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Targeting Pain Catastrophizing before Total Knee Arthroplasty: Effects of Home-Based Multimodal Physiotherapy—A Randomized Trial

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Abstract

Around 20% of patients experience ongoing chronic pain following total knee arthroplasty (TKA), and high pain catastrophizing stands out as one of the main risk factors. Targeting this adjustable psychological factor before surgery could significantly enhance recovery. The present study compared the impact of two distinct preoperative home-based multimodal physical therapy programs on pain catastrophizing levels among TKA candidates showing high catastrophizing tendencies. A secondary aim was to monitor various postoperative results over a six-month follow-up period. Overall, 40 patients with symptomatic osteoarthritis and moderate pain catastrophizing were randomly assigned to a control group, a therapeutic patient education (TPE) group, or a multimodal physiotherapy (MPT) group. The preoperative programs involved pain neuroscience education, coping skills training, and therapeutic exercises, but differed in session volume and supervision level. Assessments occurred before and after the preoperative phase, and again at 1, 3, and 6 months after surgery. Pain catastrophizing was designated as the primary outcome.

Both treatment groups recorded notable drops in pain catastrophizing before surgery. TPE participants showed reduced resting pain and lower catastrophizing scores at 1 and 6 months postoperatively, decreased kinesiophobia and improved dynamic balance at 3 and 6 months, and elevated self-efficacy at 1 month. In contrast, MPT participants demonstrated lower catastrophizing. They reduced pain while walking at 1 month post-surgery, along with improvements in kinesiophobia, self-efficacy, and dynamic balance across 1, 3, and 6 months, plus increased walking speed by 6 months postoperatively. Preoperative physiotherapy successfully decreases pain catastrophizing before surgery and leads to better pain-related outcomes, psychological adjustments, and functional behaviors in high-catastrophizing TKA patients during the recovery phase. The trial is registered with the United States Clinical Trials Registry (NCT03847324).

Keywords: Knee osteoarthritis, Total knee arthroplasty, Physiotherapy, Chronic postsurgical pain, Pain catastrophizing

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Introduction

Chronic postsurgical pain is discomfort that begins or worsens after surgery or tissue damage and persists well beyond the normal healing period [1]. After total knee arthroplasty (TKA), this issue affects approximately 20% of patients [2]. Pain catastrophizing and high preoperative pain intensity rank among the strongest predictors of

unfavorable results, such as increased disability [3, 4], poorer quality of life [5], and long-term chronic pain [4, 6-9].

Pain catastrophizing is generally understood as the tendency to dramatically amplify the threat of pain, experience helplessness, and fail to control pain-related thoughts in anticipation of, during, or after painful events [10]. However, Petrini and Arendt-Nielsen [11] recently offered a fresh biopsychosocial perspective, framing it as an emotional regulation tactic involving catastrophic worry—repetitive negative thinking—that emerges from rumination and certain personality traits associated with the behavioral inhibition system.

Experts increasingly recommend identifying patients with high catastrophizing before surgery and applying specific interventions to lower both catastrophizing and pain levels, which may optimize joint replacement success [12-14]. Only a handful of studies have examined this approach. Birch *et al*. [15] and Buvanendran *et al*. [16] investigated cognitive behavioral therapy, while Riddle *et al*. [17] focused on pain-coping skills training in similar high-risk TKA populations. These trials generally found no major differences between groups, with only one reporting a clear preoperative reduction in catastrophizing [16].

Although cognitive behavioral therapy currently has the most robust support [18], multimodal physical therapy has also proven capable of lowering pain intensity and catastrophizing in osteoarthritis patients awaiting TKA who display strong pain catastrophizing [19].

Thus, the main objective of this study was to compare two preoperative home-based multimodal physical therapy programs—both featuring pain neuroscience education, therapeutic exercise, and coping skills training—in their ability to reduce preoperative pain catastrophizing in high-catastrophizing patients scheduled for TKA. Secondary goals involved assessing effects on pain catastrophizing, general health functioning, fear of movement due to pain, self-efficacy, walking speed, and dynamic balance both preoperatively and postoperatively.

Materials and Methods

Design

This investigation was designed as a single-blinded, three-arm parallel-group randomized controlled trial. It took place at Hospital Germans Trias I Pujol between September 2019 and January 2023. The trial was prospectively registered in the United States Clinical Trials Registry (NCT03847324). Ethical clearance was obtained from the Human Research Ethics Committee of Hospital Germans Trias i Pujol (PI-18-239) and the Research Ethics Committee of the University of Vic–Central University of Catalonia (58/2018). The study followed the reporting guidelines of the Consolidated Standards of Reporting Trials (CONSORT) Statement for Randomized Trials of Nonpharmacologic Treatments [20].

Participants

Eligibility criteria and recruitment details were fully described in an earlier feasibility study [19]. Individuals qualified for inclusion if they (i) were awaiting primary TKA for symptomatic osteoarthritis; (ii) had shown no adequate response to non-surgical treatments; (iii) presented moderate to severe knee pain (≥ 40 mm on a 100 mm visual analog scale) [21]; (iv) obtained a minimum score of 20 on the Pain Catastrophizing Scale (PCS) [22]; (v) volunteered to join the research; and (vi) possessed sufficient Spanish language comprehension and reading ability. Patients were not enrolled if they (i) required revision surgery or unicompartmental knee replacement, or (ii) had inflammatory arthritis. Three orthopedic surgeons (EGA, FAO, and JHH) screened and confirmed participant suitability after TKA scheduling.

Sample size calculation

The required number of participants was estimated using findings from the preceding feasibility study [19]. Calculations were performed with G*Power 3 (version 3.1, Düsseldorf, Germany), using the PCS score as the primary outcome variable [23]. The effect size ($\eta 2 = 0.37$) was based on post-treatment PCS differences between the intervention and control groups, corresponding to a Cohen's f of 0.78. With a desired power of 0.90, $\alpha = 0.05$, and a 25% anticipated dropout rate, the analysis indicated that 33 participants (11 per group) would be needed.

Randomization and blinding

Random assignment to the control or intervention arms was achieved using a computer-generated sequence generated by a web-based random number generator (GraphPad QuickCalcs, Boston, MA, USA). Allocation was concealed using sequentially numbered, opaque sealed envelopes [24]. Only the physiotherapist conducting the outcome evaluations was kept unaware of group assignments.

Interventions

Complete details of the interventions are available in the prior feasibility study [19]. Control group participants received only routine care, which included a single multidisciplinary biomedical education session before surgery and standard inpatient physiotherapy starting on the day of surgery. This inpatient phase emphasized early mobilization and walking, typically continuing until hospital discharge, approximately 4 days after the procedure. Post-discharge, patients were referred to an

external home-based rehabilitation service that usually commenced within one to ten days, followed by ongoing domiciliary physiotherapy.

The therapeutic patient education (TPE) group received standard care plus three individual home-based preoperative sessions centered on pain neuroscience education (PNE) and coping skills training (CST). PNE focused on explaining the neurobiological aspects of pain to reshape patients' understanding, beliefs, and coping approaches. CST incorporated instruction in therapeutic exercises, self-mobilization methods, and relaxation strategies. The combined approach sought to improve pain management, physical function, and diminish negative cognitive patterns, including pain catastrophizing.

The multimodal physiotherapy (MPT) group received standard care plus eight individual home-based preoperative sessions. This more intensive program combined therapeutic education (PNE + CST), supervised exercise training, and manual therapy techniques. Exercise supervision was substantially higher, with progressive monitoring and adjustment across 8 weeks. The strengthening, balance, and stability program addressed core, hip, knee, and whole-body areas through specific movements: core work included selective abdominal activation, kneeling planks, and side planks; hip/pelvic exercises featured supine and single-leg pelvic bridges, side-lying abductions, and standing abductions with resistance bands; knee exercises consisted of isometric quadriceps sets, banded knee extensions, weighted straight-leg raises, supported half-squats, and forward lunges; global activities included single-leg balance, weighted step-ups, slow step-downs, sit-to-stand transitions, and diaphragmatic breathing. Manual therapy included tailored joint mobilizations for limited knee motion, patellar glides, soft-tissue dynamic techniques, nerve mobilizations, and knee traction, as needed, for pain relief and mobility restoration.

The preoperative phase started 2–3 months before surgery during the waiting-list period. Participants were encouraged to practice the prescribed coping strategies and exercises regularly. Treatment adherence was measured at the final preoperative assessment. All participants received identical standard postoperative care.

Outcome measures

All evaluations were conducted by a blinded physiotherapist at the initial assessment, immediately after completing the preoperative program (8 weeks from baseline), and at 1, 3, and 6 months following surgery. Before the trial, the assessor completed targeted training to ensure strict adherence to the testing protocols. Although the majority of data were collected through self-reported questionnaires, each question was carefully reviewed with participants, and clear, standardized explanations were provided when needed. To ensure consistency and reduce potential bias, the same experienced physiotherapist conducted every assessment. Ongoing quality monitoring and protocol audits were also implemented during the study.

The main outcome of interest was pain catastrophizing, assessed using the validated Spanish version of the Pain Catastrophizing Scale (PCS). This is a 13-item self-report tool that includes three subscales: rumination, magnification, and helplessness [22].

Secondary outcomes consisted of:

- Pain intensity, recorded on a 100 mm visual analog scale (VAS) [0 = no pain, 100 = worst imaginable pain], both at rest and while walking [25].
- Overall health functioning, measured with the Western Ontario and McMaster University Index (WOMAC), a 24-item questionnaire divided into pain, stiffness, and physical function domains, scored on a 5-point Likert scale [0 = none, 4 = extreme] [26].
- Pain-related fear of movement, assessed via the Tampa Scale of Kinesiophobia-11 (TSK-11), an 11-item scale with total scores ranging from 11 to 44 (higher scores indicate stronger fear) [27].
- Self-efficacy, determined by the Chronic Pain Self-Efficacy Scale (CPSES), a 19-item questionnaire using a 10-point Likert scale [0 = totally incapable, 10 = totally capable] [28].
- Walking speed, tested using the 4 m Walking Test (4mWT), where participants walked at their fastest comfortable pace along an 8 m walkway (including 2 m for acceleration and 2 m for deceleration) [29].
- Dynamic balance, evaluated with the Y-Balance Test (YBT). Participants balanced on one leg on a central platform and reached maximally in the anterior, posteromedial, and posterolateral directions with the free leg [30]. The YBT was not performed at the 1-month postoperative visit due to safety considerations.

Statistical analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS 28; SPSS Inc., Chicago, IL, USA). Baseline information was presented as means ± standard deviations for continuous variables and as counts with percentages for categorical variables. Data distribution was examined with the Shapiro–Wilk test. As the variables did not meet normality assumptions, all analyses relied on nonparametric tests. Group differences at baseline were assessed using the Kruskal–Wallis test for continuous data and the chi-squared or linear chi-squared test for categorical data. When Kruskal–Wallis results were significant, Dunn's post-hoc tests with Bonferroni correction were applied for pairwise comparisons. Changes within each group over time were analyzed using

Friedman's ANOVA, with follow-up Wilcoxon signed-rank tests for specific intervals. Between-group effect sizes were estimated from the Kruskal–Wallis H statistic using the formula $\varepsilon^2_R \frac{H}{(n2-1)/(n+1)}$, where n is the total sample size [31]. These values were classified as very small (< 0.01), small (0.01– < 0.06), medium (0.06– < 0.14), and large (≥ 0.14) [32]. Within-group effect sizes were calculated as $r = Z/\sqrt{n}$ based on the Wilcoxon Z value [31] and interpreted as small (> 0.1), medium (> 0.3), or large (> 0.5) [32].

Results and Discussion

Between 19 September 2019 and 18 March 2022, 126 patients were screened. Only 40 of them satisfied all eligibility requirements and were randomly allocated to the control group (n = 15), TPE group (n = 13), or MPT group (n = 12). Altogether, 86 patients were excluded. In the control group, two individuals dropped out due to the COVID-19 lockdown, and one was removed after failing to undergo the scheduled operation. Three participants from the TPE group were lost due to the COVID-19 lockdown. Similarly, two participants in the MPT group were lost for the same reason. A complete overview of exclusions and retention is displayed in **Figure 1**.

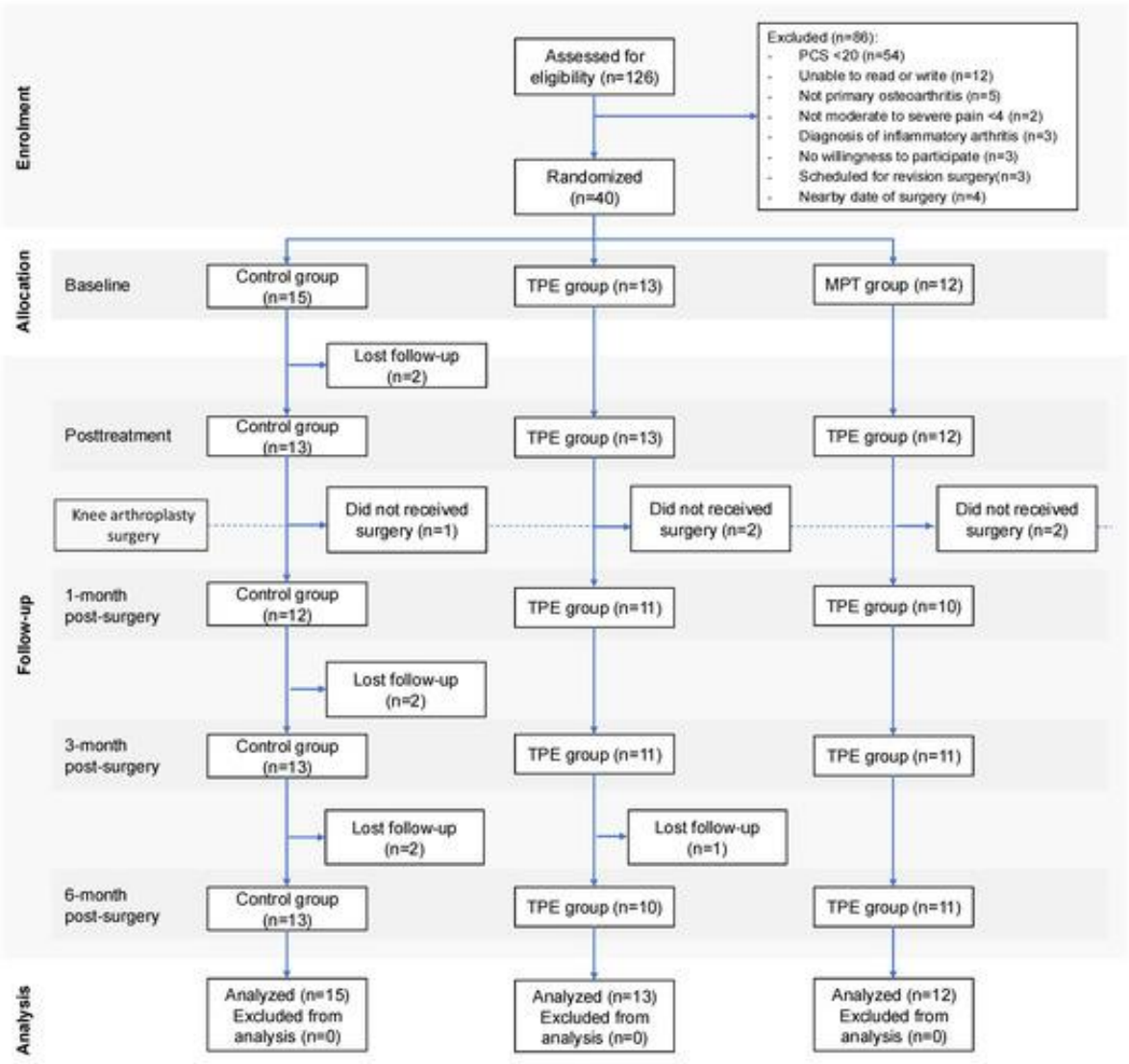

Figure 1. Flowchart of participants (CONSORT).

The baseline sociodemographic and clinical features of the sample are summarized in **Table 1**. No statistically significant differences existed between the three groups at the start of the study.

Table 1. Baseline sociodemographic and health characteristics of participants.

Variable	MPT (n = 12)	TPE (n = 13)	Control (n = 15)	P-value
Age, mean (SD)	60.6 (5.80)	66.7 (5.18)	59.4 (6.16)	0.378 *
Sex distribution				0.537 †

Male, n (%)	3 (25)	5 (38.5)	3 (20)	
Female, n (%)	9 (75)	8 (61.5)	12 (80)	
Body mass index categories				0.910 ‡
Normal weight [18.5–24.9], n (%)	–	–	1 (6.7)	
Overweight [25–29.9], n (%)	4 (33.3)	4 (30.8)	3 (20)	
Obesity class I [30–34.9], n (%)	6 (50)	9 (69.2)	7 (46.7)	
Obesity class II [35–39.9], n (%)	1 (8.3)	–	4 (26.7)	
Obesity class III [> 40], n (%)	1 (8.3)	–	–	
Charlson comorbidity index				0.109 ‡
Score 1, n (%)	–	–	–	
Score 2, n (%)	5 (41.7)	3 (23.1)	3 (20)	
Score 3, n (%)	7 (58.3)	7 (53.8)	4 (26.7)	
Score 4, n (%)	–	2 (15.4)	4 (26.7)	
Score 5, n (%)	–	1 (7.7)	4 (26.7)	
Smoking status				0.269 ‡
Never smokers, n (%)	7 (58.3)	7 (53.8)	13 (86.7)	
Former smokers, n (%)	5 (41.7)	6 (46.2)	1 (6.7)	
Current smokers, n (%)	–	–	1 (6.7)	
Alcohol intake				0.757 ‡
Abstinent, n (%)	4 (33.3)	6 (46.2)	7 (46.7)	
Light consumption, n (%)	7 (58.3)	5 (38.5)	6 (40)	
Regular consumption, n (%)	1 (8.3)	2 (15.4)	2 (13.3)	
Educational attainment				0.133 ‡
Basic literacy, n (%)	1 (8.3)	4 (30.8)	7 (46.7)	
Primary/intermediate education, n (%)	10 (83.3)	5 (38.5)	7 (46.7)	
Secondary/vocational, n (%)	1 (8.3)	3 (23.1)	1 (6.7)	
University level, n (%)	–	1 (7.7)	–	

Kruskal–Wallis Test; †Pearson's Chi-squared Test; ‡Linear Chi-squared Test. Abbreviations: TPE = Therapeutic Patient Education Group; MPT = Multimodal Physiotherapy Group.

Between-group comparisons (Table 2)

No statistically significant differences were found among the three groups for any outcome at baseline (T0). However, right after the preoperative program ended (T1), clear differences emerged across several key variables: PCS, VAS Walk, WOMAC total score, TSK-11, CPSES, YBT-A, YBT-M, and YBT-L.

Compared with the control group, the TPE group achieved significantly better results in PCS, VAS Walk, TSK-11, and YBT-A. The MPT group performed notably better than the control group in PCS, WOMAC total score, TSK-11, CPSES, YBT-A, YBT-M, and YBT-L.

At one month after surgery (T2), meaningful group differences remained in PCS, VAS Rest, VAS Walk, TSK-11, and CPSES. The TPE group again showed advantages over the control group in PCS, VAS Rest, and CPSES, while the MPT group outperformed the control group in PCS, VAS Walk, TSK-11, and CPSES.

By the three-month postoperative point (T3), significant differences were observed only in TSK-11, CPSES, YBT-A, and YBT-M. The TPE group surpassed the control group on TSK-11 and YBT-A, and the MPT group performed better than the control group on TSK-11, CPSES, and YBT-A.

At the final six-month follow-up (T4), significant inter-group differences appeared in PCS, VAS Rest, TSK-11, CPSES, 4 m Walking Test, YBT-A, YBT-M, and YBT-L. The TPE group achieved higher scores than the control group on PCS, VAS Rest, TSK-11, and YBT-M. The MPT group demonstrated better performance than the control group in TSK-11, CPSES, the 4 m Walking Test, and YBT-L.

Effect size calculations indicated large effects at T1 for PCS, VAS Rest, VAS Walk, WOMAC total score, TSK-11, CPSES, YBT-A, YBT-M, and YBT-L. Large effects were also present at T2 for PCS, VAS Rest, VAS Walk, WOMAC total score, TSK-11, and CPSES. At T3, large effects were seen for TSK-11, CPSES, YBT-A, and YBT-M. At T4, large effects were recorded for PCS, VAS Rest, WOMAC total score, TSK-11, CPSES, 4 m Walking Test, YBT-A, YBT-M, and YBT-L.

Table 2. Between-group comparisons.

Outcome measure	Group	Post-intervention (T1) median (IQR)	Baseline (T0) median (IQR)	6-month postoperative (T4) median (IQR)	3-month postoperative (T3) median (IQR)	1-month postoperative (T2) median (IQR)	Kruskal–Wallis test (P-value); effect size (ε^2R)
PCS (0–52)	Control	37 (16)	36 (13)	12 (20)	8 (20)	23 (22)	0.121; 0.108 (T0) 0.001; 0.357 (T1) 0.010; 0.287 (T2) 0.173; 0.103 (T3) 0.008; 0.291 (T4)
	TPE	19 (8)	28 (13)	0.5 (2)	2 (7)	6 (23)	
	MPT	13.5 (18)	28.5 (14)	2 (6)	3 (7)	11 (16)	
VAS at rest (0–10)	Control	5 (3.8)	6 (4)	1 (3.9)	2.5 (3.9)	5 (3.5)	0.485; 0.037 (T0) 0.065; 0.148 (T1) 0.044; 0.189 (T2) 0.260; 0.077 (T3) 0.015; 0.247 (T4)
	TPE	4 (3.8)	5 (2.8)	0 (0)	0 (2)	3 (4)	
	MPT	3.75 (3.3)	5.5 (3.1)	0 (0)	2 (4)	4 (3)	
VAS during walking (0–10)	Control	8 (2)	8 (3)	2 (5.3)	3.5 (4.3)	6 (3.3)	0.128; 0.105 (T0) 0.048; 0.164 (T1) 0.022; 0.230 (T2) 0.228; 0.084 (T3) 0.388; 0.056 (T4)
	TPE	6 (2)	9 (2)	1.5 (4.1)	1 (5)	3 (3)	
	MPT	7 (4.9)	8 (2.6)	1 (3)	2 (5)	3.5 (3.1)	
WOMAC pain (0–20)	Control	11 (6)	11 (6)	4 (3)	5 (4)	7 (4)	0.601; 0.026 (T0) 0.128; 0.111 (T1) 0.347; 0.064 (T2) 0.588; 0.030 (T3) 0.173; 0.103 (T4)
	TPE	8 (3)	12 (5)	2 (4)	4 (5)	7 (4)	
	MPT	8 (3)	10 (5)	2 (4)	3 (5)	6 (3)	
WOMAC total score (0–96)	Control	55 (24)	54 (25)	16.5 (20)	21 (15)	40 (21)	0.867; 0.007 (T0) 0.022; 0.207 (T1) 0.059; 0.172 (T2) 0.433; 0.048 (T3) 0.059; 0.167 (T4)
	TPE	47 (10)	57 (25)	8 (10)	21 (19)	28 (22)	
	MPT	37 (18)	51 (22)	4 (14)	16 (23)	29 (18)	
TSK-11 (11–44)	Control	37 (8)	33 (8)	33 (7)	31 (5)	33 (5.25)	0.213; 0.079 (T0) < 0.001; 0.390 (T1) 0.006; 0.325 (T2) < 0.001; 0.505 (T3) < 0.001; 0.496 (T4)
	TPE	25 (8)	31 (8)	23 (10)	24 (9)	25 (17)	
	MPT	27.5 (12)	30 (18)	22 (13)	22 (10)	22.5 (8)	
CPSES (0–190)	Control	78 (47)	78 (60)	125 (28)	119 (78)	89 (59)	0.186; 0.086 (T0) < 0.001; 0.461 (T1) 0.012; 0.275 (T2) 0.001; 0.405 (T3) 0.008; 0.293 (T4)
	TPE	112 (31)	94 (37)	160.5 (23)	157 (30)	147 (68)	
	MPT	148 (45)	111 (41)	176 (39)	167 (21)	145 (53)	
4-meter walk test (m/s)	Control	0.560 (0.336)	0.571 (0.321)	0.754 (0.255)	0.771 (0.173)	0.502 (0.498)	0.114; 0.111 (T0) 0.172; 0.095 (T1) 0.161; 0.118 (T2) 0.334; 0.073 (T3) 0.039; 0.197 (T4)
	TPE	0.735 (0.352)	0.774 (0.381)	0.755 (0.415)	0.818 (0.517)	0.722 (0.506)	
	MPT	0.703 (0.323)	0.688 (0.283)	0.913 (0.435)	0.812 (0.398)	0.751 (0.386)	

YBT-A (cm)	Control	0 (10.9)	0 (24)	27 (30.9)	12.17 (28.3)	–	0.449; 0.041 (T0) < 0.001; 0.421 (T1) – (T2) 0.016; 0.278 (T3) 0.043; 0.185 (T4)
	TPE	31.2 (13.7)	22.2 (32.8)	30.1 (22)	34 (19.8)	–	
	MPT	28.5 (9.9)	0 (26.8)	31.8 (20.3)	34 (10.8)	–	
YBT-M (cm)	Control	0 (20.7)	0 (0)	0 (48.4)	0 (47.5)	–	0.810; 0.011 (T0) 0.044; 0.169 (T1) – (T2) 0.037; 0.221 (T3) 0.017; 0.246 (T4)
	TPE	0 (56.6)	0 (24.6)	54.4 (15.1)	48.6 (31.1)	–	
	MPT	42 (43.25)	0 (0)	50.5 (9)	53.7 (24.9)	–	
YBT-L (cm)	Control	0 (23.3)	0 (45)	0 (58.8)	19.8 (56.9)	–	0.907; 0.005 (T0) 0.022; 0.207 (T1) – (T2) 0.154; 0.125 (T3) 0.012; 0.269 (T4)
	TPE	44.3 (59.4)	0 (48.8)	58.1 (19.1)	54.8 (38.7)	–	
	MPT	52 (10.3)	0 (38.8)	64.7 (13.2)	54.7 (23)	–	

Control vs. TPE; † Control vs. MPT; ‡ TPE vs. MPT. Abbreviations: Con = Control Group; TPE = Therapeutic Patient Education Group; MPT = Multimodal Physiotherapy Group; IQR = Interquartile Range; PCS = Pain Catastrophizing Scale; VAS = Visual Analog Scale; WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index; TSK-11 = Tampa Scale of Kinesiophobia; CPSES = Chronic Pain Self-Efficacy Scale; YBT = Y-Balance Test (A, Anterior; M, Medial; L, Lateral).

Intragroup comparison of different operative periods (Table 3)

Nearly every outcome measure showed a clear, statistically significant improvement from baseline (T0) to the six-month follow-up after surgery (T4). The only exception was CPSES, which did not improve significantly in the control group.

In the preoperative phase, designed to capture the short-term impact of preparatory interventions, the control group showed a statistically significant gain solely in YBT-A, with no meaningful shifts in any other parameter. By comparison, the TPE group achieved marked and clinically relevant improvements, characterized by large effect sizes, across a broad set of outcomes: PCS, VAS Rest, VAS Walk, WOMAC Pain, WOMAC total score, TSK-11, CPSES, YBT-A, and YBT-M. Similarly, the MPT group demonstrated substantial gains with large effect sizes in PCS, VAS Rest, VAS Walk, WOMAC Pain, WOMAC total score, TSK-11, CPSES, YBT-A, YBT-M, and YBT-L.

During the perioperative window (from T1 to T2), the control group showed notable progress with large effect sizes in PCS, WOMAC Pain, and WOMAC total score. The TPE participants experienced significant advances, also with large effect sizes, in VAS Rest, VAS Walk, WOMAC Pain, and WOMAC total score. The MPT group, for its part, recorded significant improvements in VAS Walk, WOMAC Pain, and the WOMAC total score.

The postoperative phase was analyzed in two separate intervals. In the first interval (T2 to T3), the control group showed significant improvements, with large effect sizes, in PCS, VAS Rest, WOMAC Pain, WOMAC total score, and the 4 m Walking Test. The TPE group followed a comparable pattern, improving significantly in VAS Rest, WOMAC Pain, WOMAC total score, and the 4 m Walking Test. The MPT group likewise showed meaningful gains in PCS, VAS Rest, WOMAC Pain, WOMAC total score, CPSES, and the 4 m Walking Test.

In the second postoperative interval (T3 to T4), the control group showed no further significant improvement. In contrast, the TPE group continued to register significant benefits in WOMAC Pain and WOMAC total score, while the MPT group achieved additional significant improvements in VAS Rest and YBT-L.

Table 3. Intragroup comparison results across preoperative, perioperative, and postoperative periods.

Outcome	Group	Post-intervention vs 1-month †	Baseline vs post-intervention *	3-month vs 6-month §	1-month vs 3-month ‡	Effect size (r)	Friedman's ANOVA (p-value)
PCS total	Control	0.028	0.916	0.965	0.010	0.029*, 0.693†, 0.777‡, 0.013§	< 0.001
	TPE	0.068	0.002	0.236	0.066	0.850*, 0.550†, 0.554‡, 0.375§	< 0.001
	MPT	0.575	0.003	0.864	0.035	0.848*, 0.177†, 0.667‡, 0.052§	< 0.001

VAS at rest	Control	0.219	0.813	0.593	0.049	0.065*, 0.370†, 0.545‡, 0.143§	0.001
	TPE	0.034	0.042	0.109	0.042	0.564*, 0.638†, 0.613‡, 0.507§	< 0.001
	MPT	0.779	0.004	0.027	0.046	0.839*, 0.089†, 0.632‡, 0.665§	< 0.001
VAS during walking	Control	0.075	0.752	0.430	0.171	0.088*, 0.537†, 0.379‡, 0.211§	< 0.001
	TPE	0.008	0.002	0.581	0.067	0.850*, 0.804†, 0.551‡, 0.175§	0.007
	MPT	0.011	0.037	0.105	0.609	0.604*, 0.807†, 0.162‡, 0.489§	0.003
WOMAC pain	Control	0.033	0.937	0.630	0.015	0.022*, 0.643†, 0.673‡, 0.129§	< 0.001
	TPE	0.018	0.002	0.014	0.011	0.839*, 0.715†, 0.770‡, 0.778§	< 0.001
	MPT	0.026	0.009	0.440	0.011	0.753*, 0.703†, 0.802‡, 0.233§	< 0.001
WOMAC total score	Control	0.033	0.441	0.401	0.002	0.214*, 0.644†, 0.853‡, 0.224§	< 0.001
	TPE	0.008	0.021	0.013	0.003	0.640*, 0.805†, 0.888‡, 0.787§	< 0.001
	MPT	0.012	0.005	0.069	0.009	0.805*, 0.793†, 0.822‡, 0.549§	< 0.001
TSK-11	Control	0.153	0.624	0.754	0.533	0.136*, 0.452†, 0.188‡, 0.091§	0.046
	TPE	0.798	0.004	10.000	0.284	0.801*, 0.077†, 0.323‡, 0.000§	0.005
	MPT	0.260	0.004	0.502	0.609	0.840*, 0.356†, 0.162‡, 0.203§	0.001
CPSES	Control	0.575	0.529	0.054	0.066	0.174*, 0.177†, 0.554‡, 0.555§	0.088
	TPE	0.213	0.009	0.192	0.119	0.727*, 0.375†, 0.469‡, 0.413§	< 0.001
	MPT	0.445	0.007	0.539	0.007	0.782*, 0.242†, 0.855‡, 0.185§	< 0.001
4-meter walk test	Control	0.114	0.650	0.424	0.007	0.126*, 0.500†, 0.854‡, 0.241§	0.019
	TPE	0.203	0.861	0.508	0.008	0.049*, 0.403†, 0.888‡, 0.210§	0.009
	MPT	0.445	0.530	0.214	0.012	0.181*, 0.242†, 0.891‡, 0.415§	0.018
YBT-A	Control	–	0.043	0.116	–	0.561*, 0.474§	0.008
	TPE	–	0.005	1.000	–	0.783*, 0.000§	0.008
	MPT	–	0.022	0.869	–	0.662*, 0.059§	0.005
YBT-M	Control	–	0.593	0.273	–	0.148*, 0.330§	0.021
	TPE	–	0.046	0.066	–	0.552*, 0.581§	< 0.001
	MPT	–	0.008	0.401	–	0.770*, 0.280§	< 0.001
YBT-L	Control	–	0.223	0.138	–	0.338*, 0.447§	0.004
	TPE	–	0.083	0.445	–	0.481*, 0.242§	< 0.001
	MPT	–	0.007	0.036	–	0.780*, 0.700§	0.004

Baseline vs. Post-treatment; † Post-treatment vs. 1 month post-surgery; ‡ 1 month post-surgery vs. 3 months post-surgery; § 3 months post-surgery vs. 6 months post-surgery. Abbreviations: Con = Control Group; TPE = Therapeutic Patient Education Group; MPT = Multimodal Physiotherapy Group; IQR = Interquartile Range; PCS = Pain Catastrophizing Scale; VAS = Visual Analog Scale; WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index; TSK-11 = Tampa Scale of Kinesiophobia; CPSES = Chronic Pain Self-Efficacy Scale; YBT = Y-Balance Test (A = Anterior; M = Medial; L = Lateral).

This three-arm randomized controlled trial found that both preoperative strategies—therapeutic patient education (TPE) and multimodal physical therapy (MPT)—were effective in lowering pain catastrophizing levels among individuals who were vulnerable to developing this psychological response. Beyond that, the interventions also improved pain during walking, general functional health, kinesiophobia, pain-related self-efficacy, and

dynamic postural balance. The MPT approach delivered more pronounced short-term benefits, whereas the TPE arm produced superior sustained improvements in the later postoperative stage when compared with the control condition. The three groups followed noticeably different trajectories over time. Both intervention groups showed significant improvements in most parameters during the preoperative and perioperative stages. They maintained further progress in pain severity and functional status between the 3-month and 6-month marks. The control group, however, achieved most of its gains within the first 3 months after the operation.

In the past decade, many experts have emphasized the importance of specifically targeting pain catastrophizing to improve recovery after total knee arthroplasty (TKA) [8]. A variety of methods—including cognitive behavioral therapy, pain neuroscience education (PNE), hypnosis, and structured exercise—have been tested in this surgical population, with differing success rates in diminishing catastrophizing thoughts [33]. These observations are in line with results from other chronic pain populations, which consistently identify pain catastrophizing as an adjustable risk factor [34-36]. The present findings align with this body of evidence, confirming that both experimental interventions successfully reduced catastrophizing. That said, whether and to what extent reducing catastrophizing actually translates into better surgical outcomes after TKA remains debated, owing to inconsistent reports in the literature. While Birch *et al*. [15] and Riddle *et al*. [17] found no additional benefit from adding cognitive-behavioral or coping-skills training to standard care, our results suggest that reducing preoperative catastrophizing can indeed contribute to a more favorable postoperative recovery.

Pain neuroscience education (PNE) served as a central element in both experimental programs. It uses multiple teaching approaches to help patients reframe their understanding of pain, combining behavioral modification techniques, psychologically supported strategies, and up-to-date knowledge from pain biology to decrease fear, heightened attention to pain, anxiety, and persistent worry [37]. Earlier work by Louw *et al*. [38] tested a single brief 30-minute PNE session added to routine care and observed no postoperative advantages, likely because the session was too short and patients with high catastrophizing were not specifically identified. In contrast, our study employed a home-based protocol that included three face-to-face PNE sessions and produced clearly better immediate results.

Therapeutic exercise played an equally important role in the preoperative programs. Participants in the TPE group performed the exercises with minimal guidance, whereas those in the MPT group received considerably more supervision throughout the two months. Although research on preoperative exercise before TKA has produced mixed results, such training is generally associated with better postoperative functional capacity, increased muscle strength, and shorter hospital stays, even if it does not reliably lessen pain intensity [39, 40]. These advantages tend to be temporary, and evidence regarding benefits in the mid- and long-term remains uncertain [41].

In the current study, the combination of therapeutic exercise and pain education helped preserve multiple gains after surgery, including greater self-efficacy and lower levels of kinesiophobia, alongside strong participant adherence to the exercise regimen [19]. These outcomes carry important implications because self-efficacy is known to support ongoing exercise adherence [42], while fear of movement frequently discourages physical activity among individuals with osteoarthritis [43]. Consequently, patients assigned to the experimental interventions appear to have developed more constructive behavioral patterns both around the time of surgery and in the recovery phase that followed.

Exercise combined with patient education is a cornerstone of treatment for knee osteoarthritis and is often supplemented with manual therapy in selected cases [44]. Even though the number of sessions provided was below the suggested threshold of 12 [44], the group that received more intensive supervision achieved superior immediate improvements in pain catastrophizing, overall health functioning, self-efficacy, and dynamic balance. These observations align with the short-term post-intervention advantages documented in previous research. Close supervision and personalized adjustments are essential, as they enable therapists to adapt the program to each patient's progress, thereby increasing overall treatment impact and creating further opportunities for education [44].

Nevertheless, such benefits frequently fade with time, most likely because exercise adherence tends to decline once structured supervision ends [45]. For this reason, patient education initiatives should actively strengthen self-efficacy and stress the value of staying physically active both before and after TKA. The present study indicated that the experimental groups maintained higher self-efficacy, reduced pain catastrophizing, and lower pain-related fear of movement compared with the control group. These factors likely contributed to their more durable post-treatment improvements. We therefore suggest that clinicians routinely evaluate patients' behaviors and thought patterns throughout the entire perioperative period.

Although this study's results confirm the value of preoperative multimodal physiotherapy in reducing pain catastrophizing and enhancing postoperative recovery, incorporating these approaches into everyday clinical practice poses several practical challenges. First, organizing individualized home-based programs that require different intensities of supervision may place

considerable pressure on healthcare resources, especially in settings where physiotherapy services are already limited. Achieving fair access for all patients would require thoughtful workforce planning and, if necessary, additional training for current healthcare staff. Second, while adherence to home exercises was high in this trial, real-world implementation might be less consistent due to fluctuating patient motivation and engagement. Third, the differences in session frequency and supervision intensity underscore the importance of developing standardized protocols that can balance efficient resource use with maintained intervention quality.

In light of these obstacles, upcoming research should include formal cost-effectiveness evaluations to determine whether expanding these programs is financially viable. Such evaluations would weigh the costs of delivering the interventions against the potential economic gains from improved surgical outcomes, including fewer hospital days, a lower incidence of persistent pain, and superior long-term physical function. Cost-effectiveness data could also help clarify whether the greater supervision provided in the MPT group delivers sufficient added value to justify its higher costs relative to the TPE approach with less supervision. These insights will be vital for guiding policymakers and healthcare leaders when considering the routine adoption of such programs, particularly in healthcare systems facing tight resource constraints.

Lastly, future investigations should examine the integration of additional key interventions for osteoarthritis patients, such as weight management strategies [46]. Effective weight control has been shown to make a meaningful contribution to functional recovery, notably by improving walking speed—an outcome that is critical for boosting overall mobility and quality of life [47].

Several limitations deserve attention. The study involved a relatively modest sample drawn from a single hospital, limiting the extent to which the results can be applied to other patient groups. The trial took place during the COVID-19 pandemic, which disrupted participant recruitment and surgical scheduling. Certain individuals faced extended preoperative waiting times because of postponed operations and received monthly telephone follow-ups to monitor adherence, along with an extra reinforcement session two weeks before surgery. A second round of recruitment was necessary to reach the target sample size, resulting in a modest excess of participants beyond the original plan. Furthermore, reliance on self-reported questionnaires may have introduced recall bias or social desirability bias. Objective functional tests, including the Y-Balance Test, were not conducted at every follow-up interval, which restricts the ability to draw firm conclusions from longitudinal data.

Despite these constraints, the study is distinguished by its novel strategy of addressing pain catastrophizing via preoperative home-based multimodal physiotherapy programs. The randomized controlled trial design provides strong methodological quality, and the biopsychosocial perspective combines pain neuroscience education with therapeutic exercises in line with current pain management principles. Moreover, the six-month follow-up period offers useful information on both immediate and longer-term outcomes, rendering the results particularly applicable to enhancing preoperative strategies for patients undergoing total knee arthroplasty.

Conclusion

The results of this study indicate that preoperative physiotherapy successfully lowers pain catastrophizing among individuals awaiting TKA who tend to catastrophize about their pain. Those who underwent preoperative physiotherapy demonstrated superior postoperative results in pain catastrophizing, pain-related fear of movement, self-efficacy, and dynamic balance across the 6 months. Although the approach with more sessions and greater supervision produced stronger immediate benefits, it did not translate into improved long-term outcomes. These findings endorse the practice of screening for and specifically addressing high levels of pain catastrophizing before TKA to optimize patients' postoperative pain-related results, behaviors, and cognitive patterns.

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