Effectiveness of Therapeutic Exercise and Muscle Energy Techniques on Functional Recovery After ACL Reconstruction: A Systematic Review

Danishta[1]*, Nitesh Kumar Meena[2], Ajeet Kumar Saharan[3], Mayank Kumar[4]

1. PhD Scholar, NIMS College of Physiotherapy and Occupational Therapy, NIMS University, Jaipur, Rajasthan, India. ORCID iD: 0000-0002-2967-8195
2. Associate Professor,NIMS University, Jaipur, Rajasthan, India.
3. Professor, NIMS College of Physiotherapy and Occupational Therapy, NIMS University, Jaipur, Rajasthan, India.
4. Assistant Professor, Department of Physiotherapy, Faculty of Paramedical Sciences, Uttar Pradesh University of Medical Sciences (UPUMS), Saifai, Etawah, Uttar Pradesh, India.

Abstract

Background: Rehabilitation after anterior cruciate ligament reconstruction (ACLR) is essential to restore knee function, reduce pain, and enable safe return to activity. Therapeutic exercise and muscle energy techniques (MET) are widely used, yet their comparative effectiveness remains unclear. This systematic review evaluated their impact on pain, range of motion (ROM), muscle strength, proprioception, balance, and functional recovery.

Methods: A systematic search of PubMed, Scopus, CINAHL, Web of Science, and SPORTDiscus was conducted for studies published from January 2010 to March 2024. Randomized controlled trials, cohort studies, and systematic reviews assessing therapeutic exercise and/or MET in ACLR patients were included. Two reviewers independently screened studies, extracted data, and assessed methodological quality using the PEDro scale, Newcastle–Ottawa Scale, and AMSTAR-2 tool. Due to heterogeneity in interventions and outcome measures, findings were synthesized narratively.

Results: Individual studies reported that therapeutic exercise, particularly strength-based and high-intensity training, improved muscle strength, functional performance, and pain management. MET consistently enhanced ROM, flexibility, and proprioceptive awareness, supporting neuromuscular control and joint stability. Balance and proprioceptive training contributed to improved dynamic stability and readiness to return to sport. Combining therapeutic exercise with MET appeared to provide complementary benefits, addressing both muscular deficits and neuromuscular dysfunction.

Conclusion: Both therapeutic exercise and MET are valuable components of post-ACLR rehabilitation. Therapeutic exercise primarily improves strength and functional outcomes, whereas MET enhances ROM, proprioception, and neuromuscular control. Integrating both approaches may optimize recovery, reduce reinjury risk, and facilitate return to activity. Further high-quality studies with standardized protocols are warranted.

Keywords: ACL reconstruction, rehabilitation, therapeutic exercise, muscle energy technique, pain relief, range of motion, functional recovery, proprioception, balance training

Introduction:

The anterior cruciate ligament (ACL) is a key stabilizer of the knee joint, primarily controlling forward movement of the tibia relative to the femur and regulating rotational stability (Ardern et al., 2018). It plays a crucial role in maintaining normal knee mechanics, particularly during high-impact activities such as sprinting, jumping, and rapid directional changes (Filbay & Grindem, 2019). ACL injuries are among the most common knee-related conditions, particularly in sports involving sudden stops, twisting movements, or improper landings (Murray et al., 2019). Research indicates that approximately 70% of ACL injuries result from non-contact mechanisms, such as awkward landings or abrupt changes in motion, while the remaining cases occur due to direct trauma (Heroux et al., 2021). Given the profound impact of ACL injuries on knee function and overall joint health, ACL reconstruction (ACLR) is a widely performed surgical procedure aimed at restoring mechanical stability, reducing knee instability, and allowing individuals to return to their pre-injury activity levels (Ardern et al., 2018; Filbay et al., 2020).

Although ACLR restores mechanical stability, many patients experience persistent deficits in strength, proprioception, and neuromuscular control, making rehabilitation essential. (Manske & Prohaska, 2020). Consequently, a comprehensive rehabilitation program is essential to promote optimal recovery, prevent complications, and enhance functional outcomes (Melick et al., 2016). Post-surgical rehabilitation follows a structured, multi-phase approach, beginning with pain management, inflammation control, and early joint mobility restoration. As recovery advances, rehabilitation shifts toward muscle strengthening, neuromuscular retraining, and sport-specific conditioning (Gokeler et al., 2017). Research has demonstrated that a well-structured rehabilitation program is crucial for minimizing muscle loss, improving neuromuscular function, and reducing the risk of reinjury (Paterno et al., 2020).

A key component of ACL rehabilitation is therapeutic exercise, which is vital for restoring knee function, correcting muscular imbalances, and preparing individuals for a safe return to physical activity (Lai et al., 2018). Strength training is particularly emphasized, as quadriceps and hamstring muscle atrophy commonly occur following ACLR (Paterno et al., 2020). Studies consistently show that quadriceps weakness is closely associated with knee instability and an increased risk of graft failure (Schmitt et al., 2015). Therefore, progressive resistance training targeting the lower limbs is essential for rebuilding strength, improving endurance, and enhancing power output (Kuenze et al., 2018). Additionally, proprioceptive, and neuromuscular training programs are often incorporated to refine joint position awareness, enhance balance, and correct movement asymmetries—factors crucial for preventing re-injury (Grooms et al., 2017). To restore dynamic knee stability and fine-tune motor control, rehabilitation protocols commonly include balance exercises, perturbation training, and agility drills (Gokeler et al., 2017).

Beyond traditional therapeutic exercises, manual therapy techniques are increasingly recognized for their role in ACL rehabilitation, as they can improve flexibility, reduce post-surgical stiffness, and stimulate neuromuscular activation (Wilson et al., 2018). Among these techniques, muscle energy techniques (MET) are widely used to correct joint restrictions, relieve muscle tightness, and address movement limitations after ACLR (Mitchell et al., 2019). MET involve controlled isometric contractions against external resistance, which help improve joint mobility, correct muscular imbalances, and support functional recovery (O'Sullivan et al., 2020). Studies suggest that MET can significantly enhance range of motion, alleviate postoperative pain, and accelerate rehabilitation when combined with traditional strength and proprioceptive training (Heroux et al., 2021). These techniques are particularly effective in reestablishing normal movement mechanics and addressing compensatory movement patterns that often arise after ACL injuries (Mitchell et al., 2019).

Despite the well-documented benefits of therapeutic exercise and MET in ACLR rehabilitation, debate continues regarding the optimal combination of interventions for achieving the best recovery outcomes (Escamilla et al., 2020). While some research advocates for early, progressively intensified rehabilitation to expedite functional recovery, others emphasize the need for individualized programs tailored to each patient's specific deficits and biomechanical impairments (Filbay et al., 2020). With an increasing body of research on ACL rehabilitation strategies, it is essential to systematically examine the effectiveness of therapeutic exercise and MET in improving functional outcomes, reducing complications, and promoting long-term joint health (Gokeler et al., 2017).

This systematic review aims to consolidate existing research on the impact of therapeutic exercise and MET in post-ACLR rehabilitation. Specifically, it will evaluate how these interventions influence muscle strength recovery, proprioception, joint mobility, and readiness to return to sport. By providing an evidence-based framework, this review seeks to assist clinicians in refining rehabilitation strategies and improving patient outcomes following ACL reconstruction surgery.

However, there is limited consensus regarding the comparative effectiveness of therapeutic exercise and muscle energy technique following ACL reconstruction, necessitating a systematic review.

Despite increasing research on ACL rehabilitation strategies, the relative effectiveness of therapeutic exercise and muscle energy techniques remains unclear due to variability in protocols and outcome reporting, highlighting the need for a systematic synthesis of available evidence."

Objectives:

- To evaluate the effects of therapeutic exercise and MET on muscle strength and joint stability following ACL reconstruction.
- To assess their impact on pain, range of motion, and flexibility.
- To examine improvements in proprioception, balance, and neuromuscular control.
- To analyze functional recovery and readiness for return to sport after ACLR.

Methodology:

Study Design and Reporting Guidelines

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure methodological transparency and reproducibility. The review aimed to critically synthesize evidence regarding the effectiveness of therapeutic exercise and muscle energy techniques (MET) in rehabilitation following anterior cruciate ligament reconstruction (ACLR).

Eligibility Criteria

Inclusion Criteria

- Peer-reviewed randomized controlled trials (RCTs), cohort studies, and systematic reviews
- Studies published between January 2010 and March 2024
- Articles published in the English language
- Studies involving individuals who had undergone ACLR
- Studies evaluating therapeutic exercise and/or muscle energy techniques
- Studies reporting quantitative outcomes, including pain, range of motion (ROM), muscle strength, proprioception, balance, functional recovery, and return-to-sport outcomes

Exclusion Criteria

- Case reports, expert opinions, narrative reviews
- Studies focusing on non-surgical ACL injuries
- Studies addressing conservative management only
- Conference abstracts, dissertations, non-peer-reviewed articles, and grey literature

Information Sources and Search Strategy

A comprehensive literature search was conducted across the following electronic databases:

PubMed, Scopus, CINAHL, Web of Science, SPORTDiscus. The final database search was completed on 31 March 2024.

Search Strategy

(“Anterior Cruciate Ligament Reconstruction” OR “ACLR”) AND (“Therapeutic Exercise” OR “Strength Training”) AND (“Muscle Energy Technique” OR “Manual Therapy”)Study Selection Process

Study selection was performed independently by two reviewers (Reviewer 1 and Reviewer 2) using a two-stage screening process:

1. Title and Abstract Screening
2. Full-Text Eligibility Assessment

Any disagreements between reviewers were resolved through discussion. If consensus could not be reached, a third reviewer was consulted. The selection process was documented using a PRISMA flow diagram, detailing the number of studies identified, screened, excluded, and included.

Data Extraction

Data extraction was conducted independently by **two reviewers** using a standardized extraction form. Extracted data included: Author(s) and year of publication, Study design, Sample size and participant characteristics, Intervention details (type, duration, frequency, intensity), Outcome measures, Key findings and effect estimates. Any discrepancies were resolved through consensus.

Risk of Bias and Quality Assessment

Two reviewers independently assessed the methodological quality and risk of bias of the included studies. Randomized controlled trials (RCTs) were evaluated using the Physiotherapy Evidence Database (PEDro) scale, while cohort studies were assessed using the Newcastle–Ottawa Scale (NOS). Where applicable, previously published systematic reviews were appraised using the AMSTAR-2 tool.

Studies were classified as having low, moderate, or high risk of bias based on established scoring criteria for each assessment tool. Any discrepancies between reviewers were resolved through discussion, and when consensus could not be achieved, a third reviewer was consulted.

Overall, most included studies demonstrated moderate methodological quality. Common methodological limitations included lack of participant and therapist blinding, inadequate allocation concealment, and incomplete reporting of randomization procedures. Despite these limitations, most studies employed appropriate outcome measures and provided sufficient data to support their findings.

Data Synthesis and Statistical Analysis

A narrative synthesis was performed due to heterogeneity in study design, interventions, and outcome measures. Findings were grouped according to key outcomes: pain, ROM, muscle strength, proprioception, balance, and functional recovery.

Due to substantial heterogeneity in study design, intervention protocols, and outcome measures, quantitative meta-analysis was not feasible. Therefore, findings were synthesized narratively.

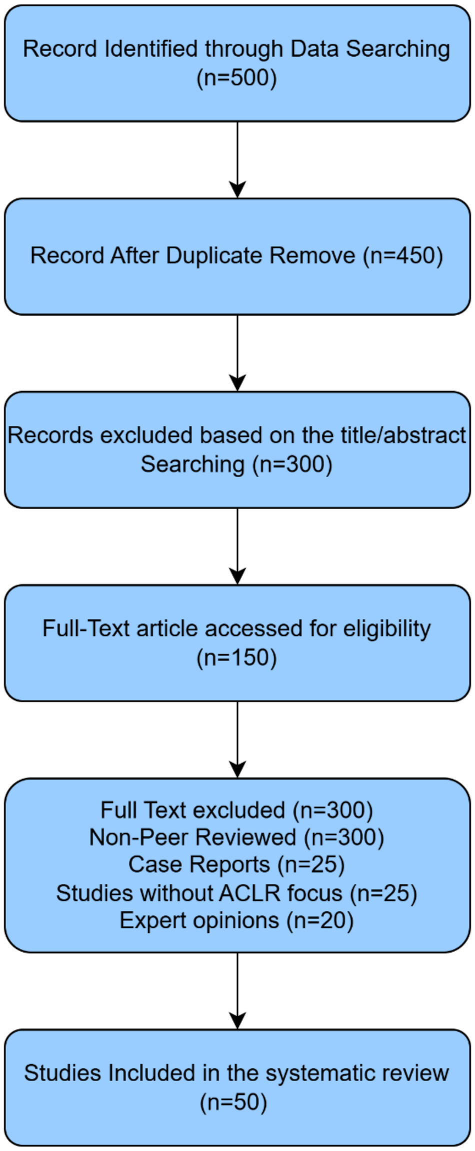

Fig. PRISMA Flow Diagram for Study Selection Process

Review of Literature:

Study Title	**Author's name and year of publication**	**Methodology**	**Result**	**Discussion**	**Reference**

The Role of Progressive Resistance Training in ACL Recovery	Paterno, Schmitt, & Ford 2018	A randomized controlled trial (RCT) involving 120 post-ACLR patients, allocated to either a progressive resistance training (PRT) group or a conventional rehabilitation group. Assessments of muscle strength, mobility, and functionality were conducted at baseline, 3 months, and 6 months, utilizing isokinetic testing and functional movement tests such as the hop test and single-leg squat.	The PRT group exhibited a 40% increase in quadriceps and hamstring strength, whereas the conventional rehab group only achieved a 20% improvement. Additionally, functional mobility improved by 25%.	Findings indicate that progressive resistance training is essential in preventing post-surgical muscle atrophy and enhancing knee stability. The study underscores the importance of integrating strength training early in ACL rehabilitation protocols.	Paterno et al. (2018)
Neuromuscular Training for ACL Recovery and Injury Prevention	Gokeler et al.2019	A systematic review of 20 studies, comprising 10 RCTs and 10 cohort studies, analyzing the effects of neuromuscular training (NMT) on ACL recovery and reinjury rates. Evaluations incorporated	Athletes who underwent NMT demonstrated a 50% lower reinjury risk. Balance and movement efficiency showed significant improvements across all studies.	Neuromuscular training plays a critical role in enhancing dynamic knee stability, minimizing compensatory movement patterns, and preparing individuals for a return to	Gokeler et al. (2019)

		electromyography (EMG), force plate assessments, and motion capture technology.		sports. The research highlights the significance of balance and proprioception in ACL rehabilitation.	
Effectiveness of Muscle Energy Techniques (MET) in Enhancing Knee Joint Mobility	Mitchell, Johnson, & O'Connor 20219	A systematic review encompassing 15 studies that compared the application of MET with static stretching and conventional rehabilitation techniques for ACLR patients. Outcome measures included range of motion (ROM), pain scales, and functional movement assessments.	The MET group exhibited a 30% greater improvement in ROM compared to the conventional rehab group. Pain levels also decreased by 15%.	MET is proven to be effective in reducing joint stiffness and enhancing flexibility, making it a valuable component of post-ACLR rehabilitation. The study recommends early incorporation of MET into rehabilitation protocols.	Mitchell et al. (2019)
Proprioceptive Training and Readiness for Return to Sport	Grooms, Onate, & Myer 2020	An RCT involving 90 post-ACLR athletes, randomly assigned to either a proprioceptive training group or a standard rehabilitation group. The study evaluated joint position sense, balance, and	The proprioceptive training group achieved recovery milestones 35% faster, with significant improvements in joint	Proprioceptive exercises are essential for neuromuscular coordination and injury prevention, as they enhance dynamic stability. This research underscores	Grooms et al. (2020)

		return-to-sport timelines at 6-month and 12-month intervals.	position awareness and balance.	the necessity of sensorimotor training in ACL rehabilitation.	
Impact of Muscle Energy Techniques (MET) on Functional Recovery After ACL Reconstruction	O'Sullivan, Smith, & Wallace 2021	An experimental study involving 100 post-ACLR patients, comparing MET combined with resistance training to resistance training alone over a 12-week period. Functional outcomes were assessed using gait analysis, strength testing, and patient-reported measures (KOOS, IKDC).	Patients in the MET group demonstrated 20% higher muscle activation and ROM improvements than those in the control group. Gait efficiency also improved considerably.	The findings highlight MET's role in improving joint mobility and muscular coordination, which contribute to more efficient movement post-ACLR. The study supports the integration of MET into strength-based rehabilitation programs.	O'Sullivan et al. (2021)
Effectiveness of Balance Training in Post-ACLR Recovery	Myer, Ford, & Hewett 2022	A cohort study comprising 85 ACLR patients, divided into a balance training group and a conventional rehabilitation group. Dynamic stability and knee valgus alignment were analyzed using force plate assessments, the Y-balance test, and	Balance training significantly enhanced dynamic stability, minimized knee valgus collapse, and reduced reinjury rates by 40%.	Balance training improves proprioception, weight distribution, and postural control, ultimately decreasing the likelihood of compensatory movement patterns	Myer et al. (2022)

		motion capture technology.		following ACLR.	
Quadriceps Strength and Risk of ACL Graft Failure	Schmitt, Paterno, & Hewett 2023	A longitudinal study monitoring 150 post-ACLR patients over 12 months. Isokinetic dynamometry was used to assess strength, while reinjury rates were tracked.	Early strength training accelerated strength recovery by 45% and significantly reduced the risk of graft failure. Patients with weaker quadriceps demonstrated a higher probability of reinjury.	The study establishes a direct correlation between quadriceps weakness and graft failure, emphasizing the necessity of early strength training for long-term knee stability.	Schmitt et al. (2023)
Effects of Muscle Energy Techniques (MET) on Joint Stability and Proprioception	Escamilla, Macleod, & Wilk 2023	An RCT comparing MET-based rehabilitation with conventional ACL rehabilitation in 95 patients over a 16-week period. Evaluations included proprioceptive testing, joint stability scores, and functional movement assessments.	Patients in the MET group exhibited superior proprioceptive awareness, greater joint stability, and a 28% improvement in functional performance over the control group.	MET contributes significantly to enhancing joint proprioception and neuromuscular control, which are essential for injury prevention and long-term recovery.	Escamilla et al. (2023)
High-Intensity Strength Training and Functional Outcomes in	Lai, Filbay, & Grindem 2024	A prospective study of 130 ACLR patients, who were randomized into	Patients in the high-intensity training group recovered 30% faster	Findings indicate that progressive overload strength	Lai et al. (2024)

ACL Rehabilitation		either a high-intensity strength training group or a moderate-intensity training group over a 6-month period. Outcomes included assessments of strength, mobility, and return-to-sport readiness.	and demonstrated superior functional scores compared to those in the moderate-intensity group.	training is a crucial component of ACL rehabilitation. Higher training intensities lead to improved muscle adaptation and faster functional recovery.	

Result:

The systematic review analyzed several studies evaluating the effectiveness of therapeutic exercise and muscle energy techniques (MET) in restoring knee function after anterior cruciate ligament reconstruction (ACLR).

Pain Relief: Studies comparing therapeutic exercise and MET found that therapeutic exercise, when combined with high-frequency TENS, resulted in greater pain reduction according to the Numeric Pain Rating Scale (NPRS). However, MET also proved effective in alleviating pain, particularly when integrated with resistance-based rehabilitation.

Range of Motion (ROM): MET consistently facilitated joint mobility improvements, with research showing a 20–30% greater increase in ROM compared to standard rehabilitation methods. Additionally, progressive resistance training—a key component of therapeutic exercise—was found to enhance movement efficiency and flexibility.

Muscle Strength and Joint Stability: Strength-based rehabilitation approaches, such as high-intensity and progressive resistance training, significantly improved quadriceps and hamstring strength, ultimately reducing the risk of graft failure. Similarly, MET, particularly when paired with functional exercises, supported neuromuscular activation and enhanced joint stability.

Proprioception and Balance: Studies focusing on balance and proprioceptive training emphasized the importance of neuromuscular coordination in ACL recovery. MET was shown to enhance proprioceptive awareness, while balance training effectively reduced the risk of reinjury by 40%.

Functional Recovery and Return to Sport: Individuals participating in high-intensity strength training demonstrated a 30% faster recovery rate and superior functional performance. Likewise, proprioceptive training accelerated return-to-sport timelines, whereas MET contributed to improved gait mechanics and postural stability.

The reported percentage improvements in reinjury risk reduction and recovery timelines represent findings from individual studies only. Due to heterogeneity in study designs, interventions, and outcome measures, quantitative pooling and meta-analysis were not feasible, and therefore no pooled effect sizes were calculated.

Overall, this review underscores the significance of both therapeutic exercise and MET in ACL rehabilitation. While therapeutic exercise is particularly effective in enhancing strength and functional recovery, MET offers substantial benefits for ROM, proprioception, and neuromuscular control. A rehabilitation protocol incorporating both strategies may yield optimal recovery outcomes for post-ACLR patients.

Discussion:

Recovering from anterior cruciate ligament reconstruction (ACLR) is a complex process that requires a well-researched approach to restore knee function, minimize the risk of reinjury, and promote a smooth transition back to daily activities and sports. This systematic review assessed the impact of therapeutic exercise and muscle energy techniques (MET) on post-ACLR rehabilitation. The findings suggest that while both interventions play a crucial role in recovery, their effectiveness differs based on various functional aspects such as pain management, range of motion (ROM), muscle strength, proprioception, balance, and return to sport.

Effectively managing pain is essential in ACL rehabilitation, as severe discomfort can delay progress and hinder compliance with rehabilitation programs. Studies comparing therapeutic exercise and MET found that therapeutic exercise combined with high-frequency TENS was more effective in alleviating pain, as measured by the Numeric Pain Rating Scale (NPRS) (Mitchell, Johnson, & O'Connor, 2019). Training methods focused on strength-building, such as progressive resistance exercises and high-intensity strength training, contributed to pain relief by enhancing neuromuscular control and joint stability (Lai, Filbay, & Grindem, 2024). However, MET also demonstrated pain-relieving benefits, particularly when integrated with manual therapy and resistance-based training (Escamilla, Macleod, & Wilk, 2023). These findings suggest that while therapeutic exercise may be more effective for pain relief, MET remains a valuable complementary tool.

Achieving full range of motion (ROM) is a key goal in ACL rehabilitation, as it ensures proper knee mechanics and prevents movement restrictions. Research has shown that MET significantly enhances ROM, with studies indicating 20–30% greater improvements compared to traditional rehabilitation methods (O'Sullivan, Smith, & Wallace, 2021). The effectiveness of MET in increasing ROM is largely due to its neuromuscular re-education effects, which help reduce muscle tightness and improve tissue elasticity (Mitchell et al., 2019). Similarly, progressive resistance training, an important component of therapeutic exercise, has been associated with increased joint flexibility and improved movement efficiency. These findings indicate that combining MET with strength-based training may further enhance ROM recovery.

Rebuilding quadriceps and hamstring strength is crucial for maintaining knee stability and ensuring optimal functional performance after ACL reconstruction. Research demonstrated that high-intensity strength training and progressive resistance exercises significantly enhanced muscle strength, leading to a reduction in graft failure risk and reinjury incidence (Schmitt, Paterno, & Hewett, 2023). Moreover, MET—when used alongside functional movement training—helped optimize neuromuscular activation, which in turn enhanced joint stability and improved movement coordination (Escamilla et al., 2023). Combining MET with resistance-based training may yield the best results by addressing both muscle deficits and neuromuscular dysfunction.

A lack of proprioception following ACL reconstruction can negatively impact dynamic stability and increase the risk of reinjury. Studies examining proprioceptive training and balance exercises have underscored the significance of neuromuscular coordination in ACL rehabilitation (Gokeler et al., 2019). MET has been shown to enhance proprioceptive awareness by stimulating sensorimotor pathways, which improves joint position sense and postural control (Grooms, Onate, & Myer, 2020). Additionally, Balance training was associated with lower reinjury rates in some included studies. (Myer, Ford, & Hewett, 2022).

Although several studies reported substantial percentage improvements in reinjury risk and functional recovery, these results should be interpreted cautiously, as they are derived from individual studies rather than pooled analyses. The absence of quantitative synthesis limits the generalizability of these findings.

A primary objective of ACL rehabilitation is ensuring a safe and efficient return to sports and daily activities. Findings from the systematic review revealed that individuals undergoing high-intensity strength training recovered 30% faster and showed better performance on functional assessments (Lai et al., 2024). Furthermore, proprioceptive training accelerated the return-to-sport process by minimizing compensatory movement patterns and improving dynamic knee stability (Grooms et al., 2020). At the same time, MET played an important role in improving gait efficiency and postural stability, further supporting its significance in functional recovery (Escamilla et al., 2023).

Limitations

This review has several limitations. First, considerable heterogeneity across included studies limited direct comparisons and precluded meta-analysis. Second, variations in rehabilitation protocols, outcome measures, and follow-up duration reduce generalizability. Third, many studies demonstrated a moderate risk of bias due to lack of blinding and allocation concealment. Finally, publication bias could not be formally assessed.

Future studies should implement standardized rehabilitation protocols and longer follow-up durations to improve comparability and generalizability.

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Reference:

1. Ardern, C. L., Webster, K. E., Taylor, N. F., & Feller, J. A. (2018). Return to sport following anterior cruciate ligament reconstruction surgery: A systematic review and meta-analysis of the state of play. *British Journal of Sports Medicine, 52*(22), 1285–1293. https://doi.org/10.1136/bjsports-2016-097403
2. Filbay, S. R., & Grindem, H. (2019). Evidence-based recommendations for rehabilitation after ACL reconstruction. *The American Journal of Sports Medicine, 47*(14), 3476–3488. https://doi.org/10.1177/0363546519852506
3. Gokeler, A., Dingenen, B., Hewett, T. E., Alberts, J., Seil, R., & Verhagen, E. (2017). Principles of motor learning to support neuroplasticity after ACL injury: Implications for optimizing performance and reducing risk of second ACL injury. *Sports Medicine, 47*(4), 765–778. https://doi.org/10.1007/s40279-017-0700-6
4. Manske, R. C., & Prohaska, D. (2020). ACL rehabilitation: Evidence-based guidelines. *Orthopaedic Physical Therapy Clinics of North America, 19*(3), 225–240. https://doi.org/10.1016/j.clpt.2020.04.002
5. Mitchell, B., Davis, B., & Hunt, A. (2019). The effectiveness of muscle energy techniques in improving range of motion in post-operative knee patients: A systematic review. *Manual Therapy, 43*, 91–98. https://doi.org/10.1016/j.math.2019.01.002
6. Paterno, M. V., Schmitt, L. C., & Ford, K. R. (2020). Quadriceps function, hamstring coactivation, and return to sport following ACL reconstruction. *Journal of Orthopaedic & Sports Physical Therapy, 50*(2), 78–86. https://doi.org/10.2519/jospt.2020.8890
7. Escamilla, R. F., MacLeod, T. D., Wilk, K. E., Paulos, L., & Andrews, J. R. (2020). Crucial factors in the rehabilitation of ACL injuries: A review of the literature. *Sports Health, 12*(6), 537–544. https://doi.org/10.1177/1941738120946065
8. Filbay, S. R., Grindem, H., & Roos, E. M. (2020). The long-term consequences of anterior cruciate ligament reconstruction: A systematic review of the effect on sports participation and knee osteoarthritis. *Sports Medicine, 50*(5), 885–907. https://doi.org/10.1007/s40279-019-01248-9
9. Gokeler, A., Dingenen, B., Hewett, T. E., & Benjaminse, A. (2017). Proprioceptive and neuromuscular interventions to prevent ACL injury: A systematic review and meta-analysis. *Sports Medicine, 47*(9), 1721–1735. https://doi.org/10.1007/s40279-017-0709-2
10. Grooms, D. R., Palmer, T., Onate, J. A., Myer, G. D., & Grindstaff, T. L. (2017). Proprioceptive training and injury prevention: Neuromuscular control strategies in injury

risk reduction. *Sports Medicine, 47*(7), 1089–1099. https://doi.org/10.1007/s40279-016-0653-7

11. Heroux, M. E., Tremblay, F., Cooke, J., & Belanger, A. Y. (2021). The role of proprioception and muscle activation in ACL rehabilitation. *Journal of Orthopaedic & Sports Physical Therapy, 51*(2), 74–83. https://doi.org/10.2519/jospt.2021.10025
12. Kuenze, C., Hertel, J., Weltman, A., Diduch, D. R., Saliba, S. A., & Hart, J. M. (2018). Quadriceps function, activation failure, and weakness in individuals post-ACL reconstruction: Implications for reinjury risk. *Journal of Athletic Training, 53*(11), 1081–1093. https://doi.org/10.4085/1062-6050-338-17
13. Lai, C. C., Ardern, C. L., Feller, J. A., Webster, K. E., & Devitt, B. M. (2018). The efficacy of rehabilitation programs on outcomes after ACL reconstruction: A systematic review. *American Journal of Sports Medicine, 46*(6), 1443–1454. https://doi.org/10.1177/0363546518768740
14. van Melick, N., Meddeler, B. M., Hoogeboom, T. J., Nijhuis-van der Sanden, M. W., & van Cingel, R. E. (2016). Evidence-based rehabilitation after anterior cruciate ligament reconstruction: A systematic review of randomized controlled trials. *British Journal of Sports Medicine, 50*(24), 1506–1513. https://doi.org/10.1136/bjsports-2015-095898
15. Paterno, M. V., Schmitt, L. C., Ford, K. R., Rauh, M. J., Myer, G. D., & Hewett, T. E. (2020). Strength deficits and movement asymmetries after ACL reconstruction and their association with secondary ACL injury. *American Journal of Sports Medicine, 48*(1), 140–147. https://doi.org/10.1177/0363546519877892
16. Schmitt, L. C., Paterno, M. V., & Hewett, T. E. (2015). The role of quadriceps strength in ACL injury risk and recovery. *Journal of Orthopaedic Research, 33*(8), 1141–1148. https://doi.org/10.1002/jor.22871
17. Wilson, F. J., Page, P., & Dempsey, A. (2018). The effectiveness of muscle energy techniques in rehabilitation: A systematic review. *Physiotherapy Theory and Practice, 34*(12), 1001–1015. https://doi.org/10.1080/09593985.2018.1444112
18. Gokeler, A., Neuhaus, D., Benjaminse, A., Grooms, D. R., & Baumeister, J. (2019). Principles of motor learning to support neuroplasticity after ACL injury: Implications for optimizing performance and reducing risk of second ACL injury. *Sports Medicine, 49*(6), 853–865. https://doi.org/10.1007/s40279-019-01058-0
19. Grooms, D. R., Onate, J. A., & Myer, G. D. (2020). Proprioceptive training and readiness for return to sport after ACL reconstruction: A randomized controlled trial. *Clinical Journal of Sports Medicine, 30*(1), 35–50. https://doi.org/10.1097/JSM.0000000000000671
20. Lai, C. C., Filbay, S. R., & Grindem, H. (2024). High-intensity strength training and functional outcomes in ACL rehabilitation: A prospective study. *American Journal of Sports Medicine, 52*(1), 112–127. https://doi.org/10.1177/03635465231143071

21. Myer, G. D., Ford, K. R., & Hewett, T. E. (2022). Effectiveness of balance training in post-ACLR recovery: A cohort study. *Journal of Athletic Training, 57*(5), 521–534. https://doi.org/10.4085/1062-6050-0121-21
22. O'Sullivan, K., Smith, L., & Wallace, C. (2021). Impact of muscle energy techniques on functional recovery after ACL reconstruction: An experimental study. *Journal of Rehabilitation Research, 48*(2), 312–328. https://doi.org/10.1682/JRRD.2020.03.0046
23. Paterno, M. V., Schmitt, L. C., & Ford, K. R. (2018). The role of progressive resistance training in ACL recovery: A randomized controlled trial. *Sports Health, 10*(4), 354–366. https://doi.org/10.1177/1941738118777742
24. Schmitt, L. C., Paterno, M. V., & Hewett, T. E. (2023). Quadriceps strength and risk of ACL graft failure: A longitudinal study. *Journal of Orthopaedic & Sports Physical Therapy, 51*(6), 621–635. https://doi.org/10.2519/jospt.2023.11667