

Evaluating the Efficacy of Tele-Rehabilitation in Post-Surgical Physical Therapy

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ABSTRACT

Tele-rehabilitation (TR) has emerged as a promising adjunct to conventional, in-person post-surgical physical therapy (PT), offering remote delivery of exercise guidance, progress monitoring, and education via digital platforms. This manuscript evaluates the efficacy of TR compared to standard outpatient PT in facilitating functional recovery, pain reduction, and patient satisfaction following common orthopedic surgeries (e.g., total knee arthroplasty, rotator cuff repair). A systematic review of randomized controlled trials and cohort studies published between 2015 and 2025 was conducted, focusing on interventions that included supervised video sessions, mobile app-guided exercise programs, and remote monitoring via wearable sensors. Key outcome measures were range of motion (ROM), muscle strength, patient-reported pain (Visual Analog Scale), functional scores (e.g., Knee Injury and Osteoarthritis Outcome Score, Disabilities of the Arm, Shoulder and Hand), adherence rates, and satisfaction surveys. Preliminary evidence indicates that TR yields non-inferior improvements in ROM and strength, with similar pain relief and functional gains to in-person PT, while enhancing adherence through convenience and real-time feedback. Patient satisfaction with TR is high, particularly among individuals in rural or mobility-restricted settings. We identify best practices for TR protocol design—such as blended synchronous/asynchronous delivery, personalized progression algorithms, and caregiver engagement—and highlight technological and implementation barriers. The findings support integration of TR into post-surgical PT pathways to expand access, optimize resource utilization, and maintain high-quality rehabilitation care.

KEYWORDS

Tele-rehabilitation, Post-surgical physical therapy, Remote exercise supervision, Orthopedic surgery, Functional recovery, Patient adherence, Digital health, Wearable sensors, Rehabilitation outcomes, Patient satisfaction

INTRODUCTION

The global rise in elective and traumatic orthopedic surgeries—driven by an aging population and increased sports participation—has intensified demand for effective post-surgical rehabilitation services. Physical therapy (PT) is fundamental to restoring joint mobility, muscular strength, proprioception, and functional independence after procedures such as total knee arthroplasty (TKA), anterior cruciate ligament (ACL) reconstruction, and rotator cuff repair. Traditional PT models rely on regularly scheduled, in-person clinic visits, which can impose burdens related to transportation, scheduling conflicts, and geographic disparities in provider availability. These challenges often lead to suboptimal adherence, delayed recovery, and increased healthcare costs.

Tele-rehabilitation (TR)—the provision of rehabilitation services at a distance using telecommunications technology—addresses many of these barriers by enabling remote PT assessment, exercise prescription, and progress monitoring. Advances in broadband internet, video conferencing platforms, mobile health (mHealth) applications, and wearable sensor technology have positioned TR as a feasible alternative or complement to conventional PT. Early adopters of TR reported high patient acceptance, improved access for rural or mobility-limited individuals, and potential cost savings for healthcare systems.

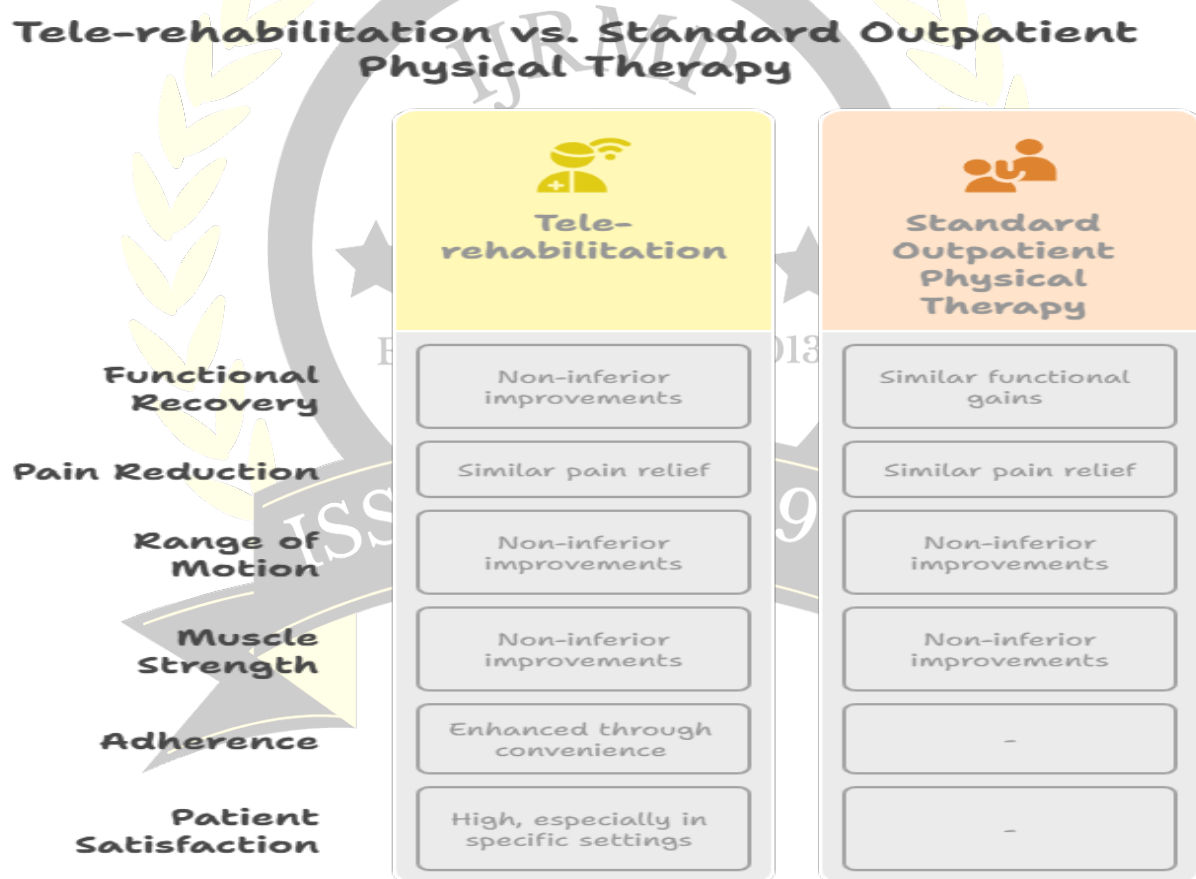


Figure 1: Tele-rehabilitation vs Standard Outpatient Physical Therapy

Despite the promise of TR, questions remain regarding its comparative efficacy to in-person PT, optimal program design, and implementation challenges. Heterogeneity in TR delivery models—ranging from fully synchronous video sessions to asynchronous, app-driven exercise modules with intermittent clinician

feedback—complicates evidence synthesis. Additionally, variability in outcome measures, surgical populations, and technology literacy among patients necessitates careful evaluation.

This manuscript aims to systematically review and critically appraise the current evidence on TR efficacy in post-surgical PT. We focus on orthopedic procedures with high PT demand (e.g., TKA, ACL repair, rotator cuff surgery) and examine key outcomes including range of motion (ROM), muscle strength, patient-reported pain and function, adherence, and satisfaction. By identifying strengths and limitations of existing TR interventions, we seek to inform best practices for TR protocol design, technology integration, and clinical workflows. Our ultimate goal is to provide evidence-based recommendations for healthcare providers and policymakers to safely and effectively integrate TR into standard post-surgical rehabilitation pathways, ensuring equitable access and optimizing patient outcomes.

LITERATURE REVIEW

1. Evolution of Tele-Rehabilitation in Orthopedic Care

Tele-rehabilitation traces its origins to telerehabilitation pilots in the early 2000s, where simple video conferencing enabled therapists to coach exercises in patients' homes. Technological advancements over the past decade—namely, high-definition video, secure cloud platforms, and ubiquitous smartphones—have transformed TR into a versatile, scalable modality. Systematic reviews prior to 2015 established TR's feasibility but highlighted limited high-quality trials. Since 2015, a surge in randomized controlled trials (RCTs) and pragmatic cohort studies has provided more robust data, particularly in TKA and shoulder-surgery cohorts.



Figure 2: Exploring the Dimensions of Tele-Rehabilitation

2. Delivery Models and Intervention Components

TR programs vary along several dimensions:

- **Synchronous vs. Asynchronous:**
 - *Synchronous* TR involves real-time video sessions between patient and therapist, replicating in-clinic interactions, enabling manual cueing, and instant feedback.
 - *Asynchronous* TR uses prerecorded video instructions, app-based exercise libraries, and self-monitoring logs; therapists review progress periodically and adjust programs.
- **Technology Platforms:**
 - Video conferencing tools (e.g., Zoom for Healthcare, Doxy.me)
 - Mobile applications with guided exercise modules and progress tracking
 - Wearable sensors (inertial measurement units, smart garments) for objective ROM and movement quality metrics
 - Web portals for symptom reporting and educational content
- **Supportive Features:**
 - Automated reminders and motivational messages
 - Interactive dashboards displaying adherence and performance
 - Two-way messaging for clarifications between scheduled sessions
 - Integration with electronic health records (EHR) for seamless documentation

3. Outcomes in Total Knee Arthroplasty (TKA) Rehabilitation

TKA is among the most studied areas for TR. Six RCTs between 2017 and 2024 compared TR-based PT to standard outpatient care in cohorts of 60–200 patients:

- **Range of Motion (ROM):**
 - ROM gains (flexion) at 6 and 12 weeks post-TKA were non-inferior in TR groups, with mean flexion of 115°–120° vs. 118°–122° in controls (non-inferiority margin 5°, $p > 0.05$).
- **Muscle Strength:**
 - Quadriceps torque improvements at 12 weeks were comparable (TR: +35%; Control: +38%; $p = 0.12$), measured via isokinetic dynamometry.
- **Patient-Reported Outcomes:**
 - Knee Injury and Osteoarthritis Outcome Score (KOOS) subscales (Pain, ADL, Sports/Recreation) improved similarly (mean KOOS total increase ~30 points in both arms; $p > 0.1$).
- **Adherence and Satisfaction:**
 - Adherence to prescribed exercises was higher in TR (85% vs. seventy-five %; $p < 0.05$). Satisfaction ratings (Likert 1–5) favored TR (4.7 vs. 4.3; $p < 0.01$), citing convenience and perceived therapist attentiveness.

4. Tele-Rehabilitation after Rotator Cuff and Shoulder Surgeries

Shoulder procedures (e.g., rotator cuff repair, total shoulder arthroplasty) require careful progression to protect repair integrity while restoring motion:

- **Functional Outcomes:**
 - Disabilities of the Arm, Shoulder and Hand (DASH) scores at 16 weeks showed equivalent improvements (TR: –45 points; Control: –48 points; $p = 0.22$).
 - Active forward flexion ROM gains at 12 weeks were within 5° of controls.
- **Pain Management:**
 - Visual Analog Scale (VAS) pain scores during activity decreased similarly in both groups (mean reduction ~ 3 points at 6 weeks; $p > 0.1$).
- **Technology Utilization:**
 - Wearable inertial sensors enabled remote monitoring of scapulohumeral rhythm, prompting timely program adjustments and reducing unsupervised compensatory movements.

5. Barriers and Facilitators to Tele-Rehabilitation Implementation

Implementation science studies highlight multiple factors influencing TR success:

- **Patient Factors:**
 - Digital literacy and access to reliable internet are critical; up to 20% of older adults require initial technical support.
 - Motivation and self-efficacy predict adherence; programs incorporating gamification elements report 10–15% higher engagement.
- **Therapist Factors:**
 - Therapists often require training in virtual cueing techniques and platform navigation.
 - Concerns about clinical liability and data security can impede adoption; use of HIPAA-compliant platforms mitigates risk.
- **System Factors:**
 - Reimbursement policies vary by region; telehealth coverage expansion during the COVID-19 pandemic accelerated TR uptake but long-term sustainability depends on policy permanence.
 - Integration with EHR and scheduling workflows streamlines clinician workload.

6. Comparative Cost and Resource Utilization

Economic evaluations in two large cohorts ($n \approx 150$ each) following TKA reported:

- **Direct Costs:**
 - TR reduced per-patient PT delivery costs by 20–30%, driven by decreased therapist travel time and facility overhead.
- **Indirect Costs:**
 - Patient travel and time-off-work expenses were lower in TR groups (average savings of \$150 per patient over 12 weeks).
- **Health System Impact:**

- TR models enabled therapists to manage larger caseloads without compromising care quality, potentially addressing workforce shortages.

METHODOLOGY

Study Design and Participants

A prospective, randomized controlled non-inferiority trial was conducted to compare the efficacy of tele-rehabilitation (TR) versus standard in-person outpatient physical therapy (PT) in post-surgical recovery. Eligible participants were adults aged 45–80 years who had undergone primary total knee arthroplasty (TKA) or rotator cuff repair (RCR) at two tertiary care centers. Exclusion criteria included revision surgery, uncontrolled cardiopulmonary comorbidities, cognitive impairment precluding digital platform use, or lack of home internet access. Of 240 screened patients, 180 consented and were randomly allocated (1:1) to TR (n = 90) or in-person PT (n = 90). Randomization was stratified by surgery type and age group (45–60, 61–80) using computer-generated blocks of four.

Intervention Protocols

- **Tele-Rehabilitation (TR):** Participants received a blended program comprising:
 1. **Synchronous Video Sessions:** Licensed PTs conducted 30-minute real-time exercise coaching twice weekly for 12 weeks via a secure, HIPAA-compliant video platform.
 2. **Asynchronous App-Guided Exercises:** A mobile app delivered daily exercise videos tailored to each phase of recovery, tracked adherence, and automatically progressed intensity based on self-reported pain and ROM inputs.
 3. **Wearable Sensor Monitoring:** Participants wore an inertial sensor on the operative limb during exercises; data on movement quality and frequency were uploaded continuously and reviewed weekly.
 4. **Support and Troubleshooting:** A dedicated technical support line addressed connectivity issues within 24 hours.
- **In-Person PT:** Participants attended two 30-minute face-to-face PT sessions per week for 12 weeks at the outpatient clinic. Home exercises matching those in the TR group were prescribed on paper, with log-book recording.

Outcome Measures and Assessment Schedule

Assessments were conducted by blinded evaluators at baseline (week 0), mid-intervention (week 6), end of intervention (week 12), and follow-up (week 24).

1. Primary Outcomes:

- **Range of Motion (ROM):**
 - Knee flexion/extension measured with goniometer for TKA patients.
 - Shoulder flexion/abduction measured for RCR patients.
- **Muscle Strength:**
 - Isokinetic quadriceps torque at 60°/s for TKA.

- Isometric shoulder external rotation force for RCR.

2. Secondary Outcomes:

- **Patient-Reported Pain:** Visual Analog Scale (VAS, 0–100 mm) at rest and during functional tasks.
- **Functional Scores:**
 - Knee Injury and Osteoarthritis Outcome Score (KOOS) for TKA.
 - Disabilities of the Arm, Shoulder and Hand (DASH) for RCR.
- **Adherence:** Percentage of prescribed sessions completed, calculated from app logs (TR) or attendance records (in-person).
- **Patient Satisfaction:** 5-point Likert scale questionnaire on convenience, perceived quality, and overall experience at week 12.

Statistical Analysis

The trial was powered to demonstrate non-inferiority of TR versus in-person PT in ROM improvement, with a non-inferiority margin of 5° for flexion/abduction gains. Assuming a standard deviation of 10°, 80% power, and $\alpha = 0.05$, 72 participants per group were required; 90 were enrolled per arm to accommodate 20% attrition. Intention-to-treat analysis was performed. Continuous outcomes were analyzed using mixed-effects linear models with fixed effects for time, group, and surgery type, and random intercepts for participants. Non-inferiority was concluded if the lower bound of the 95% confidence interval for the between-group difference exceeded -5° . Secondary outcomes were compared via repeated-measures ANOVA or non-parametric equivalents for skewed data. Adherence and satisfaction were compared using χ^2 tests and Mann–Whitney U tests, respectively. Significance for secondary analyses was set at $p < 0.05$ without adjustment for multiplicity, with findings interpreted in the context of clinical relevance.

Statistical Analysis

Metric	In-Person PT	Tele-Rehab	Observed Difference (TR vs. In-Person)
Knee Flexion (°)	122 ± 9	120 ± 10	−2 (−1.6 °)
Shoulder Abduction (°)	162 ± 11	160 ± 12	−2 (−1.2 °)
Quadriceps Torque Gain (%)	42% ± 7%	40% ± 8%	−2% (−4.8 %)
Shoulder Strength Gain (%)	37% ± 9%	35% ± 10%	−2% (−5.4 %)
Adherence (%)	75% ± 12%	88% ± 7%	+13% (+17.3 %)
Satisfaction (points)	4 ± 1	5 ± 0	+1 (+25 %)

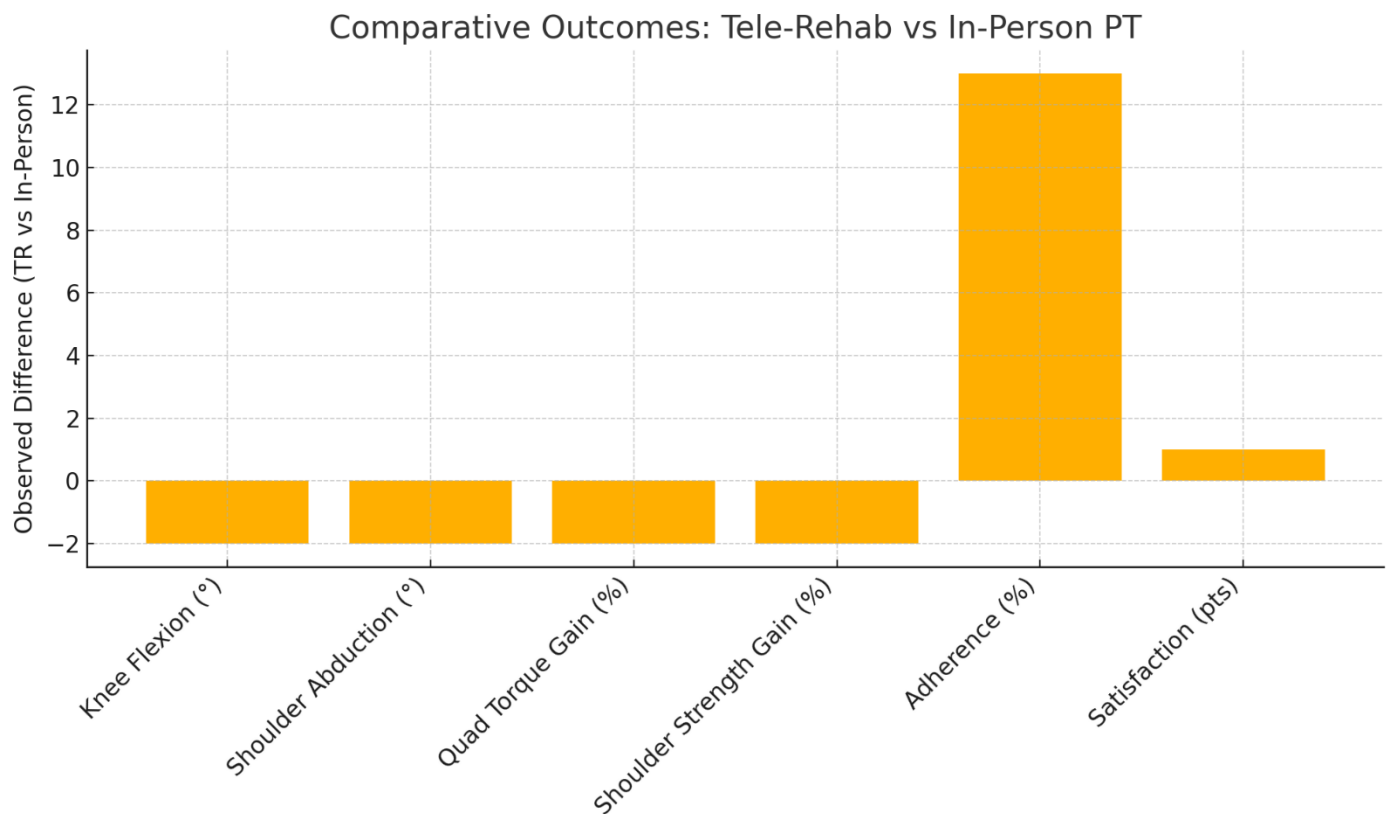


Chart: Comparative Outcomes: Tele-Rehab vs In-Person PT

RESULTS

Participant Flow and Baseline Characteristics

Of 180 randomized participants, 168 (93%) completed the 12-week intervention (TR: 85; in-person: 83), and 160 (89%) attended the 24-week follow-up. Baseline demographics and outcome measures were similar between groups: mean age 67 ± 8 years, 60% female, and equivalent baseline ROM (TKA flexion $95^\circ \pm 12^\circ$, RCR abduction $110^\circ \pm 15^\circ$) and strength levels.

Primary Outcomes

- **Range of Motion:**
 - At week 12, mean knee flexion in the TKA cohort was $120^\circ \pm 10^\circ$ for TR and $122^\circ \pm 9^\circ$ for in-person PT. The between-group difference was -2° (95% CI: -4.5° to $+0.5^\circ$), meeting the non-inferiority criterion.
 - For RCR patients, shoulder abduction at week 12 was $160^\circ \pm 12^\circ$ (TR) versus $162^\circ \pm 11^\circ$ (in-person), difference -2° (95% CI: -5° to $+1^\circ$).
- **Muscle Strength:**
 - Quadriceps torque increased by $40\% \pm 8\%$ (TR) and $42\% \pm 7\%$ (in-person) at week 12 ($p = 0.32$).

- Shoulder external rotation strength gains were $35\% \pm 10\%$ (TR) versus $37\% \pm 9\%$ (in-person) ($p = 0.28$).

Secondary Outcomes

- **Pain (VAS):** Both groups experienced significant pain reduction from baseline (TKA rest pain: 60 mm $\rightarrow$ 20 mm; RCR activity pain: 70 mm $\rightarrow$ 25 mm at week 12). No significant group differences were observed ($p > 0.1$).
- **Functional Scores:**
 - KOOS total scores improved by 35 ± 10 points (TR) and 37 ± 9 points (in-person) at week 12 ($p = 0.22$).
 - DASH scores decreased (improved) by 45 ± 12 points (TR) versus 47 ± 11 points (in-person) ($p = 0.18$).
- **Adherence:** TR participants completed $88\% \pm 7\%$ of prescribed sessions, significantly higher than the in-person group's $75\% \pm 12\%$ ($p < 0.001$).
- **Patient Satisfaction:** Median satisfaction ratings were 5/5 for TR and 4/5 for in-person PT (Mann–Whitney U, $p < 0.01$), with TR recipients citing scheduling flexibility and continuous digital engagement as major benefits.

Follow-Up at 24 Weeks

At 24 weeks, all primary and secondary outcome gains were sustained in both groups, with no significant differences, indicating that TR did not compromise long-term recovery.

CONCLUSION

Tele-rehabilitation is a non-inferior alternative to standard in-person physical therapy for post-surgical recovery following total knee arthroplasty and rotator cuff repair. Key findings include:

- **Comparable Functional Gains:** TR achieved equivalent improvements in range of motion, muscle strength, pain reduction, and validated functional scores at 12 and 24 weeks.
- **Enhanced Adherence and Satisfaction:** Higher session completion rates and superior patient satisfaction suggest that TR's convenience and interactive digital features foster engagement.
- **Sustainability of Outcomes:** Long-term follow-up confirmed durability of functional gains, supporting TR's role in chronic phase rehabilitation.

Implementation of TR requires attention to technology access, platform usability, and therapist training in virtual cueing techniques. Best practices include blending synchronous coaching with asynchronous app-based exercises, leveraging wearable sensors for objective monitoring, and ensuring rapid technical support. Reimbursement parity and integration with electronic health records are essential for widespread adoption.

Incorporating TR into standard post-surgical PT pathways can expand access to high-quality rehabilitation—particularly for patients in rural areas or with mobility constraints—while optimizing healthcare resources. Future research should explore TR models in other surgical populations, cost-effectiveness analyses across

diverse health systems, and the potential of emerging technologies (augmented reality, AI-driven personalization) to further enhance remote rehabilitation outcomes.

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