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FROM OPERATING ROOM TO REHABILITATION: EVIDENCE-BASED PHYSICAL THERAPY IN TOTAL KNEE REPLACEMENT: A NARRATIVE REVIEW

Narrative Review

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ABSTRACT

Background: Total knee replacement (TKR) is the gold standard intervention for advanced knee osteoarthritis, offering substantial pain relief and improved function. However, up to 20% of patients experience persistent postsurgical pain (PPP), which adversely affects recovery and quality of life. Physiotherapy plays a central role in rehabilitation, yet considerable heterogeneity in protocols, patient responses, and long-term outcomes has created uncertainty regarding the most effective strategies.

Objective: This narrative review aims to synthesize recent evidence (2020–2025) on physiotherapy interventions following TKR, with a particular focus on managing PPP, highlighting effective modalities, challenges, and future directions.

Main Discussion Points: Evidence supports a phase-based approach: early mobilization reduces complications and enhances range of motion; progressive strengthening and functional retraining restore independence; and adjunctive modalities such as neuromuscular electrical stimulation, aquatic therapy, and cryotherapy enhance recovery. Technology-based solutions, including telerehabilitation and wearable monitoring, demonstrate promise in improving adherence and accessibility. Psychological factors such as catastrophizing and depression also strongly influence outcomes but remain under-addressed in physiotherapy programs. Persistent challenges include protocol variability, underrepresentation of high-risk subgroups, limited long-term evidence, and barriers to patient adherence.

Conclusion: Physiotherapy after TKR is indispensable in reducing PPP and optimizing functional outcomes. Future research should prioritize large-scale, long-term trials, incorporate cost-effectiveness analyses, and integrate digital and psychological support. A personalized, multidisciplinary rehabilitation framework represents the most promising pathway to achieving sustainable improvements in postoperative recovery.

Keywords: Total knee replacement (TKR); knee osteoarthritis; persistent postsurgical pain; physiotherapy; rehabilitation; telerehabilitation.

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INTRODUCTION

Knee osteoarthritis is recognized as the most prevalent form of osteoarthritis globally and is a major cause of pain, disability, and reduced quality of life (1). When conservative management fails, Total Knee Replacement (TKR), also termed Total Knee Arthroplasty (TKA), is considered the gold standard surgical intervention for individuals with advanced disease, offering substantial pain relief and functional restoration (1,2). In 2008 alone, over 650,000 TKRs were performed in the United States, and with the rising prevalence of joint disease and the aging global population, this number continues to increase worldwide (2,3). Despite the generally favorable surgical outcomes, between 10% and 30% of patients experience persistent postoperative pain (PPP) extending beyond three months, which negatively influences rehabilitation, functionality, and overall satisfaction (1,4). Emerging evidence highlights the multifactorial nature of PPP. A prospective cohort study demonstrated that up to 13% of patients report significant pain at six months and 9% at one year following surgery, with preoperative pain severity, prosthesis loosening, and psychological factors such as depression and anxiety identified as predictors (4). A large-scale meta-analysis involving over 26,000 TKR patients further revealed that pain catastrophizing, younger age, and severe acute postoperative pain increase the risk of chronic pain by as much as 30% (5). Additionally, neurophysiological factors such as impaired conditioned pain modulation and heightened temporal summation, markers of central sensitization, have been linked to persistent postoperative pain, indicating that altered pain processing mechanisms may prolong symptoms even after mechanical nociceptive sources are addressed (6).

Physiotherapy is pivotal in postoperative recovery, as it targets pain reduction, restoration of joint range of motion, strengthening of periarticular muscles, and improvement of functional independence (3). However, substantial variability exists across institutions in terms of rehabilitation protocols, including timing, intensity, and modalities applied, and consensus on standardized best practices remains limited. Given the growing global burden of TKR and the high prevalence of PPP, there is a critical need to evaluate and synthesize the latest evidence on physiotherapy interventions tailored to this population. The objective of this narrative review is to consolidate current evidence from 2020 to 2025 regarding physiotherapy approaches for managing persistent postoperative pain following TKR, with the aim of identifying effective strategies, highlighting existing challenges, and guiding directions for future clinical practice and research.

METHODS

The present narrative review was designed to summarize and critically interpret contemporary evidence regarding physical therapy interventions in the rehabilitation of patients undergoing total knee replacement (TKR). A comprehensive literature search was carried out across four major databases—PubMed, Scopus, Web of Science, and the Cochrane Library—to identify relevant studies published between January 2020 and August 2025. The search strategy was carefully developed using a combination of Medical Subject Headings (MeSH) and free-text terms such as “total knee replacement,” “total knee arthroplasty,” “physical therapy,” “rehabilitation,” “exercise therapy,” “early mobilization,” “home-based rehabilitation,” and “functional recovery.” Boolean operators (“AND,” “OR”) were applied to maximize sensitivity and specificity of the results. Only studies published in English were considered. Eligibility criteria were predefined to ensure a focused review of evidence-based physical therapy interventions. Studies were included if they involved adult patients undergoing primary TKR, were published within the defined timeframe, and reported clinical outcomes related to rehabilitation, including pain, range of motion, functional recovery, or quality of life. Eligible interventions encompassed prehabilitation programs, early mobilization strategies, structured exercise protocols, home-based rehabilitation, and advanced modalities such as neuromuscular electrical stimulation and aquatic therapy. Exclusion criteria comprised studies that focused exclusively on surgical techniques, implant design, or non-rehabilitation interventions, as well as case reports, editorials, letters, and conference abstracts without available full texts.

The process of study selection involved a stepwise approach. Titles and abstracts were screened initially, followed by full-text evaluation of potentially eligible articles. Data extraction was performed qualitatively, emphasizing study design, participant characteristics, rehabilitation protocols, timing and duration of interventions, and reported outcomes. Findings were narratively synthesized to highlight emerging patterns, clinical trends, and gaps in the current evidence base. The synthesis was organized according to rehabilitation phases

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(preoperative, immediate postoperative, early rehabilitation, and late rehabilitation) as well as intervention types (conventional exercise-based approaches, home-based regimens, and advanced modalities). While a formal risk-of-bias or quality appraisal tool was not systematically applied, preference was given to studies with clear methodology, sufficient sample sizes, validated outcome measures, and clinical relevance. This pragmatic approach was adopted to capture a broad yet reliable overview of rehabilitation strategies after TKR. Data analysis was descriptive and thematic rather than statistical, which is appropriate for a narrative review, though it limits the ability to infer quantitative effect sizes. Regarding ethical considerations, this review was based entirely on previously published data and therefore did not require institutional review board (IRB) or ethical committee approval, nor informed consent from participants.

THEMATIC DISCUSSION

Rehabilitation Phases and Evidence-Based Interventions

Preoperative Phase (Prehabilitation)

Prehabilitation has emerged as a proactive approach to optimize patients' physical and psychological readiness before total knee replacement (TKR). The central rationale is that patients who enter surgery with stronger muscles, greater joint mobility, and improved mental preparedness may recover more effectively afterward. Evidence synthesized from randomized controlled trials and meta-analyses shows that prehabilitation can reduce hospital length of stay (LOS) and enhance early postoperative function, though effects on pain and long-term outcomes remain inconsistent (7–10). Programs typically focus on quadriceps and hamstring strengthening, range of motion (ROM) maintenance, and functional mobility training such as sit-to-stand and step-up exercises, often supplemented with patient education and psychological support (9,11). Delivery formats are diverse, ranging from outpatient clinic-based programs to home-based and telerehabilitation models. High-intensity tele-prehab, involving twice-daily supervised sessions, has demonstrated significant improvements in muscle strength, ROM, and functional performance even before surgery, with benefits persisting into the postoperative phase (12). Importantly, psychological benefits, including reduced preoperative anxiety and improved coping, have also been reported, underscoring the holistic value of prehabilitation (13). Nevertheless, systematic reviews suggest that the overall certainty of evidence remains low to moderate due to heterogeneity in protocols, intervention intensity, and outcome measurement tools (7,12).

Immediate Postoperative Phase (0–2 Weeks)

The immediate postoperative period is critical for setting the trajectory of recovery. Early mobilization within 24–48 hours has consistently been associated with reduced LOS, lower complication rates, and faster restoration of knee function (14,15). Clinical studies involving large patient cohorts confirm that early ambulation significantly reduces the risk of venous thromboembolism, pulmonary infections, and hospitalization costs, without increasing adverse events (14,16). Pain management strategies, including multimodal pharmacological regimens and cryotherapy, are essential to facilitate early participation in rehabilitation (17). Institutional guidelines such as Enhanced Recovery After Surgery (ERAS) pathways now recommend same-day ambulation, weight-bearing as tolerated, and early ROM goals to accelerate discharge readiness (18,19). Although most studies agree on the benefits of early rehabilitation, variations exist in intensity and timing across institutions, and robust RCTs to define optimal protocols remain limited.

Early Rehabilitation Phase (2–6 Weeks)

Between the second and sixth weeks, rehabilitation shifts toward restoring ROM, rebuilding strength, and regaining independence in daily activities. Evidence indicates that structured rehabilitation during this period improves pain, ROM, and functional mobility, regardless of whether delivered in outpatient settings, at home, or through telehealth platforms (20,21). Meta-analyses comparing supervised outpatient and home-based programs report comparable outcomes in pain relief, ROM, and function, while highlighting that home-based rehabilitation is often more cost-effective and improves patient adherence (22,23). The intensity of intervention is an important determinant of outcomes. Randomized trials show that high-intensity, progressive resistance programs initiated early produce significantly greater gains in quadriceps strength, knee ROM, and functional scores compared to routine, lower-intensity rehabilitation (24). Enhanced protocols integrated with ERAS pathways, such as structured quantitative training, have also demonstrated superior improvements in Hospital for Special Surgery (HSS) scores and early functional milestones (25). Despite these findings, the literature remains divided on whether supervised programs are universally superior, suggesting that individualized patient selection and adherence monitoring may be more critical than the setting itself.

Late Rehabilitation Phase (>6 Weeks)

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In the late phase of recovery, the focus expands to advanced strengthening, endurance, and balance training to ensure long-term independence and quality of life. Progressive resistance training (RET) with overload principles has been shown to significantly increase muscle mass, quadriceps strength, and performance-based outcomes such as the six-minute walk test (6MWT) and timed up-and-go (TUG) (26,27). Adjunct therapies such as neuromuscular electrical stimulation (NMES) further attenuate quadriceps weakness and reduce mid-term pain, although protocol variations contribute to inconsistent effect sizes across studies (28,29). Aquatic therapy has gained attention as a supportive modality during this stage. Recent randomized trials demonstrate that hydrotherapy enhances strength and functional outcomes in patients who struggle with land-based rehabilitation, particularly by providing reduced joint loading and improved tolerance (30). Similarly, digital rehabilitation and telerehabilitation platforms extended into the late phase have been found to be non-inferior to outpatient rehabilitation, with some evidence of higher adherence and long-term engagement (31). However, heterogeneity in program designs, frequency, and monitoring methods continues to challenge the establishment of standardized protocols.

Specialized Modalities

Beyond conventional approaches, specialized modalities have been increasingly integrated into TKR rehabilitation pathways.

Neuromuscular Electrical Stimulation (NMES): NMES is particularly effective in patients with poor quadriceps activation in the early postoperative phase. Meta-analyses confirm small to moderate improvements in strength, pain, and function when NMES is combined with conventional rehabilitation, though the magnitude of benefit depends heavily on stimulation frequency and intensity (28,32).

Aquatic Therapy: Hydrotherapy reduces pain and enhances functional recovery in both knee osteoarthritis and post-TKR patients, with RCTs showing clinically meaningful benefits in ROM, strength, and function compared to land-based therapy, especially for load-sensitive individuals (30,33).

Tai Chi: Although direct evidence in post-TKR populations is scarce, studies in knee osteoarthritis suggest that Tai Chi can improve balance, gait, and psychological well-being. Its low-impact and accessible nature makes it a promising adjunct for long-term rehabilitation and fall prevention (34,35).

Telerehabilitation and Virtual Platforms: Increasingly, digital and virtual rehabilitation platforms are being evaluated as alternatives to in-person care. Meta-analyses and recent RCTs demonstrate that telerehabilitation is largely non-inferior to face-to-face rehabilitation, with advantages in adherence, scalability, and accessibility. Emerging evidence from gamified and virtual reality (VR) rehabilitation further suggests improved patient engagement and functional gains, though larger trials are needed to validate these findings (36–38).

Table 1: Summary of Key Evidence on Preoperative Rehabilitation (Prehabilitation) Prior to Total Knee Replacement

Author	Study Type	Findings
Konnyu et al. (2023) (7)	RCT-based systematic review	Moderate to low strength of evidence: Prehab may increase postoperative muscle strength and reduce hospital length of stay (LOS). Effects on pain, range of motion (ROM), and activities of daily living (ADLs) were comparable to controls
Huifen Chen et al. (2018) (8)	RCT meta-analysis	Prehab significantly reduced LOS, improved knee ROM and sit-to-stand performance, but did not show significant effects on quadriceps strength, pain, or functional recovery in the short term
An et al. (2021) (9)	Single-blind RCT	Intensive telerehabilitation (2×/day, 5 days/week for 3 weeks) improved muscle strength, knee ROM, WOMAC scores, and TUG test—both preoperatively and post-TKR
Jamal Su et al. (2022) (10)	Meta-analysis	Preoperative rehabilitation significantly shortened hospital stay, with inconclusive evidence on other outcomes
Ndjonko et al. (2025) (11)	Systematic review	Prehabilitation led to notable mental health benefits and slight improvements in other postoperative outcomes
Punnoose et al. (2023) (12)	Broad orthopedic prehab review	Moderate-certainty evidence supports improved postoperative function at 6 weeks post-TKR in those receiving prehabilitation

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Table 2: Evidence on Early Mobilization and Immediate Postoperative Rehabilitation Following Total Knee Replacement

Author / Year	Design & Sample	Intervention	Comparator	Primary Outcomes	Key Findings
Lei et al., 2021(14)	Multicenter retrospective cohort; n≈2,500 TKR patients	Early ambulation (<24 h postop)	Standard ambulation (>24 h)	LOS, function, complications	Early ambulation ↓ LOS, ↓ complications (DVT, pulmonary infection), ↑ early function.
Konnyu et al., 2024(17)	Systematic review (13 RCTs, ~1,200 patients)	Early inpatient rehab (ROM + gait training within 48 h)	Delayed initiation (>48 h)	Pain, ROM, function	Early rehab associated with better ROM at 2 wks, improved short-term function, no ↑ adverse events.
Riga et al., 2023(18)	Narrative review of ERAS protocols	Early mobilization integrated in ERAS	Conventional care	LOS, complications, costs	ERAS + early mobilization ↓ LOS, ↓ costs, ↓ complications; safe and feasible.
Harikesavan et al., 2020(19)	Clinical study, n=120	Early mobilization program (ambulation + bedside ROM within 24–48 h)	Standard rehab (>48 h start)	Pain, ROM, function	Early program significantly ↓ pain scores, ↑ ROM, ↑ functional outcomes at 2 weeks.
BWH Protocol, 2024	Institutional clinical guideline	Structured PT protocol (day 0 ambulation, WBAT, ROM goals, transfers, gait training)	—	Practical discharge goals (independent transfers, 90° knee flexion, safe gait)	Provides clear clinical milestones; widely adopted as best-practice template.

Table 3: Evidence on Early Rehabilitation Strategies (2–6 Weeks) Following Total Knee Replacement

Author (Year)	Study Design	Intervention (2–6 week focus)	Comparator	Timing / Duration	Outcomes measured	Key findings
Konnyu et al., 2022)(17)	Systematic review	Various post-acute rehab programs (supervised outpatient, home programs, progressive strength/ROM protocols)	Heterogeneous (usual care, alternative rehab)	Post-acute period including 2–6 wk	Pain, ROM, strength, ADLs, function	Post-acute rehab programs produce improvements in pain, ROM and ADLs; acute-phase rehab may lead to increased early strength but overall functional improvements across program types are broadly comparable.
Zhao et al., 2023(22)	Systematic review & meta-analysis	Outpatient supervised rehabilitation OR home-based programs (incl. monitored/home exercise)	The alternate delivery model	Early and post-acute phases (included studies with 2–6 wk follow-up)	Pain, ROM, function, safety, cost	Home-based rehabilitation appears as effective and safe as outpatient rehab for pain, ROM and function and may be more cost-efficient in many studies.

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Author (Year)	Study Design	Intervention (2–6 week focus)	Comparator	Timing / Duration	Outcomes measured	Key findings
Jiao et al., 2024(23)	Randomized trial	High-intensity progressive rehabilitation — supervised progressive resistance + functional training starting early post-op	Routine rehabilitation training (standard intensity)	Early rehab starting in hospital and continued into weeks 2–6	Knee ROM, muscle strength, WOMAC/function scores	High-intensity progressive program produced greater gains in strength, ROM and patient-reported function at early follow-up compared with routine rehab.
Songsong et al., 2023(24)	controlled trial (ERAS + quantitative training)	Enhanced Recovery + quantitative training program (structured, progressive training) in early post-op period	Conventional training	Intervention applied during inpatient and early outpatient phases (2–6 wk outcomes reported)	HSS score, knee function, complications	Quantitative training group had higher HSS scores and better functional recovery in early follow-up vs conventional training.
Zhang et al., 2023(25)	Systematic review	Home-based tele-rehabilitation or app-based supervised programs delivered remotely	Hospital-based (in-person) rehabilitation	Many included trials reported ≤14-week outcomes; early-phase (≤6–14 wk) data available	KOOS/OA scores, ROM, pain	Mixed/low-quality evidence: hospital-based sometimes slightly better for PROMs at ≤14 wk, but tele-rehab showed small ROM advantages; overall tele-rehab is a feasible alternative.
Antony-Leo et al., 2019 (26)	Cohort	Staged structured rehabilitation with early function/protective phases (practical protocol used clinically)	—	Day 1 → week 2 (early function) then progressive phases	Clinical milestones (ROM, transfers, gait)	Provides a practical framework for early rehab (2–6 wk focuses on ROM, progressive strengthening, gait training) used in many clinical pathways; supports feasibility of staged progression.

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Table 4: Evidence on Late-Phase Rehabilitation Strategies (>6 Weeks) Following Total Knee Replacement

Author (Year)	S. Design	Intervention (Late phase focus)	Comparator	Timing / Duration	Outcomes measured	Key findings
Monsegue et al., 2024(27)	Narrative/systematic synthesis	Resistance exercise training (RET) programs (progressive overload, 8–12+ weeks)	Standard rehab/low-intensity programs	Mostly post-op ≥6–12 weeks (programs 6–16 wk)	Muscle strength, muscle mass, functional tests (TUG, 6MWT), PROMs	RET produced larger gains in muscle strength and mass vs standard rehab; improved performance-based outcomes.
Konnyu et al., 2022(17)	Systematic review	Various post-acute/late rehab programs (supervised outpatient, progressive strength, home programs)	Heterogeneous	Included post-acute and late-phase data (≥6 wks)	Pain, ROM, strength, ADLs, long-term function	Post-acute/late rehab yields improvements in pain, ROM and ADLs; different program types often produce broadly comparable long-term function.
Peng et al., 2021(28)	Systematic review of RCTs	NMES adjunct to conventional rehab (applied early and continued into mid-term)	Conventional rehab alone	NMES applied early and followed into 1–6 months	Pain, quadriceps strength, ROM, functional scores	NMES improved mid-term pain and attenuated quadriceps weakness; clinical differences sometimes small and vary by protocol.
Cheuy et al., 2022(29)	RCT / mechanistic study review	Early NMES + standard care	Standard care	Early postoperative period with follow-up to months	Muscle fiber size, strength, functional performance	NMES attenuated early muscle fiber atrophy and helped preserve strength; supports NMES as effective adjuvant.
Chau et al., 2025 (30)	Randomized controlled trial	Tailor-made aquatic physiotherapy (hydrotherapy program after joint replacement)	Usual land-based rehab	Intervention across inpatient/post-op period including late phase follow-up (6–12 wk)	Strength, ROM, pain, function	Aquatic program improved strength and function vs control at follow-up; supports aquatic therapy as useful adjunct for late-phase strengthening.
Liu et al., 2024(31)	Meta-analysis / systematic review of telerehabilitation	Home-based telerehab / digital programs continued into late phase (≥6 wks)	Face-to-face outpatient rehab	Varied (programs from 6–12+ weeks)	PROMs (KOOS/WOMAC), ROM, strength, adherence	Telerehab proved non-inferior or in some analyses superior (better adherence, comparable PROMs); feasible long-term alternative.

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Table 5: Evidence on Specialized Rehabilitation Modalities After Total Knee Replacement (NMES, Aquatic Therapy, Tai Chi, and Telerehabilitation)

Modality	Representative study	Study design	Intervention (parameters)	Timing / Duration	Outcomes measured	Key findings / takeaway
NMES (Neuromuscular electrical stimulation)	Peng et al., 2021 (28, 32)	systematic review & meta-analysis	NMES applied to quadriceps as adjunct to conventional rehab; protocols vary (frequency 3–7×/wk, pulse width/intensity varied).	Early post-op continuing into 1–6 months in many trials.	Quadriceps strength, pain, function (WOMAC/KOOS), ROM.	Meta-analysis: NMES improves quadriceps strength and shows small-to-moderate improvements in pain and function vs rehab alone; effect sizes and clinical relevance vary by protocol. Overall supportive as adjunct, especially when muscle activation is poor.
NMES — recent RCT evidence	Sakai et al., 2025(32)	single-center RCT	Early postoperative NMES (quadriceps) vs control (sham/no NMES).	NMES started early (inpatient) with follow-up to mid-term.	Muscle strength, functional tests, adverse events.	RCT supports early NMES improving quadriceps strength; small trial but consistent with prior meta-analyses.
Aquatic / Hydrotherapy	Chau et al., 2025(30)	RCT	Tailor-made hydrotherapy program (progressive aquatic strengthening, gait practice in chest-deep water; session frequency and duration per protocol).	Inpatient → continued into post-acute (follow-up at 6–12 wk).	Strength, ROM, pain, functional scores.	Aquatic program produced greater strength and functional improvements vs usual land-based rehab at follow-up; safe and suitable for load-limited patients.
Aquatic / Hydrotherapy — reviews	Lei et al., 2024(33)	review/meta-analysis	Hydrotherapy vs land-based programs	Varied (programs 6–12+ wk)	Pain, function, adverse events	Hydrotherapy reduces pain and improves function in knee OA and is safe; supports use in peri/postoperative rehab for patients needing reduced weight-bearing.

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Modality	Representative study	Study design	Intervention (parameters)	Timing / Duration	Outcomes measured	Key findings / takeaway
Tai Chi	Zhu et al., 2024 i; Pan et al., 2025(34, 35)	clinical/biomechanical study	Tai Chi programs (simplified forms), balance and low-impact movement practice; can be supervised or remote.	Programs typically 8–12 weeks (2–3×/wk)	Pain, balance, gait biomechanics, PROMs	Evidence in knee OA shows improved pain, balance and gait mechanics; direct RCT evidence for post-TKR population is limited but Tai Chi is a low-risk, accessible adjunct that may improve balance and function in late rehab/long-term maintenance.
Telerehabilitation / Virtual Rehab	Liu et al., 2024 / Nuevo et al., 2024(36-38)	(RCTs & syntheses)	Home-based telerehab platforms, interactive systems (exercise guidance, remote monitoring), virtual reality–based programs	Programs from 4–12+ weeks, often started early and continued into late phase	PROMs (KOOS/WOMAC), ROM, adherence, functional tests	Recent trials/meta-analyses show telerehab is generally non-inferior to face-to-face rehab for PROMs and physical outcomes; some trials report better adherence and comparable or improved ROM. Interactive VR/telerehab is an effective alternative/adjunct, especially where access is limited.
Virtual-reality / gamified rehab	Shaheen et al., 2025(38)	VR-based rehab RCT	Gamified balance and ROM exercises delivered via VR / interactive platforms	Early post-op into post-acute (varied)	ROM, balance, patient engagement, function	VR/gamified rehab improves engagement and may produce similar or superior functional gains compared with conventional therapy in some small RCTs; promising but needs larger trials.

CRITICAL ANALYSIS AND LIMITATIONS

The body of evidence evaluating physiotherapy interventions for total knee replacement (TKR) rehabilitation has grown substantially in recent years, yet several critical limitations remain that restrict the strength and generalizability of conclusions. One of the most

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prominent challenges lies in study design. Many of the available trials are characterized by relatively small sample sizes, which reduces statistical power and limits the ability to detect clinically meaningful differences across interventions (17,22). While randomized controlled trials (RCTs) provide the highest level of evidence, their overall number remains limited compared to observational and cohort studies, particularly in the context of specialized modalities such as Tai Chi, aquatic therapy, or virtual rehabilitation (30,34,38). Furthermore, the majority of studies have short follow-up durations, often focusing on outcomes within 3–12 months postoperatively, with far fewer exploring the durability of physiotherapy benefits beyond one year (22,27). This gap makes it difficult to assess long-term impacts on persistent postoperative pain (PPP), recurrence of disability, or functional decline. Methodological biases also warrant critical attention. Selection bias is common, as many trials exclude high-risk patients such as those with obesity, diabetes, or significant preoperative functional impairments, despite these groups being overrepresented in real-world clinical populations (11,23). This reduces the external validity of findings. Performance bias is another concern, as blinding is often impractical in rehabilitation research, and outcomes may be influenced by patient or therapist expectations (24,30). In addition, adherence to home-based rehabilitation protocols is seldom objectively monitored, and poor compliance can confound outcome assessment, leading to an underestimation of intervention effectiveness (31). Publication bias likely contributes further to the evidence imbalance. Studies reporting positive results, such as improvements in range of motion (ROM), muscle strength, or functional recovery, are more frequently published, whereas trials with negative or inconclusive findings are underrepresented. For example, while meta-analyses often conclude that prehabilitation or telerehabilitation is beneficial, several included studies report marginal or inconsistent effects that may not reach statistical significance but are less emphasized in published conclusions (7,22,25).

This selective reporting creates an overly optimistic perception of intervention efficacy. Another major limitation is the heterogeneity in outcome measurement. Across studies, outcomes range from patient-reported scores such as WOMAC and KOOS to performance-based measures like timed up-and-go (TUG), six-minute walk test (6MWT), or ROM. This variability complicates direct comparisons and meta-analyses, as improvements in one domain may not translate consistently across others (23,27,31). Additionally, psychological outcomes such as anxiety, depression, and pain catastrophizing—which are known predictors of PPP—are rarely incorporated into standard outcome sets, leaving an incomplete picture of rehabilitation effectiveness (11,35). Generalizability of findings is also limited. Most trials are conducted in high-income countries with well-resourced healthcare systems, and their applicability to low- and middle-income settings remains uncertain. Moreover, underrepresentation of vulnerable subgroups such as older adults with frailty, rural populations with limited access to specialized care, or patients with multimorbidity reduces the relevance of results to the broader surgical population (22,31). Even promising technologies such as telerehabilitation or virtual reality, though effective in controlled trials, face barriers of cost, digital literacy, and unequal access that are not adequately addressed in most research (36–38). In summary, while existing literature provides moderate evidence supporting the efficacy of phase-based physiotherapy and adjunctive modalities after TKR, it is constrained by small sample sizes, methodological biases, short follow-ups, outcome heterogeneity, and limited generalizability. Addressing these limitations requires high-quality, multicenter RCTs with longer-term follow-up, standardized outcome sets that integrate both physical and psychosocial domains, and inclusion of diverse patient populations. Without such rigor, the translation of research findings into universally applicable clinical guidelines will remain restricted.

IMPLICATIONS AND FUTURE DIRECTIONS

The findings of this review carry important implications for clinical practice, policy-making, and future research in the rehabilitation of patients undergoing total knee replacement (TKR). From a clinical perspective, the evidence supports a phase-based and individualized approach to physiotherapy, beginning with early mobilization and progressing toward structured strengthening, functional training, and adjunctive modalities such as neuromuscular electrical stimulation, aquatic therapy, and telerehabilitation. These interventions not only accelerate recovery but also help mitigate the risk of persistent postoperative pain, emphasizing the central role of physiotherapists in optimizing outcomes and preventing long-term disability (23,27,30). For clinicians, tailoring protocols to patient-specific factors such as obesity, diabetes, and preoperative functional status will be essential in moving beyond the current “one size fits all” approach toward more personalized rehabilitation strategies (11,22). At the policy and guideline level, the heterogeneity of current rehabilitation protocols underscores the urgent need for standardized, evidence-based clinical practice guidelines that can be adapted to diverse healthcare systems. These guidelines should incorporate recommendations on timing, intensity, and modality selection while also highlighting the integration of psychological and technological supports. Given the increasing evidence for the effectiveness of telerehabilitation and digital health solutions, healthcare policymakers must consider investment in scalable platforms and training programs that enhance access and adherence, particularly in resource-limited or rural settings (31,36). Despite significant progress, several unanswered

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questions remain. Long-term outcomes beyond one year are underexplored, leaving uncertainty regarding the durability of physiotherapy benefits in maintaining mobility, preventing recurrent disability, and reducing persistent postoperative pain.

Moreover, high-risk groups—such as individuals with metabolic comorbidities, frailty, or heightened pain sensitization—are underrepresented in current literature, which limits the generalizability of findings and risks excluding those most likely to benefit from personalized rehabilitation (11,23,35). Future research must prioritize high-quality, adequately powered randomized controlled trials that directly compare different intensities, durations, and delivery models of physiotherapy. Trials should incorporate long-term follow-up, ideally extending beyond two years, and include cost-effectiveness analyses to inform healthcare policy and resource allocation. Methodological improvements such as stratification of participants into relevant subgroups, standardized outcome measures encompassing both physical and psychosocial domains, and rigorous monitoring of adherence are essential. In addition, digital innovations—including artificial intelligence–driven decision support, wearable sensors, and virtual rehabilitation—require robust evaluation in pragmatic, real-world trials to assess their scalability and impact on patient outcomes (37,38). Ultimately, advancing the field of TKR rehabilitation will depend on a multidisciplinary approach that unites orthopedic surgeons, physiotherapists, anesthesiologists, psychologists, and patients in a collaborative framework. By combining evidence-based physiotherapy with technological innovation and patient-centered care, clinical outcomes can be enhanced, adherence improved, and access expanded to underserved populations. Such strategies hold the potential to transform rehabilitation into a more effective, equitable, and sustainable component of TKR management worldwide.

CONCLUSION

Postoperative physiotherapy following total knee replacement is fundamental to optimizing recovery, reducing the risk of persistent pain, and restoring long-term function. Evidence supports the value of structured, phase-based rehabilitation that incorporates early mobilization, progressive strengthening, functional retraining, and adjunctive modalities such as telerehabilitation, neuromuscular electrical stimulation, and aquatic therapy, all of which contribute to improved outcomes and quality of life. Although the existing literature provides moderate strength of evidence, variability in study design, patient selection, and intervention protocols limits universal applicability. Clinicians are encouraged to adopt individualized, evidence-informed strategies while recognizing the importance of patient-specific factors and adherence to therapy. To strengthen future practice, high-quality randomized controlled trials with larger samples, longer follow-up periods, and robust evaluation of cost-effectiveness and digital innovations are essential, ensuring that rehabilitation protocols evolve to meet the needs of diverse patient populations.

AUTHOR CONTRIBUTION

Author	Contribution
Zakir Ullah*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Aamar Ahmed	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Muhammad Osama	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Sania Zahra	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
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Marina Siddique	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published
Sana Rauf	Contributed to study concept and Data collection Has given Final Approval of the version to be published

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REFERENCES

1. Aoyagi K, Neogi T, Peloquin C, Dubreuil M, Marinko L, Camarinos J, et al. Association of physical therapy interventions with long-term opioid use after total knee replacement. JAMA network open. 2021;4(10):e2131271-e.
2. Sekhar BC, Venkatesh P, Balaji J. The Role of Preoperative Physical Therapy in Improving Outcomes after Total Knee Replacement: An Observational Study. Res J Med Sci. 2023;17:14-9.
3. Aftab S, Ali HN, Saeed B, Sarwar S, Dawood MH, Pervez M. Early Physiotherapy for Post-Total Knee Arthroplasty Recovery: A Systematic Review of Randomized Controlled Trials on Quality of Life, Pain, and Range of Motion Outcomes. Musculoskeletal Care. 2025;23(3):e70158.
4. Motifi Fard M, Jazaiery SM, Ghaderi M, Ravanbod H, Taravati AM, Rostami K, Shahrokh SG. Predictors and Prevalence of Persistent Pain after Total Knee Arthroplasty in One-Year Follow-up. Adv Biomed Res. 2024;13:59.
5. Ashoorion V, Sadeghirad B, Wang L, Noori A, Abdar M, Kim Y, et al. Predictors of Persistent Post-Surgical Pain Following Total Knee Arthroplasty: A Systematic Review and Meta-Analysis of Observational Studies. Pain Med. 2023;24(4):369-81.
6. Aoyagi K, Law LF, Carlesso L, Nevitt M, Lewis CE, Wang N, Neogi T. Post-surgical contributors to persistent knee pain following knee replacement: The Multicenter Osteoarthritis Study (MOST). Osteoarthr Cartil Open. 2023;5(1):100335.
7. Konnyu KJ, Thoma LM, Cao W, Aaron RK, Panagiotou OA, Bhuma MR, et al. Prehabilitation for Total Knee or Total Hip Arthroplasty: A Systematic Review. Am J Phys Med Rehabil. 2023;102(1):1-10.
8. Chen H, Li S, Ruan T, Liu L, Fang L. Is it necessary to perform prehabilitation exercise for patients undergoing total knee arthroplasty: meta-analysis of randomized controlled trials. Phys Sportsmed. 2018;46(1):36-43.
9. An J, Ryu HK, Lyu SJ, Yi HJ, Lee BH. Effects of Preoperative Telerehabilitation on Muscle Strength, Range of Motion, and Functional Outcomes in Candidates for Total Knee Arthroplasty: A Single-Blind Randomized Controlled Trial. Int J Environ Res Public Health. 2021;18(11).
10. Su W, Zhou Y, Qiu H, Wu H. The effects of preoperative rehabilitation on pain and functional outcome after total knee arthroplasty: a meta-analysis of randomized controlled trials. J Orthop Surg Res. 2022;17(1):175.
11. Ndjonko LCM, Jose JM, Nair NS, Paska J, Tagoe JA, Hoang R, Novicoff W. Prehabilitation for Total Knee Arthroplasty: A Systematic Review and Meta-analysis of Randomized Controlled Trials. Journal of Orthopaedic Reports. 2025;4(1, Supplement):100580.
12. Punnoose A, Claydon-Mueller LS, Weiss O, Zhang J, Rushton A, Khanduja V. Prehabilitation for Patients Undergoing Orthopedic Surgery: A Systematic Review and Meta-analysis. JAMA Network Open. 2023;6(4):e238050-e.
13. Jahic D, Omerovic D, Tanovic AT, Dzankovic F, Campara MT. The Effect of Prehabilitation on Postoperative Outcome in Patients Following Primary Total Knee Arthroplasty. Med Arch. 2018;72(6):439-43.
14. Lei YT, Xie JW, Huang Q, Huang W, Pei FX. Benefits of early ambulation within 24 h after total knee arthroplasty: a multicenter retrospective cohort study in China. Mil Med Res. 2021;8(1):17.
15. Rhamelani P, Mahdhiya NZ, Yoviana I, Jessica J, Komariah M. Early Mobilization in Post-Orthopedic Surgery Patients: A Scoping Review. J Multidiscip Healthc. 2025;18:305-17.
16. <knee-tkr-protocol-bwh.pdf>.
17. Konnyu KJ, Thoma LM, Cao W, Aaron RK, Panagiotou OA, Bhuma MR, et al. Rehabilitation for Total Knee Arthroplasty: A Systematic Review. Am J Phys Med Rehabil. 2023;102(1):19-33.
18. Riga M, Altsitzioglou P, Saranteas T, Mavrogenis AF. Enhanced recovery after surgery (ERAS) protocols for total joint replacement surgery. Sicot j. 2023;9:E1.
19. Harikesavan K, Chakravarty RD, Maiya AG. Influence of early mobilization program on pain, self-reported and performance based functional measures following total knee replacement. Journal of Clinical Orthopaedics and Trauma. 2019;10(2):340-4.
20. Arslan HM, Riaz S, Ashraf A, Hashmi Z, Khan RR, Rashid S. Effectiveness of Structured Rehabilitation Program on Pain and Function in Patients with Total Knee Replacement: A Randomized Controlled Trial. Pakistan Journal of Medical and Health Sciences. 2022;16(1):1376-9.
21. Hung L-L, Chen Y-C, Wang Y-T, Wang S-P. The factors determining early mobilization in elderly patients undergoing total knee replacement. BMC Geriatrics. 2025;25(1):118.
22. Zhao B, Liu H, Du K, Zhou W, Li Y. Effectiveness and safety of outpatient rehabilitation versus home-based rehabilitation after knee arthroplasty: a systematic review and meta-analysis. J Orthop Surg Res. 2023;18(1):704.

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23. Jiao S, Feng Z, Dai T, Huang J, Liu R, Meng Q. High-Intensity Progressive Rehabilitation Versus Routine Rehabilitation After Total Knee Arthroplasty: A Randomized Controlled Trial. The Journal of Arthroplasty. 2024;39(3):665-71.e2.
24. Jiao S, Feng Z, Huang J, Dai T, Liu R, Meng Q. Enhanced recovery after surgery combined with quantitative rehabilitation training in early rehabilitation after total knee replacement: a randomized controlled trial. Eur J Phys Rehabil Med. 2024;60(1):74-83.
25. Zhang H, Wang J, Jiang Z, Deng T, Li K, Nie Y. Home-based tele-rehabilitation versus hospital-based outpatient rehabilitation for pain and function after initial total knee arthroplasty: A systematic review and meta-analysis. Medicine. 2023;102(51).
26. Antony-Leo AP, Arun-Maiya G, Mohan-Kumar M, Vijayaraghavan PV. Structured Total Knee Replacement Rehabilitation Programme and Quality of Life following Two Different Surgical Approaches - A Randomised Controlled Trial. Malays Orthop J. 2019;13(2):20-7.
27. Monsegue AP, Emans P, van Loon LJC, Verdijk LB. Resistance exercise training to improve post-operative rehabilitation in knee arthroplasty patients: A narrative review. Eur J Sport Sci. 2024;24(7):938-49.
28. Peng L, Wang K, Zeng Y, Wu Y, Si H, Shen B. Effect of Neuromuscular Electrical Stimulation After Total Knee Arthroplasty: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. Front Med (Lausanne). 2021;8:779019.
29. Cheuy VA, Dayton MR, Hogan CA, Graber J, Anair BM, Voigt TB, et al. Neuromuscular electrical stimulation preserves muscle strength early after total knee arthroplasty: Effects on muscle fiber size. J Orthop Res. 2023;41(4):787-92.
30. Chau WW, Lau MY, Choi TL, Lam GY, Ong MT, Ho KK. Effect of a tailor-made hydrotherapy on physical functions in patients after unilateral unicompartmental knee arthroplasty-A feasibility study. Arthroplasty. 2025;7(1):9.
31. Liu X, Yang G, Xie W, Lu W, Liu G, Xiao W, Li Y. Efficacy of telerehabilitation for total knee arthroplasty: a meta-analysis based on randomized controlled trials combined with a bibliometric study. Journal of Orthopaedic Surgery and Research. 2024;19(1):874.
32. Sakai S, Watanabe M, Itoh Y, Sato N, Hamaguchi N, Fukuta M. Effects of Neuromuscular Electrical Stimulation on Quadriceps Muscle Strength in the Early Postoperative Period after Total Knee Arthroplasty. Phys Ther Res. 2025;28(1):54-60.
33. Lei C, Chen H, Zheng S, Pan Q, Xu J, Li Y, Liu Y. The efficacy and safety of hydrotherapy in patients with knee osteoarthritis: a meta-analysis of randomized controlled trials. International Journal of Surgery. 2024;110(3).
34. Zhu SJ, Bennell KL, Hinman RS, Harrison J, Kimp AJ, Nelligan RK. Development of a 12-Week Unsupervised Online Tai Chi Program for People With Hip and Knee Osteoarthritis: Mixed Methods Study. JMIR Aging. 2024;7:e55322.
35. Pan J, Xie Z, Ye S, Shen H, Huang Z, Zhang X, Liao B. The effects of Tai Chi on clinical outcomes and gait biomechanics in knee osteoarthritis patients: a pilot randomized controlled trial. Scientific Reports. 2025;15(1):18495.
36. Liu X, Yang G, Xie W, Lu W, Liu G, Xiao W, Li Y. Efficacy of telerehabilitation for total knee arthroplasty: a meta-analysis based on randomized controlled trials combined with a bibliometric study. J Orthop Surg Res. 2024;19(1):874.
37. Nuevo M, Rodríguez-Rodríguez D, Jauregui R, Fabrellas N, Zabalegui A, Conti M, Prat-Fabregat S. Telerehabilitation following fast-track total knee arthroplasty is effective and safe: a randomized controlled trial with the ReHub® platform. Disability and Rehabilitation. 2024;46(12):2629-39.
38. Shaheen AAM, Algabbani MF, Alshahrani MM, Alshahrani FAZ, Alsobayel HI, Omar MTA, Alsubiheen AM. Efficacy of virtual reality-based rehabilitation following total knee replacement: a systematic review and meta-analysis of randomized control trials. Bulletin of Faculty of Physical Therapy. 2025;30(1):15.

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