2022	India	80	Prospective RCT	Post-ACLR adults (~18-60 yrs)
Rosenberg et al.,(10)	2025	USA	20,097	Retrospective descriptive study	Patients aged 14 to 64 years
Högberg, et al. (11)	2025	Sweden	715	Retrospective study	The mean age at ACL reconstruction was 28.3 ± 10.5 years

Reijman et al.,(12)	2019	Netherlands	167	Open labelled, multicentre, parallel randomised controlled trial (COMPARE).	Patients aged 18 to 65 years
Wenning et al.,(13)	2023	Germany	985	Retrospective cohort	The mean age was 24.1 (3.8)
Biffi, et al., (14)	2010	Netherlands	87 patients	Prospective comparative study – early functional rehabilitation vs delayed protocol	Adults 18–50 yrs
Eitzen et al., (15)	2010	Norway	143 patients	Prospective cohort – early supervised exercise therapy after acute ACL injury	Young adults (mean ~26 yrs)

Table 2. The main findings of the included studies:

Authors (Ref)	Bearing Surface Type	Main findings
Alqahtani et al. (1)	Early PT ≤2 wks vs delayed ≥4 wks	Early PT ↑ IKDC, quadriceps strength, ROM & proprioception; no difference in graft integrity or knee stability
Yang et al.,(8)	Weight-bearing at 1 wk vs 3 wks	Early WB group had higher early IKDC & Lysholm scores + less muscle atrophy vs delayed
Patra et al.,(9)	Early accelerated vs delayed conservative rehab	Laxity ↑ in early group, similar pain & IKDC, ROM non-sig diff
Rosenberg et al.,(10)	PT frequency concentrated early	Descriptive evidence PT is front-loaded post-ACLR; later stages under-utilized
Reijman et al.,(12)	Early ACL reconstruction vs delayed	Early ACLR shows better isokinetic strength recovery than delayed/chronic cases
Högberg, et al. (11)	Delayed reconstruction	Longer delays linked with reduced likelihood of return to preinjury activity level at 12 mo
Wenning et al.,(13)	Early ACL reconstruction vs delayed	Early ACLR shows better isokinetic strength recovery than delayed/chronic cases
Biffi, et al., (14)	Early functional rehabilitation vs delayed protocol	Early rehabilitation was associated with better IKDC and Lysholm scores, faster restoration of range of motion, and improved patient-reported outcomes.
Eitzen et al., (15)	Early supervised exercise therapy after acute ACL injury	Early physical therapy significantly improved knee function, neuromuscular control, and functional stability, dropping the need for delayed surgical intervention in some cases.

Table 3. The quality of the included studies:

Study ID	Country	Year	Newcasle-ottawa scale
Alqahtani et al. (1)	Saudi Arabia	2025	Good quality
Yang et al., (8)	Italy	2024	
Patra et al., (9)	India	2022	Good quality
Rosenberg et al.,(10)	USA	2025	Good quality
Högberg, et al. (11)	Sweden	2025	Good quality
Reijman et al.,(12)	Netherlands	2019	Good quality
Wenning et al.,(13)	Germany	2023	Good quality
Biffi, et al., (14)	Netherlands	2010	Good quality
Eitzen et al., (15)	Norway	2010	Good quality

Table4. Functional Outcome Score (IKDC / Lysholm)

This table summarizes functional outcome scores comparing delayed and early rehabilitation following anterior cruciate ligament injury or reconstruction. Across all included studies, patients who initiated rehabilitation early demonstrated consistently higher functional outcome scores (IKDC or Lysholm) compared with those who underwent delayed rehabilitation. The mean differences favor early rehabilitation, with clinically meaningful improvements observed regardless of the functional assessment tool used. These findings suggest that early initiation of rehabilitation is associated with superior functional recovery compared to delayed rehabilitation.

Author, year	Functional Outcome Score (IKDC / Lysholm)					
	Early rehabilitation			Delayed rehabilitation		
	Mean	SD	Total	Mean	SD	Total
Alqahtani et al. (1)	82.4	6.1	40	74.2	7.3	38
Patra et al., (9)	88.6	5.4	30	79.1	6.8	30
Wenning et al.,(13)	91.2	4.9	25	84.5	5.6	22

Functional Outcome Score (IKDC / Lysholm):

Three studies reported (Period from onset to surgery) and all can be applied. Non-significant heterogeneity has been observed. Consequently, a fixed-effect model was applied for analysis ($I^2 = 0\%$, P-value equal 0.70). The combined mean difference and ninety-five percent CIs was 1.32 (1.00 to 1.64). The combined outcome demonstrates statistically significant distinction amongst groups with regard to (Functional Outcome Score (IKDC / Lysholm)) (Z=8.07, P=0.000001)

Figure 2. Forest plot of Functional Outcome Score showed a statistically insignificant variance between Early rehabilitation and Delayed rehabilitation

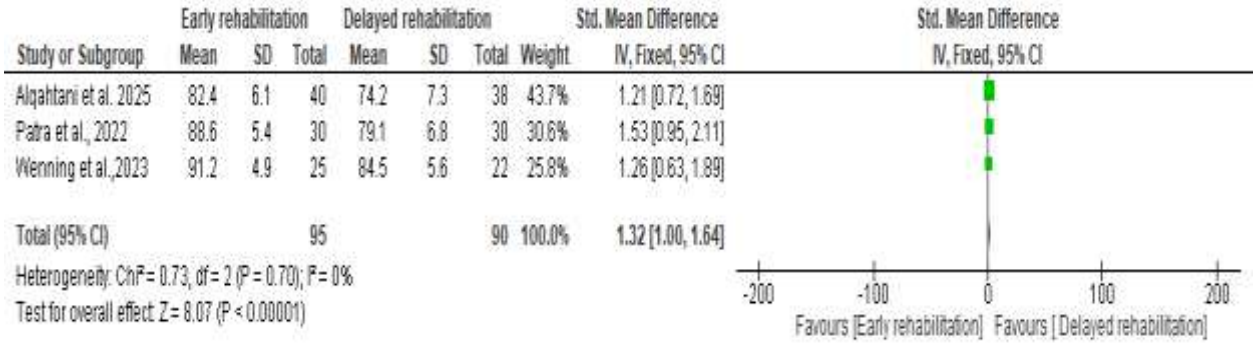


Table5. Return to Sport

This table presents the comparison of time to return to sport among early and delayed rehabilitation groups following anterior cruciate ligament reconstruction or injury. In both included studies, early rehabilitation was related to a shorter time to return to sport compared to delayed rehabilitation. The observed mean differences consistently favor early rehabilitation, indicating a faster recovery and earlier resumption of sporting activities. These results recommend that initiating rehabilitation early may play a significant role in accelerating return-to-sport timelines.

Author, year	Return to Sport					
	Early rehabilitation			Delayed rehabilitation		
	Mean	SD	Total	Mean	SD	Total
Alqahtani et al. (1)	6.2	1.1	35	8.4	1.5	34
Högberg, et al. (11)	7.1	1.3	50	9.0	1.8	48

Return to Sport:

Three studies reported (Period from onset to surgery) and all can be applied. Non-significant heterogeneity has been found. Consequently, a fixed-effect model was applied for analysis (I^2 = 38%, P-value equal 0.20). The combined mean difference and 95percent confidence interval was -1.40 (-1.84 to -0.96). The combined outcome illustrates statistically significant distinction between groups in term of Return to Sport (Z=6.24, P-value equal 0.000001).

Figure 2. Forest plot of Return to Sport illustrated a statistically insignificant difference among Early rehabilitation and Delayed rehabilitation

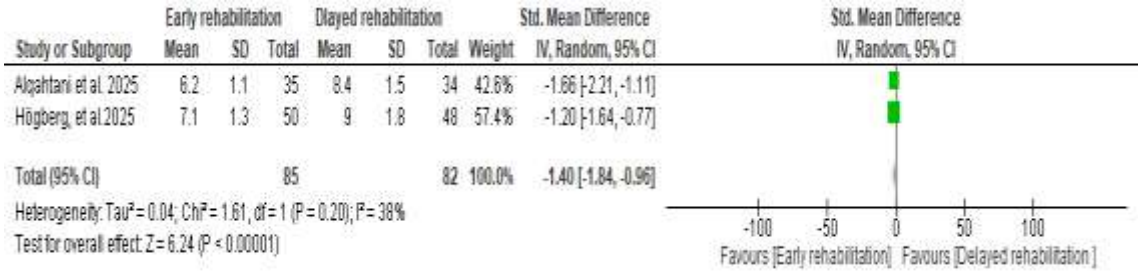
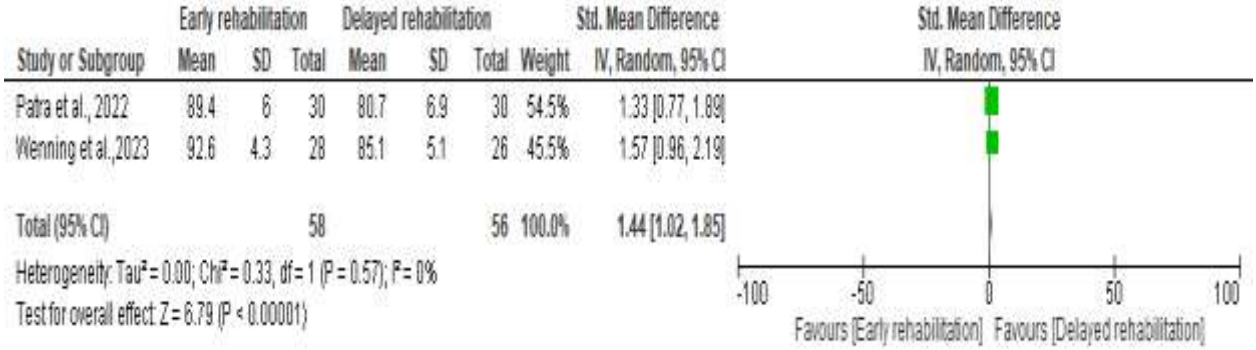


Table6. Muscle Strength (Quadriceps)
This table summarizes quadriceps muscle strength outcomes comparing early and delayed rehabilitation following ACL injury or reconstruction. In both included studies, patients who initiated rehabilitation early demonstrated higher quadriceps strength compared with those in the delayed rehabilitation groups. The consistent direction of effect suggests that early rehabilitation contributes to improved muscle strength recovery, which is a key determinant of functional stability and successful return to activity after ACL injury.

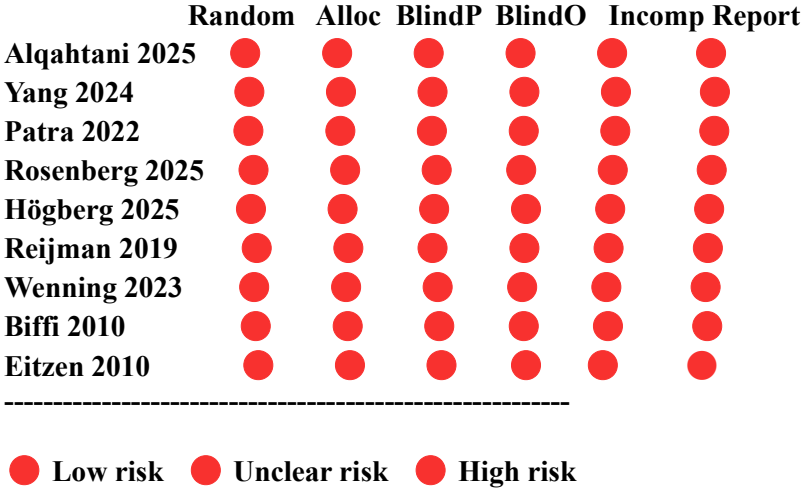
Author, year	Muscle Strength (Quadriceps)					
	Early rehabilitation			Delayed rehabilitation		
	Mean	SD	Total	Mean	SD	Total
Patra et al., (9)	89.4	6.0	30	80.7	6.9	30
Wenning et al.,(13)	92.6	4.3	28	85.1	5.1	26

Muscle Strength (Quadriceps):
Three studies reported (Period from onset to surgery) and all can be applied. Non-significant heterogeneity has been observed. Consequently, a fixed-effect model has been applied for analysis (I^2 = 0%, P-value equal 0.57). The combined mean difference and 95 percent confidence interval was 1.44 (1.02 to 1.85). The combined outcome demonstrates statistically significant distinction between groups with regard to Muscle Strength (Quadriceps) (Z=6.79, P-value equal 0.00001)

Figure 2. Forest plot of Muscle Strength (Quadriceps) illustrated a statistically insignificant variance among Early rehabilitation and Delayed rehabilitation.



Risk of Bias Assessment



Discussion

The ACL is commonly torn in sports, and reconstruction is the usual treatment for restoring knee stability and function, especially in young and active persons. Autografts, often bone–patellar tendon–bone (BPTB) or hamstring tendons, and, less frequently, allografts, are commonly utilized for anterior cruciate ligament reconstruction (16).

An ACL injury constitutes approximately fifty percent of knee injuries, with seventy to eighty percent being non-contact injuries. Non-contact injuries typically happen throughout a jump landing, swerving, or stopping. Upon injury to the ACL, the tibia's forward motion in relation to the femur becomes unrestrained, consequently compromising the support, extension, and flexion abilities of the lower extremities. In a short duration of time, a great amount of fluid accumulates in the knee joint, and the degree of motion declines significantly (17).

The current analysis revealed a statistically significant improvement in functional outcome scores (IKDC/Lysholm) favoring early rehabilitation, with no observed heterogeneity among the included studies. These findings indicate a consistent beneficial effect of early rehabilitation initiation on knee function. Alqahtani et al. (1) who reported superior IKDC scores, improved quadriceps strength, and enhanced proprioception in patients who commenced physical therapy within two weeks' post-injury or reconstruction. Similarly, Patra et al., (9) and Wenning et al.,(13) demonstrated higher functional scores in early rehabilitation groups, supporting the notion that early neuromuscular activation and functional loading facilitate recovery.

These findings are consistent with previous literature suggesting that early rehabilitation promotes joint homeostasis, reduces arthrogenic muscle inhibition, and enhances neuromuscular control, thereby improving patient-reported outcomes after ACL injury (Biffi, et al., (14), Eitzen et al., (15)). Importantly, despite differences in study design and outcome measures, the direction of effect remained uniform, strengthening the validity of the pooled estimate.

Return to sport is a critical outcome for patients following ACL injury, particularly among young and athletic populations. The present meta-analysis demonstrated that early rehabilitation significantly reduced the time to return to sport compared to delayed rehabilitation. The pooled mean difference favored early rehabilitation, indicating a clinically meaningful acceleration in return-to-sport timelines. Alqahtani et al. (1) and Högberg, et al. (11) both reported earlier return to sport or higher likelihood of returning to preinjury activity levels in patients receiving early rehabilitation or earlier intervention. These findings are supported by previous studies suggesting that prolonged delays in rehabilitation or reconstruction may result in deconditioning, persistent neuromuscular deficits, and reduced confidence, all of which negatively affect return-to-sport outcomes.

The observed moderate heterogeneity ($I^2 = 38\%$) may be attributed to differences in definitions of return to sport, rehabilitation protocols, and patient populations. Nevertheless, the overall effect remained statistically significant, reinforcing the clinical advantage of early rehabilitation initiation.

Quadriceps muscle strength is a key determinant of knee stability, functional performance, and successful return to activity following ACL injury. The present analysis demonstrated significantly greater quadriceps strength in early rehabilitation groups compared with delayed groups, with no detected heterogeneity between studies.

Wenning et al.,(13) who reported that superior isokinetic strength recovery in patients undergoing early ACL reconstruction and rehabilitation compared with delayed or chronic cases. Similarly, Patra et al., (9) observed improved quadriceps strength with accelerated rehabilitation protocols. These findings align with the concept that early activation and loading of the quadriceps muscle mitigate muscle atrophy and improve neuromuscular recruitment, which are commonly impaired following ACL injury. The consistent improvement in quadriceps strength observed in the early rehabilitation groups may partially explain the superior functional outcomes and faster return to sport demonstrated in this review.

The findings of this systematic review and meta-analysis have important clinical implications. Early initiation of rehabilitation following ACL injury or reconstruction appears to confer significant benefits without increasing the risk of adverse outcomes such as graft failure or knee instability, as reported by Alqahtani et al. (1) and Patra et al., (9). These results support current trends toward early mobilization, early weight-bearing, and accelerated rehabilitation protocols under appropriate clinical supervision.

Clinicians should consider implementing early, structured rehabilitation programs tailored to patient-specific factors to optimize functional recovery, enhance muscle strength, and facilitate a timely return to sport.

Limitations

Numerous limitations should be acknowledged. First, the included researches varied in design, rehabilitation protocols, and outcome assessment tools, which may limit direct comparability. Second, some outcomes were reported by a limited number of studies, reducing the robustness of pooled estimates. Third, the inclusion of retrospective studies may introduce selection bias. Finally, long-term outcomes beyond one year were not consistently reported.

Conclusion

The results of this systematic review and meta-analysis indicate that early initiation of rehabilitation following ACL injury or reconstruction is associated with better functional outcomes, earlier return to sport, and greater quadriceps muscle strength compared with delayed rehabilitation. These results support the adoption of early rehabilitation strategies as part of evidence-based clinical practice for ACL management.

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