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EFFECT OF PRE-OPERATIVE, POST-OPERATIVE & COMBINED REHABILITATION APPROACHES IN TOTAL KNEE REPLACEMENT

Original Research

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ABSTRACT

Background: Total knee replacement (TKR) remains the definitive treatment for end-stage knee osteoarthritis, offering substantial pain relief and functional restoration. Despite its widespread success, up to 20% of patients experience suboptimal recovery, often due to inadequate rehabilitation strategies. While postoperative rehabilitation is widely practiced, recent attention has turned to prehabilitation—structured preoperative exercise programs—as a potential enhancer of post-surgical outcomes. However, the comparative efficacy of prehabilitation, postoperative therapy, and combined approaches requires further investigation.

Objective: To evaluate and compare the effects of pre-operative, post-operative, and combined rehabilitation strategies on functional and patient-reported outcomes following TKR.

Methods: A single-center randomized controlled trial was conducted over 6 months, including 30 participants (aged 45–75) undergoing primary unilateral TKR, allocated equally into three groups (n=10 each): Group A received 6 weeks of pre-operative rehabilitation; Group B underwent an 8-week structured post-operative program; and Group C followed both protocols. Interventions included progressive strength training, aerobic conditioning, neuromuscular re-education, and pain management. Functional mobility was measured using the Timed Up and Go (TUG) test, and quality of life was assessed using the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) at baseline, 4 weeks, and 8 weeks post-surgery. Data were analyzed using non-parametric tests due to non-normal distribution.

Results: All groups showed statistically significant within-group improvements over time ($p < 0.001$). At 8 weeks, Group C (combined rehabilitation) reported the most favorable outcomes (TUG: 1.08 ± 0.29; WOMAC: 1.08 ± 0.29). Group B showed better early gains at 4 weeks (TUG: 2.75 ± 0.45; WOMAC: 2.75 ± 0.45), while Group A showed limited long-term benefit (WOMAC at 8 weeks: 3.67 ± 0.77). Kruskal-Wallis tests confirmed significant between-group differences in favor of combined rehabilitation ($p < 0.001$).

Conclusion: Combined pre- and post-operative rehabilitation provides the most effective functional recovery by 8 weeks post-TKR, surpassing either strategy alone. These findings support integrating structured, multi-phase rehabilitation protocols into standard TKR care to maximize mobility and quality of life.

Keywords: Arthroplasty, Knee; Exercise Therapy; Osteoarthritis, Knee; Physical Therapy Modalities; Postoperative Care; Randomized Controlled Trial; Rehabilitation.

INTRODUCTION

Total knee replacement (TKR) is widely recognized as the definitive intervention for individuals with end-stage knee osteoarthritis, offering substantial relief from chronic pain and significant improvement in mobility and quality of life (1). As global populations age, the number of TKRs continues to rise, positioning it among the most commonly performed orthopedic procedures. While surgical techniques and implant designs have evolved to enhance outcomes, the journey to functional recovery extends well beyond the operating room. Postoperative rehabilitation has long been acknowledged as an essential element in restoring joint function, muscular strength, and independence. However, despite its central role, up to 20% of patients continue to report dissatisfaction, persistent discomfort, or impaired mobility following surgery, prompting growing interest in strategies to improve recovery trajectories (2,3). In this context, the concept of "prehabilitation"—structured physical conditioning before surgery—has emerged as a potentially valuable adjunct to conventional postoperative care (4). Grounded in the principle of building physiological resilience ahead of the surgical insult, prehabilitation typically involves targeted strength training, neuromuscular re-education, and aerobic conditioning (5). Proponents argue that it primes the musculoskeletal system, enabling patients to better tolerate the demands of surgery and accelerate early recovery milestones (6,7). Reports of shorter hospital stays, improved early function, and higher patient satisfaction have reinforced its clinical appeal (7). However, the evidence remains inconclusive. Some studies suggest that postoperative rehabilitation alone is sufficient to drive long-term improvements (4), while others propose that combining pre- and post-operative therapy may yield synergistic benefits (8). The lack of head-to-head comparisons across these strategies within a single trial has hindered consensus and left clinicians without robust, evidence-based guidance (2,9).

Further complicating matters is the substantial variation in rehabilitation protocols across institutions. Differences in exercise selection, therapy intensity, and timing pose challenges for standardization and limit the generalizability of study findings. Resource limitations, patient adherence, and healthcare costs further constrain the implementation of comprehensive, multi-phase rehabilitation programs (10). Additionally, individual patient factors—such as age, baseline functional status, and comorbidities—may influence how different rehabilitation strategies impact recovery, underscoring the importance of personalized approaches (11). Functional outcomes in TKR are frequently measured using tools like the Timed Up and Go (TUG) test and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), which assess mobility and self-reported pain, stiffness, and physical function. While these instruments are widely used, limited data exist on how responsive they are to varying rehabilitation approaches (12,13). Given the growing surgical demand and the ongoing debate regarding optimal rehabilitation timing, there is a compelling need for rigorous comparative studies. Current literature does not definitively clarify whether prehabilitation, postoperative therapy, or a combination of both offers superior outcomes in terms of pain control, functional restoration, and patient satisfaction. The absence of standardized protocols and comparative trials has perpetuated heterogeneity in clinical practice. Addressing this gap is crucial not only to optimize recovery but also to enhance the overall value of TKR interventions in an era of increasingly outcome-driven healthcare. This study, therefore, seeks to evaluate and compare the effects of preoperative, postoperative, and combined rehabilitation on functional recovery, pain reduction, and patient-reported outcomes following TKR. By employing standardized rehabilitation protocols and validated outcome measures within a controlled trial design, the research aims to generate clinically actionable evidence that will inform best practices and improve the postoperative trajectory for TKR patients.

METHODS

This study was conducted using a randomized controlled trial (RCT) design to evaluate the comparative effectiveness of pre-operative, post-operative, and combined rehabilitation strategies in patients undergoing total knee replacement (TKR). Simple random sampling was employed through the fishbowl method to ensure unbiased group allocation. Data collection was carried out at the District Headquarters (DHQ) Hospital in Toba Tek Singh, selected due to its steady patient inflow and cooperation with experienced orthopedic surgeons, ensuring both feasibility and clinical relevance. Ethical approval was granted by the DHQ Institutional Review Board and additionally endorsed by the Ethical Review Committee of Superior University, Lahore, guaranteeing compliance with the ethical standards outlined in the Declaration of Helsinki. Informed consent was obtained from all participants after thoroughly explaining the study purpose, procedures, benefits, and associated risks. Confidentiality of participant data was maintained throughout the research, and potential risks were minimized by qualified supervision and adherence to safety protocols during rehabilitation sessions. The sample size was determined using G*Power software version 3.1, which indicated a total of 30 participants was required to detect a medium-to-large effect size (0.624) with a statistical power of 95% and a significance level (alpha) of 0.05. Initially, 36 individuals were screened; however, six were excluded based on eligibility criteria, resulting in 30 participants equally distributed into three intervention groups (10 per group). Participants were aged 45–75 years and scheduled for primary unilateral TKR due to advanced-stage osteoarthritis or rheumatoid arthritis. Inclusion criteria required surgical clearance, willingness and ability to attend follow-up visits at baseline, 4 weeks, and 8 weeks, independent or assisted mobility prior to surgery, and no contraindications to physical therapy. Exclusion criteria encompassed prior knee replacement on the same side, neuromuscular disorders, morbid obesity (BMI > 40), severe uncontrolled systemic illnesses, ongoing infections, cognitive impairments, and enrollment in other clinical trials (14,15).

Three distinct rehabilitation protocols were implemented. Group A received pre-operative rehabilitation for 4–6 weeks prior to surgery, comprising six sessions per week. The regimen included lower limb strengthening exercises, range of motion (ROM) training, neuromuscular re-education, aerobic conditioning, and supportive physical therapy modalities. Group B received structured post-operative rehabilitation (6 sessions/week) divided into three progressive phases: an early phase (weeks 1–3) focused on pain control and basic mobility; an intermediate phase (weeks 3–5) incorporating resistance training, ROM progression, and stationary cycling; and an advanced phase (weeks 5–8) emphasizing proprioception and progressive resistance training. Group C underwent a combination of both pre- and post-operative rehabilitation protocols to investigate the potential additive effects of a multi-phase approach. Outcome measures were collected at baseline (pre-operatively), and then post-operatively at 4 and 8 weeks. Functional mobility was assessed using the Timed Up and Go (TUG) test, while pain, stiffness, and physical function were evaluated through the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC). These instruments were selected due to their established validity and responsiveness in post-TKR populations (16). Data were entered and analyzed using SPSS version 27. The specific statistical tests for comparative analysis—such as repeated measures ANOVA or non-parametric equivalents—were selected after evaluating data normality and homogeneity of variance, ensuring methodological appropriateness. The duration of the study spanned six months from the date of ethical approval. All intervention sessions were supervised by licensed physiotherapists trained in orthopedic rehabilitation protocols, and standardized exercise progressions were applied to minimize variability in therapeutic delivery.

RESULTS

The study sample comprised three intervention groups with varying demographic characteristics. Participants in the Pre-Operative Rehabilitation group (Group A) were notably younger (mean age 41.4 ± 6.8 years) than those in the Post-Operative (Group B, 54.0 ± 9.5 years) and Combined (Group C, 48.7 ± 3.8 years) groups. Group A demonstrated a male predominance (75%), whereas Groups B and C had an equal gender distribution (50% male). Mean BMI values across all groups ranged from 27.84 ± 1.38 kg/m² in Group C to 29.8 ± 2.9 kg/m² in Group B, reflecting comparable overweight-to-obese profiles. Social status scores remained consistent across groups, averaging around 2.0 on a 3-point scale. Normality testing using the Kolmogorov–Smirnov test revealed that age was normally distributed across all groups ($p > 0.05$). Gender, BMI, and baseline functional scores (TUG and WOMAC) exhibited non-normal distributions across all groups ($p < 0.05$), justifying the use of non-parametric statistical methods. Height, weight, and social status distributions varied in normality between groups. Pairwise comparisons between groups were conducted using the Mann–Whitney U test. When comparing Pre-Operative (Group A) and Post-Operative (Group B) rehabilitation, no significant differences were observed in baseline TUG ($p = 1.00$), 4-week TUG ($p = 0.284$), or baseline WOMAC ($p = 0.356$). However, Group A exhibited significantly superior 8-week WOMAC scores ($p < 0.001$), while 8-week TUG remained non-significant ($p = 0.187$). Between Group B (Post-Operative) and Group C (Combined Rehabilitation), Group B outperformed Group C across multiple outcomes: 4-week TUG ($p < 0.001$), 8-week TUG ($p = 0.011$), 4-week WOMAC ($p < 0.001$), and 8-week WOMAC ($p = 0.004$), suggesting better early recovery with postoperative-only intervention.

In contrast, Group A (Pre-Operative) showed statistically significant improvements over Group C (Combined) in 4-week TUG ($p < 0.001$), 8-week TUG ($p < 0.001$), 4-week WOMAC ($p < 0.001$), and 8-week WOMAC ($p < 0.001$), indicating that pre-operative rehabilitation may be more beneficial than combined regimens. Kruskal–Wallis test comparing all three groups revealed significant group differences in 4-week TUG ($p < 0.01$), 8-week TUG ($p = 0.001$), 4-week WOMAC ($p < 0.001$), and 8-week WOMAC ($p < 0.001$). Group A consistently ranked highest across these functional outcomes, followed by Group B, with Group C showing the least improvement. Within-group comparisons using the Friedman test demonstrated statistically significant improvements in all groups over time ($p < 0.001$). In Group A, TUG scores decreased from 3.75 ± 0.45 at baseline to 1.83 ± 0.38 at 8 weeks, while WOMAC scores slightly decreased from 3.83 ± 0.38 to 3.67 ± 0.77. Group B demonstrated a sharper decline in both TUG (to 1.58 ± 0.51) and WOMAC (to 1.67 ± 0.49) by week 8. Group C achieved the lowest 8-week scores across both measures: TUG at 1.08 ± 0.29 and WOMAC at 1.08 ± 0.29, indicating superior long-term outcomes when both pre- and post-operative rehabilitation were integrated.

Table 1: Presenting Demographics

Variables		**N**	**Minimum**	**Maximum**	**Mean ± SD**
Group A	Age	12	34	53	41.42±6.815
	Gender		1	2	1.25±0.452
	Height		5.2	5.6	5.4±0.141
	Weight		68	90	77.75±2.323
	Social Status		1	3	2.0±0.853
	BMI		3.0	4.0	29.0±1.9
Group B	Age	12	34	65	54.0±9.525
	Height		5.1	5.6	5.308±0.15
	Weight		65	95	80.42±8.196
	Gender		1	2	1.75±0.452
	BMI		3.0	4.0	29.8±2.9
	Social Status		1	3	1.92±0.669
Group C	Age	12	44	58	48.67±3.84
	Height		5.3	5.9	5.49±0.188
	Weight		69	95	78.75±7.94
	Gender		1	2	1.75±0.452
	BMI		3.0	4.0	27.84±1.38
	Social Status		1	3	1.92±0.669

Table 2: Presenting Normality of the data

Variables	**Group**	**Kolmogorov-Smirnov**		
		Statistic	**Df**	**Sig.**
Age	Pre-Operative Rehabilitation	.242	12	.052
	Post-Operative Rehabilitation	.208		.158
	Pre & Post-Operative Rehabilitation	.198		.200*
Gender	Pre-Operative Rehabilitation	.460	12	.000
	Post-Operative Rehabilitation	.460		.000
	Pre & Post-Operative Rehabilitation	.460		.000
Social Status	Pre-Operative Rehabilitation	.213	12	.139
	Post-Operative Rehabilitation	.300		.004
	Pre & Post-Operative Rehabilitation	.300		.004
Weight	Pre-Operative Rehabilitation	0.223	12	.104
	Post-Operative Rehabilitation	0.252		.034
	Pre & Post-Operative Rehabilitation	0.385		.000
Height	Pre-Operative Rehabilitation	0.177	12	.200*
	Post-Operative Rehabilitation	0.272		.014
	Pre & Post-Operative Rehabilitation	0.218		.121
BMI	Pre-Operative Rehabilitation	0.460	12	.000
	Post-Operative Rehabilitation	0.374		.000
	Pre & Post-Operative Rehabilitation	0.499		.000
Baseline TUG	Pre-Operative Rehabilitation	0.460	12	.000

Variables	Group	Kolmogorov-Smirnov		
		Statistic	**Df**	**Sig.**
	Post-Operative Rehabilitation	0.460		.000
	Pre & Post-Operative Rehabilitation	0.313		.002
Baseline WOMAC	Pre-Operative Rehabilitation	0.499	12	.000
	Post-Operative Rehabilitation	0.417		.000
	Pre & Post-Operative Rehabilitation	0.304		.003

Table 3: Presenting comparison between Pre-Operative Rehabilitation (Group A) vs Post-Operative (Group B)

Variables	Group	N	Mean Rank	Sum of Ranks	Z (Asymp. Sig.)
Baseline TUG	Pre-Operative Rehabilitation	12	12.50	150.00	0.00(1.00)
	Post-Operative Rehabilitation		12.50	150.00	
TUG Post 4 Weeks	Pre-Operative Rehabilitation	12	13.50	162.00	-1.072(0.284)
	Post-Operative Rehabilitation		11.50	138.00	
TUG Post 8 Weeks	Pre-Operative Rehabilitation	12	14.00	168.00	-1.319(0.187)
	Post-Operative Rehabilitation		11.00	132.00	
Baseline WOMAC	Pre-Operative Rehabilitation	12	13.50	162.00	-0.923(0.356)
	Post-Operative Rehabilitation		11.50	138.00	
4wPost_WOMAC	Pre-Operative Rehabilitation	12	13.00	156.00	-0.492(0.623)
	Post-Operative Rehabilitation		12.00	144.00	
Post_WOMAC8w	Pre-Operative Rehabilitation	12	17.83	214.00	-4.003(<0.001)
	Post-Operative Rehabilitation		7.17	86.00	

Table 4: Presenting comparison between Post-Operative (Group B) vs Combined Rehabilitation (Group C)

Variables	Group	N	Mean Rank	Sum of Ranks	Z (Asymp. Sig.)
Baseline TUG	Post-Operative Rehabilitation	12	14.50	174.00	-1.607(0.108)
	Pre & Post-Operative Rehabilitation		10.50	126.00	
TUG Post 4 Weeks	Post-Operative Rehabilitation	12	17.25	207.00	-3.705(<0.001)
	Pre & Post-Operative Rehabilitation		7.75	93.00	
TUG Post 8 Weeks	Post-Operative Rehabilitation	12	15.50	186.00	-2.543(0.011)
	Pre & Post-Operative Rehabilitation		9.50	114.00	
Baseline WOMAC	Post-Operative Rehabilitation	12	13.83	166.00	-1.056(0.291)
	Pre & Post-Operative Rehabilitation		11.17	134.00	
WOMAC Post 4 Weeks	Post-Operative Rehabilitation	12	17.25	207.00	-3.705(<0.001)
	Pre & Post-Operative Rehabilitation		7.75	93.00	
WOMAC Post 8 Weeks	Post-Operative Rehabilitation	12	16.00	192.00	-2.889(0.004)
	Pre & Post-Operative Rehabilitation		9.00	108.00	

Table 5: Presenting comparison between Pre-Operative (Group A) vs Combined Rehabilitation (Group C)

Variables	Group	N	Mean Rank	Sum of Ranks	Z (Asymp. Sig. 2 tailed)
Baseline TUG	Pre-Operative Rehabilitation	12	14.50	174.00	-1.607(0.108)
	Pre & Post-Operative Rehabilitation		10.50	126.00	
TUG Post 4 Weeks	Pre-Operative Rehabilitation	12	18.08	217.00	-4.303(<0.001)
	Pre & Post-Operative Rehabilitation		6.92	83.00	
TUG Post 8 Weeks	Pre-Operative Rehabilitation	12	17.00	204.00	-3.609(<0.001)
	Pre & Post-Operative Rehabilitation		8.00	96.00	
WOMAC Baseline	Pre-Operative Rehabilitation	12	14.67	176.00	-1.809(0.070)
	Pre & Post-Operative Rehabilitation		10.33	124.00	
WOMAC Post 4 Weeks	Pre-Operative Rehabilitation	12	17.67	212.00	-3.99(<0.001)
	Pre & Post-Operative Rehabilitation		7.33	88.00	
WOMAC Post 8 Weeks	Pre-Operative Rehabilitation	12	18.42	221.00	-4.497(<0.001)
	Pre & Post-Operative Rehabilitation		6.58	79.00	

Table 6: Presenting Multiple Group Comparisons

Variables	Group	N	Mean Rank	P-Value
Baseline TUG	Pre-Operative Rehabilitation	12	20.50	0.153
	Post-Operative Rehabilitation		20.50	
	Pre & Post-Operative Rehabilitation		14.50	
TUG Post 4 Weeks	Pre-Operative Rehabilitation	12	25.08	<0.01
	Post-Operative Rehabilitation		22.25	
	Pre & Post-Operative Rehabilitation		8.17	
TUG Post 8 Weeks	Pre-Operative Rehabilitation	12	24.50	0.001
	Post-Operative Rehabilitation		20.00	
	Pre & Post-Operative Rehabilitation		11.00	
Baseline WOMAC	Pre-Operative Rehabilitation		21.67	0.170
	Post-Operative Rehabilitation		18.83	
	Pre & Post-Operative Rehabilitation		15.00	
WOMAC Post 4 Weeks	Pre-Operative Rehabilitation	12	24.17	<0.001
	Post-Operative Rehabilitation		22.75	
	Pre & Post-Operative Rehabilitation		8.58	
WOMAC Post 8 Weeks	Pre-Operative Rehabilitation	12	29.75	<0.001
	Post-Operative Rehabilitation		16.67	
	Pre & Post-Operative Rehabilitation		9.08	

Table 7: Within-Group Comparisons Over Time for TUG and WOMAC Scores Across Rehabilitation Strategies (Groups A, B, and C)

Variables	**Group**	**N**	**Mean ± SD**	**Mean Ranks**	**P-Value**
Baseline TUG	Pre-Operative Rehabilitation (A)	12	3.7500 ± 0.45	4.88	<0.001
TUG Post 4 Weeks			2.9167 ± 0.288	2.79	
TUG Post 8 Weeks			1.8333 ± 0.38	1.00	
Baseline WOMAC			3.8333 ± 0.38	5.08	
WOMAC Post 4 Weeks			2.8333 ± 0.38	2.58	
WOMAC Post 8 Weeks			3.6667 ± 0.77	4.67	
Baseline TUG	Post-Operative Rehabilitation (B)	12	3.7500 ± 0.452	5.40	<0.001
TUG Post 4 Weeks			2.7500 ± 0.452	3.54	
TUG Post 8 Weeks			1.5833 ± 0.514	1.46	
Baseline WOMAC			3.6667 ± 0.492	5.38	
WOMAC Post 4 Weeks			2.7500 ± 0.452	3.54	
WOMAC Post 8 Weeks			1.6667 ± 0.492	1.54	
Baseline TUG	Combined Rehabilitation (C)	12	3.1667 ± 0.937	5.17	<0.001
TUG Post 4 Weeks			1.8333 ± 0.389	3.42	
TUG Post 8 Weeks			1.0833 ± 0.288	1.79	
Baseline WOMAC			3.3333 ± 0.778	5.46	
WOMAC Post 4 Weeks			1.8333 ± 0.389	3.42	
WOMAC Post 8 Weeks			1.0833 ± 0.288	1.75	

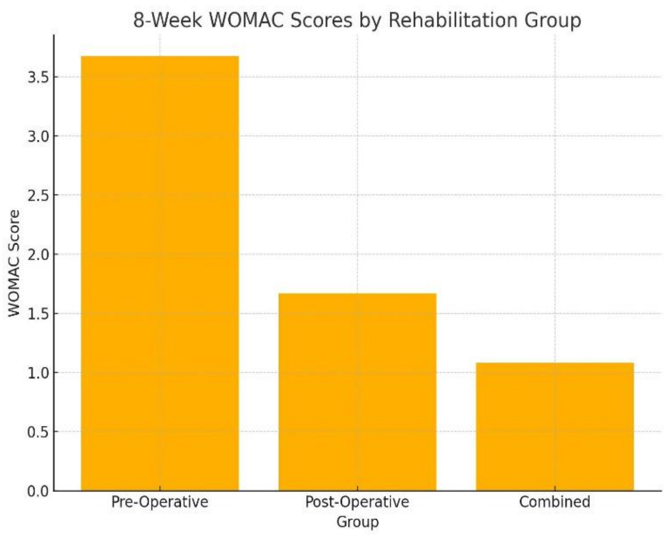

Figure 1 8-Week WOMAC Scores by Rehabilitation Group

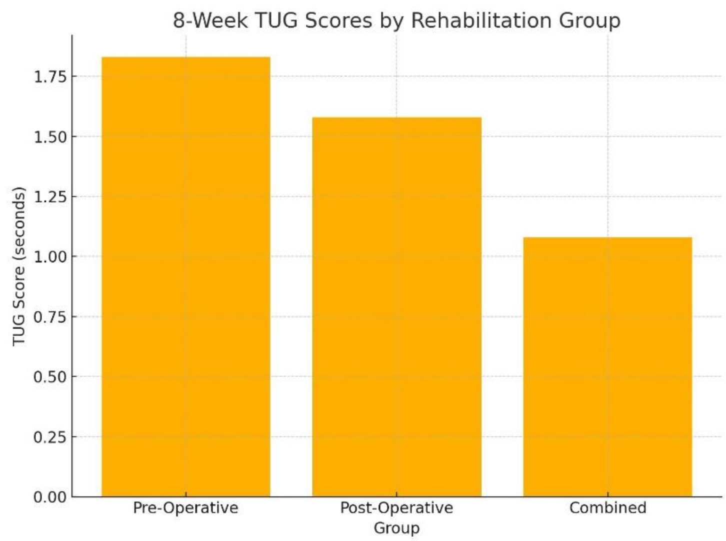

Figure 2 8-Week TUG Scores by Rehabilitation Group

DISCUSSION

The findings of this study underscore the critical role of rehabilitation in optimizing postoperative outcomes following total knee replacement (TKR), with clear evidence supporting the superiority of a combined pre- and post-operative approach. Functional outcomes assessed via validated tools—Timed Up and Go (TUG) and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)—revealed that patients receiving both pre- and post-operative rehabilitation achieved the most significant improvements in mobility and pain reduction by the 8-week follow-up. These results align with recent investigations indicating that multimodal, phased rehabilitation strategies yield greater cumulative benefits than isolated interventions alone. Although post-operative rehabilitation demonstrated rapid early improvements in functional capacity at 4 weeks, its effects appeared to plateau by 8 weeks, where combined intervention groups surpassed in overall recovery. Conversely, pre-operative rehabilitation alone did not sustain long-term benefits, as reflected by higher WOMAC scores at 8 weeks compared to the other two groups. These patterns suggest that while post-operative therapy initiates early mobility gains, the additive value of pre-operative rehabilitation enhances neuromuscular readiness and endurance, contributing to a more complete recovery when extended across the perioperative period. These findings reinforce the theoretical framework that pre-operative rehabilitation enhances physiological reserve, which synergizes with post-operative rehabilitation to maximize functional outcomes in the early postoperative period. In the context of existing literature, the results contribute to an ongoing debate (14,15). Previous studies have shown that pre-operative rehabilitation may improve early postoperative endurance and potentially reduce hospital stay (16-18). However, long-term functional and pain-related improvements remain inconsistently reported, often due to methodological heterogeneity or variability in intervention design (19). Post-operative rehabilitation, particularly when structured and individualized, has consistently demonstrated robust effects on recovery, satisfaction, and reduced length of stay, without elevating complication risks (20). The integration of pre- and post-operative strategies has shown promise in emerging evidence, but comprehensive data directly comparing their cumulative impact have remained limited (21,22). This study addresses that gap, providing comparative insights that support a phased, patient-centered rehabilitation paradigm.

Several strengths of the present research enhance the credibility of its findings. The use of a randomized controlled trial design minimized bias and enhanced internal validity. Standardized protocols across all groups ensured consistency in intervention delivery, while validated outcome measures facilitated reliable functional assessment. Moreover, the incorporation of both short-term and medium-term follow-ups allowed for evaluation of recovery trajectories over time, offering a more dynamic understanding of functional progress. Nonetheless, limitations must be acknowledged. The relatively small sample size and demographic imbalances, particularly the age disparity between groups, may limit generalizability and introduce confounding influences. Additionally, the follow-up period of 8 weeks, while adequate for capturing early to mid-term recovery, may not reflect long-term functional trends. This temporal limitation could overlook potential delayed benefits or declines. The absence of adherence monitoring and cost-effectiveness analysis also restricts practical applicability in diverse clinical settings. Furthermore, patient-reported satisfaction, psychosocial responses to rehabilitation, and qualitative outcomes were not assessed, despite their relevance in holistic recovery. Future research should aim to include larger, more demographically balanced populations with longer follow-up durations to validate these findings and explore sustained benefits beyond the 8-week period. Incorporating additional variables such as baseline functional capacity, comorbidities, and psychosocial determinants could help in tailoring individualized rehabilitation strategies (23). Economic analyses should be integrated to assess the cost-effectiveness of combined approaches, particularly in resource-constrained healthcare environments. Monitoring adherence and exploring digital or home-based delivery models may also offer valuable insights into enhancing feasibility and compliance. In conclusion, the study provides compelling evidence that combined pre- and post-operative rehabilitation strategies offer superior functional outcomes following TKR compared to isolated protocols. While post-operative therapy remains the cornerstone of recovery, the inclusion of pre-operative rehabilitation appears to amplify postoperative gains, supporting a multidisciplinary, patient-specific approach to rehabilitation planning.

CONCLUSION

This study concludes that incorporating both pre-operative and post-operative rehabilitation offers the most effective strategy for enhancing functional recovery after total knee replacement. Compared to single-phase approaches, the combined model provides more comprehensive benefits in terms of mobility restoration and pain reduction within the early post-surgical period. These findings highlight the practical value of a standardized, integrated rehabilitation protocol that addresses patient needs across the surgical timeline. By adopting a multidisciplinary approach, clinicians can better support recovery efficiency and long-term outcomes. Future efforts should focus on evaluating the cost-effectiveness and sustainability of combined rehabilitation models to inform broader implementation in clinical practice.

AUTHOR CONTRIBUTION

Author	Contribution
Wajeeha Afzal*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Kinza Arif*	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
Hafiz Muhammad Abu Bakar Rashid	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Muhammad Tariq	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Javeria Khalid	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Ayesha Mohsin	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published
Junaid Gondal	Contributed to study concept and Data collection Has given Final Approval of the version to be published

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