ARAŞTIRMA MAKALESİ / *RESEARCH ARTICLE*

Early Whole-Body Vibration vs Progressive Resistance Training in Fast-Track Total Knee Arthroplasty: A Randomized Comparative Trial

Hızlı İyileşmeli Total Diz Artroplastisinde Erken Tüm Vücut Vibrasyonu ve Progresif Dirençli Eğitim: Randomize Karşılaştırmalı Çalışma

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ABSTRACT

Aim: *Whole-body vibration (WBV) and progressive resistance training (PRT) are utilized for rehabilitation in end-stage knee osteoarthritis in total knee arthroplasty (TKA). This randomized study compared the six-week progressive WBV and PRT interventions early after fast-track TKA with respect to primary and secondary outcomes.*

Material and Methods: *This randomized comparative trial was conducted between 2021 and 2022 and comprised two groups: WBV (n=17) and PRT (n=17). All patients underwent a structured fast-track rehabilitation protocol before and after the surgery. After four weeks post-TKA, the groups initiated two sessions per week of WBV or PRT exercises for six weeks. After each training session, both groups performed neuromuscular balance training. Assessments were conducted at baseline (4th week) and postoperative 10th week. The primary outcomes included neuromuscular balance and quadriceps strength, while secondary outcomes encompassed knee pain and function, physical performance, and quality of life.*

Results: *Two-way mixed-design repeated-measures analysis of variance (ANOVA) test demonstrated similar improvements in primary (F=0.614–2.291, p=0.093–0.439) and secondary outcomes (F=0.009–2.285, p=0.140–0.925) with no significant difference in group×time interaction between groups. When the changes within the groups (time × main effect) were analyzed, significant improvements were found in both groups for primary (F=43.581–89.627, p<0.001) and secondary outcomes (F=36.082–292.834, p<0.001).*

Conclusion: *Early six-week progressive WBV or PRT was identically effective in promoting neuromuscular balance, quadriceps strength, knee pain and function, physical performance, and quality of life in fast-track TKA patients. Early postoperative adoption of progressive WBV or PRT interventions is considered feasible for promoting early rehabilitation after fast-track TKA.*

Key words: *knee osteoarthritis; total knee arthroplasty; physical therapy; exercise; quality of life*

Trial registration: *The study protocol was registered at www.clinicaltrials.gov (NCT04831411).*

ÖZET

Amaç: *Tüm vücut vibrasyonu (TVV) ve progresif dirençli eğitim (PDE) total diz artroplastisinde (TDA) son evre diz osteoartritinde rehabilitasyon için kullanılmaktadır. Bu randomize çalışmada hızlı iyileşmeli TDA sonrası erken dönemde altı haftalık ilerleyici TVV ve PDE müdahalelerinin birincil ve ikincil sonuçları karşılaştırıldı.*

Materyal ve Metot: *Bu randomize karşılaştırmalı çalışma 2021–2022 yılları arasında gerçekleştirildi ve iki gruptan oluştu: TVV (n=17) ve PDE (n=17). Tüm hastalara ameliyattan önce ve sonra yapılandırılmış hızlı iyileşmeli rehabilitasyon protokolü uygulandı. TDA'dan dört hafta sonra gruplara haftada iki seans ve altı hafta süreyle TVV veya PDE egzersizleri başlatıldı. Her eğitim seansından sonra her iki gruba da nöromüsküler denge eğitimi uygulandı. Değerlendirmeler başlangıçta (4. hafta) ve ameliyat sonrası 10. haftada yapıldı. Birincil sonuçlar arasında nöromüsküler denge ve kuadriseps kuvveti yer alırken, ikincil sonuçlar diz ağrısı ve fonksiyonu, fiziksel performans ve yaşam kalitesini kapsadı.*

Bulgular: *İki yönlü karışık tasarımlı tekrarlı ölçümler varyans analizi (ANOVA) testi, gruplar arasında grup×zaman etkileşiminde anlamlı farklılık olmaksızın birincil (F=0,614–2,291, p=0,093–0,439) ve ikincil sonuçlarda (F=0,009–2,285, p=0,140–0,925) benzer iyileşmeler olduğunu gösterdi. Grup içi değişiklikler (zaman×ana etki) analiz edildiğinde her iki grupta da birincil (F=43,581–89,627, p<0,001) ve ikincil sonuçlarda (F=36,082–292,834, p<0,001) anlamlı iyileşmeler bulundu.*

Sonuç: *Altı haftalık ilerleyici erken TVV veya PDE, hızlı iyileşmeli TDA hastalarında nöromüsküler denge, kuadriseps kuvveti, diz ağrısı ve fonksiyonu, fiziksel performans ve yaşam kalitesini artırmada benzer derecede etkilidir. İlerleyici TVV veya PRT müdahalelerinin cerrahi sonrası erken dönemde uygulanmasının hızlı iyileşmeli TDA sonrası erken rehabilitasyonun desteklenmesi için uygun olduğu düşünülmektedir.*

Anahtar kelimeler: *diz osteoartriti; total diz artroplastisi; fizik tedavi; egzersiz; yaşam kalitesi*

Deneme kaydı: *Çalışma protokolü www.clinicaltrials.gov (NCT04831411) adresinde kaydedilmiştir.*

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Introduction

The knee joint is a primary site of knee osteoarthritis (KOA) pathology (1). Patients with KOA often present pain and joint stiffness, restrictions of daily living activities like walking and stair climbing, and decreased quality of life (QoL) (2). Total knee arthroplasty (TKA) stands as the predominant surgical intervention for end-stage KOA, effectively addressing issues such as deformity, functional decline, and pain unresponsive to conservative treatments. After TKA replacement, a significant number of patients still endure considerable pain and encounter functional issues (3). Fast-track TKA surgery provides preoperative nutritional optimization, minimally invasive surgical techniques, effective pain management, early oral intake, rapid mobilization, early initiation of rehabilitation, and early discharge, facilitating accelerated postoperative recovery (4). Recent research indicates that the fast-track surgical protocol enhances early recovery following TKA (5).

Quadriceps strengthening has received considerable attention after TKA due to decreased knee function levels (6). Recent findings indicate significant loss of quadriceps strength (up to 60%) one month post-TKA, as well as a 17% decrease in muscle activation despite early physical therapy initiation within 24 hours (7). Whole-body vibration (WBV), an exercise intervention with a stationary vibrating platform, shows promise in improving functional capacity without harming knee prostheses after TKA (1). However, the optimal frequency, intensity, and training load of WBV following TKA require further investigation, as there is no clear consensus on its use (1,6). Progressive resistance training (PRT) post-TKA has also gained attention and has been shown to improve strength without exacerbating joint issues, enhancing knee function (6,8,9). Progressive resistance training can increase quadriceps strength by up to 147% early after fast-track TKA (10,11), and both WBV and PRT similarly improve quadriceps strength, pain, and mobility without adverse effects (6).

The last two decades have seen a growing trend towards WBV and PRT after TKA, and these interventions have been shown to enhance quadriceps strength and functional capabilities (6,8,12). However, early post-TKA balance and QoL decline (13,14), and it is unclear how WBV and PRT after fast-track TKA affect neuromuscular balance and QoL, underscoring the need for further research. This study compares the effects of early WBV and PRT training on neuromuscular balance, quadriceps strength, knee pain and function, physical performance, and QoL in fast-track TKA patients. This study hypothesizes that both WBV and PRT would lead to improvements in neuromuscular balance, quadriceps strength, knee pain and function, physical performance, and QoL. Additionally, the study explores whether one intervention offers additional benefits over the other.

Material and Methods

This prospective randomized-comparative trial, employing concealed allocation and single-blinded methodology, was conducted at Pamukkale University's physiotherapy research laboratory from 2021 to 2022. Ethical approval for this study was obtained from the Pamukkale University Research Ethics Committee (60116787-47317/14). The clinical trial number approval for the study was obtained from the Protocol Registration and Results System (NCT04831411). Informed consent was obtained from all participants, and the study was conducted in accordance with the principles of the Declaration of Helsinki.

Trial Design

An experienced orthopedist diagnosed end-stage KOA, and all surgeries were performed by the same surgical team using the same prosthesis type and following the institutional fast-track surgical protocol. Patients received posterior-stabilized fixed-bearing TKA (NexGen Legacy®, Zimmer-Biomet Inc., Warsaw, Indiana, USA) with high viscosity poly-methyl methacrylate bone cement. Postoperative physical therapy commenced immediately, focusing on early mobilization under the guidance of a physical therapist. Activities included mobilization within 4–6 hours post-surgery, cold-pack application, ankle pumping, quadriceps isometric setting, in-bed activities, and knee range of motion (ROM) exercises. Patients adhered to a standardized home-based exercise regimen for 4 weeks post-discharge, with instructions to avoid additional exercises and prolonged walking. Surgical sutures were removed approximately 15–17 days post-operation, followed by instructions to massage the area near the surgical incision.

Participants

Patients with KOA who volunteered for unilateral fast-track TKA surgery and fulfilled specific criteria were considered for inclusion in the study. Inclusion criteria were as follows: Age between 50 and 75,

scheduled for unilateral fast-track TKA surgery due to end-stage KOA, proficient in the local formal language, and capable of comprehending verbal and written information provided. Exclusion criteria were as follows: History of revision TKA surgery, American Society of Anesthesiologists classification score >3, diagnosis of rheumatoid arthritis, cancer, or neurological disorders leading to functional impairment, presence of psychiatric disorders, hearing or visual impairment, and regular use of hypnotic or anxiolytic medications, being morbidly obese, and participation in strength training within the last three months.

Sample Size

G*Power 3.1.9.4 (Heinrich Heine University, Düsseldorf, Germany) was used for sample size determination (11). A previous study reported a large effect of quadriceps strengthening training (Cohen's d=1) (6). We conducted a two-way mixed design repeated-measure analysis of variance (ANOVA) with time and between-factor interaction to detect a large effect size of d=1 for the interaction. Considering the quadriceps strength measurement as the primary outcome, the program generated a priori sample size of 32 patients (16 per group), with a power of 85% (1-β error probability) and an α error level probability of 0.05. Considering the anticipated dropout rate of 15% and aiming to increase statistical power, a total of 37 participants were recruited for the study. The patients were randomly allocated to the WBV and PRT groups after a blinded investigator conducted a baseline assessment using IBM Statistical Package for Social Sciences (SPSS) Statistics Editor with block randomization.

Outcomes

All assessments were conducted by a single-blinded 10-year clinically experienced investigator, unaware of patient group allocations. Demographic and clinical information were recorded. Outcomes were assessed at baseline (4th week post-surgery) and following WBV or PRT interventions, beginning at the 10th postoperative week. The modified Charlson Comorbidity Index was used to measure morbidity levels.

Primary Outcome Measures

The Korebalance Mobile System (KMS) assessed neuromuscular balance with variable air pressure and a tilt sensor, tracking 360° horizontal and 20° vertical movement. Its software scores static and dynamic balance, with lower scores indicating better balance. Korebalance mobile system shows excellent reliability and validity (ICC 0.965–0.987) (15). Quadriceps strength was measured with a handheld dynamometer (Commander Muscle Tester, J Tech, USA; ICC >0.90). Maximum force from three trials was recorded in Newtons (N) (16).

Secondary Outcome Measures

Pain and knee functions were assessed using the Western Ontario and McMaster Universities Arthritis Index (WOMAC) (3). Knee flexion ROM was assessed with a goniometer. Physical performances were assessed using a 40-meter fast-paced walk test (40 mFPWT), a 30-second sit-to-stand (30STS) test, a 9-step stair-climbing test (9 sSCT), and a timed up-and-go (TUG) test (17). Health-related QoL was assessed using Short-Form 36 (SF-36) (18). The Borg Rating of Perceived Exertion-15 (Borg-RPE15) scale was used to measure perceived exertion (19).

Interventions

Exercises in the WBV and PRT groups were administered under the supervision of an experienced blinded physiotherapist specializing in TKA patient recruitment, with personalized face-to-face sessions. Before WBV and PRT sessions, patients performed a 5–10-minute treadmill warm-up. Strengthening training comprised twelve sessions over six weeks, twice weekly for both groups, followed by gastrocnemius and hamstring stretching exercises. Weekly load adjustments ensured training progression. WBV and PRT targeted both lower extremities, with a one-minute rest period between sets and repetitions to optimize patient recovery. Additionally, the WBV and PRT groups also received standardized neuromuscular balance training (Supplementary material).

Whole-Body Vibration

The WBV group was administered using a Compex® WinPlate fixed platform. Exercises shown in Figure 1 included lunges (a), high squats (b), heel raises (c), dynamic squats (with a 3-second squat and 3-second rise, d), and ball squeezing with a 2 or 3 kg medicine ball (e) (6,20). Patients were shown proper exercise positions and asked to try the exercises without vibration before the WBV intervention. Vibration time started at 2 minutes and gradually increased

Figure 1. *Whole-body vibration (WBV) exercises.*

Figure 2. *Progressive resistance training (PRT) exercises.*

to 14 minutes, adjusted according to the Borg-RPE scale and patient pain tolerance. Vibration frequency ranged from 30 to 40 Hz, with a consistent 2 mm amplitude (Fig. 1).

Progressive Resistance Training

In the PRT group, training focused on resistance exercises and closed-chain kinetic chain exercises. Progressive resistance training exercise regimen included knee extension (f)-flexion (g), hip abduction (h)-adduction (i) using elastic resistance bands, high squats (j), rising on tiptoes (k), stool scoots (m1–2), step-up-down (n), and side-step-up-down (o) exercises (Fig. 2). Patients were taught proper exercise techniques and asked to practice before starting PRT sessions. Exercises began with 1–2 sets of 8–10 reps, progressing to 1–3 sets of 10–12 reps based on the Borg RPE 15 scale and pain. Loading increased when patients performed exercises correctly and felt fatigue or strain only at the end of the last set, as previously defined (6). (Fig. 2).

Neuromuscular Balance Training

Following WBV or PRT interventions, each training session incorporated a standardized neuromuscular balance training program that included activities such

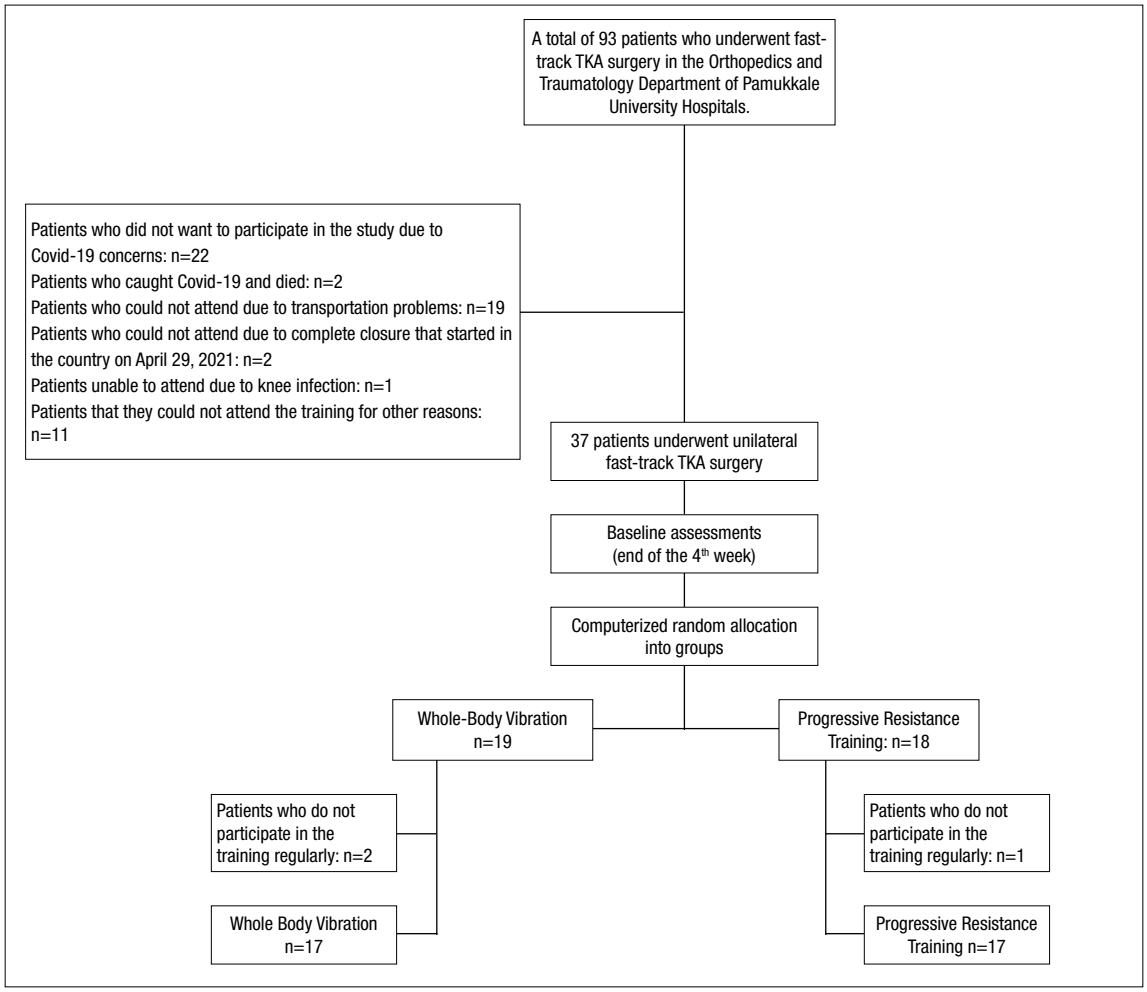

Figure 3. *Flow chart of the study.*

as standing on a balance beam, using a Bosu ball, a balance board, tandem walking, and sit-to-stand on a chair. The standardized neuromuscular balance training was similar in content, duration, and progression for both groups.

Statistical Analysis

Data were analyzed using IBM SPSS program software version 27.0 (IBM, Armonk, NY, USA). Normality was checked visually (histograms, probability graphs) and analytically (Shapiro-Wilk). The Pearson Chi-square test was used for categorical variables; Mann-Whitney U and Student t-tests were used for group differences. Analysis of variance (ANOVA) assumptions (independence, normality, homogeneity of variances/covariances) were verified (Shapiro-Wilk, Q-Q plots, Levene's, Box's M). Repeated-measures two-way mixed ANOVA examined group (WBV vs. PRT), time (Baseline vs. 10th week), and group-by-time interactions. Effect sizes were presented as Eta squares. The total type-1 error level was 5%, with statistical significance set at $p<0.05$.

Results

Between 2021 and 2022, 93 patients underwent unilateral fast-track TKA. Initially, 37 patients (19 in the WBV group and 18 in the PRT group) were assessed. However, two patients in the WBV group and one in the PRT group were excluded from the study due to irregular participation. The study was completed with a final sample of 17 patients in each group, as shown in the flow chart (Fig. 3). The recruitment rate for the WBV and PRT groups was 39%, the dropout rate was 8%, and the training adherence rate was 100% in both groups. Importantly, neither the WBV nor the PRT intervention, combined with neuromuscular balance training, caused any adverse effects in patients (Fig. 3).

Table 1. *Demographic and clinical characteristics of the groups*

	WBV (n=17)		PRT (n=17)		
	Mean (SD)	95%CI	Mean (SD)	95%CI	P
Age (year)	66.12 (5.50)	63.29–68.94	66.59 (4.68)	64.18–68.99	0.790 (t=-0.269)
Body mass index (kg/m²)	31.73 (5.88)	28.70–34.75	31.28 (3.83)	29.30–33.24	0.265 (t=0.265)
Modified Charlson Comorbidity Index	0.29 (0.70)	0.05–0.53	0.29 (0.59)	0.01–0.59	0.838 (z=-0.269)
	n (%)		n (%)		χ^2
Gender					
Female:Male	16:1 (94.1:5.9)		16:1 (94.1:5.9)		1.000
Dominant side					
Right:Left	17:0 (100:0)		17:0 (100:0)		-
Affected side					
Right:Left	8:9 (47.1:52.9)		9:8 (52.9:47.1)		0.732

WBV: whole-body vibration; PRT: progressive resistance training; t: Student t-test; z: Mann-Whitney U test, χ^2:Chi-square test; P <0.05 is highlighted in bold in tables; values represented as mean (standard deviation [SD]) unless otherwise stated.

Table 2. *Comparison of the two-way mixed design repeated-measure analysis of variance (ANOVA) test in primary outcomes between groups*

		WBV (n=17)	PRT (n=17)	Between-group differences in change scores	Main effect (time)	Group × time (interaction)	
Primary outcomes		Mean (SD)	Mean (SD)	Mean (95%CI)	P^1	F/P^2 value	η^2
Neuromuscular balance (KMS)	Baseline	650.86 (79.35)	650.06 (113.31)	-42.52 (-134.05:49.01)	**<0.001**	0.614/0.439	0.019
	10th postoperative week	569.14 (83.49)	547.47 (59.52)				
Quadriceps strength (N)	Baseline	108.33 (31)	119.2 (23.1)	12.76 (-21.51:47.04)	**<0.001**	2.291/0.093	0.085
	10th postoperative week	136.87 (41.29)	160.51 (32.18)				
Quadriceps strength deficit rate	Baseline	-31.35 (12.92)	-27.41 (11.07)	-4.05 (-10.38:2.26)	**<0.001**	1.182/0.285	0.036
	10th postoperative week	-17 (9.23)	-17.12 (11.91)				

WBV: whole-body vibration; PRT: progressive resistance training; KMS: Korebalance mobile system; N: newton; P^1: within group comparison (time); P^2: group comparison (group); η^2: eta square effect size; CI: confidence interval.

Patients' demographic and clinical characteristics are shown in Table 1. The mean age was 66.12 in the WBV and 66.59 in the PRT group (p=0.790). Body mass index (p=0.265), Charlson Comorbidity Index (p=0.838), gender (p=1.000), and affected extremity (p=0.732) also did not differ between groups.

The baseline, 10th postoperative week, and score changes for the groups' primary outcomes are presented in Table 2. There were statistically significant main effects of time for KMS neuromuscular balance (F=47.953, p<0.001), quadriceps strength (F=89.627, p<0.001), and quadriceps deficit rate (F=43.581, p<0.001) within WBV and PRT groups. The ANOVA calculation of the baseline versus 10th postoperative week primary outcomes in KMS neuromuscular balance (F=0.614, p=0.439, η^2:0.019), quadriceps strength (F=2.291, p=0.093, η^2:0.085), and quadriceps deficit rate (F=1.182, p=0.285, η^2:0.036) indicated that WBV and PRT groups had similar improvements. In addition, a comparison of change scores in baseline versus 10th postoperative week between WBV and PRT groups demonstrated a between-group difference of -42.52 (95%CI: -134.05:49.01) on the KMS neuromuscular balance, 12.76N (95%CI: -21.51:47.04) on the quadriceps strength, and -4.05 (95%CI: -10.38:2.26) on the quadriceps deficit rate.

The baseline, 10th postoperative week, and score changes for the secondary outcomes of the groups are shown in Table 3. There were statistically significant main effects of time for WOMAC-Pain (F=65.090, p<0.001), WOMAC-Total (F=292.834, p<0.001), knee flexion ROM (F=84.674, p<0.001), SF-36-Physical Function (F=184.481, p<0.001), SF-36-General Health (F=58.561, p<0.001), 40 mFPWT (F=36.082, p<0.001), 30STS test (F=250.894,

Table 3. *Comparison of the two-way mixed design repeated-measure analysis of variance (ANOVA) test in secondary outcomes between groups*

		WBV (n=17)	PRT (n=17)	Between-group differences in change scores	Main effect (time)	Group × time (interaction)	
Secondary outcomes		Mean (SD)	Mean (SD)	Mean (95%CI)	P^1	F/P^2 value	η^2
WOMAC-Pain	Baseline	3.98 (3.13)	4.53 (1.73)	0.06 (-0.91:1.03)	**<0.001**	0.009/0.925	0.001
	10th postoperative week	1.35 (1.6)	1.96 (1.68)				
WOMAC-Total	Baseline	32.54 (7.81)	30.39 (6.62)	1.65 (-3.18:6.49)	**<0.001**	0.693/0.411	0.021
	10th postoperative week	14.71 (5.82)	14.21 (5.25)				
Knee flexion range of motion (degrees)	Baseline	96.53 (9.6)	92.94 (9.79)	3.17 (-3.98:10.33)	**<0.001**	1.728/0.198	0.051
	10th postoperative week	103.24 (8.2)	101.88 (7.95)				
SF-36 - physical function	Baseline	41.18 (17.99)	54.41 (12.61)	-3.52 (-15.51:8.45)	**<0.001**	0.502/0.424	0.015
	10th postoperative week	76.76 (11.45)	86.47 (7.86)				
SF-36 - general health	Baseline	56.47 (11.01)	53.82 (12.31)	1.47 (-3.88:6.82)	**<0.001**	0.193/0.663	0.006
	10th postoperative week	68.53 (14.34)	67.35 (12.76)				
40-meter fast-paced walk test (seconds)	Baseline	42.27 (11.62)	35.4 (6.99)	0.86 (-3.73:5.45)	**<0.001**	0.072/0.790	0.002
	10th postoperative week	32.19 (5.92)	26.18 (6.5)				
30-second sit-to-stand test (seconds)	Baseline	9.06 (1.2)	9.29 (1.57)	-0.05 (-0.67:0.55)	**<0.001**	0.040/0.842	0.001
	10th postoperative week	11.41 (1.54)	11.59 (1.73)				
9-step stair climbing test (second)	Baseline	26.81 (8.03)	22.58 (5.8)	0.44 (-3.33:4.21)	**<0.001**	0.075/0.876	0.002
	10th postoperative week	19.4 (5.74)	15.62 (4.46)				
TUG test (second)	Baseline	11.92 (2.91)	10.46 (1.99)	0.73 (-0.15:1.61)	**<0.001**	2.285/0.140	0.167
	10th postoperative week	9.62 (1.83)	8.89 (1.61)				

WBV: whole-body vibration; PRT: progressive resistance training; WOMAC: Western Ontario and McMaster Universities' osteoarthritis index; SF36: short form-36; TUG: timed up and go; P^1: within group comparison (time); P^2: group comparison (group); η^2: eta square effect size; CI: confidence interval.

p<0.001), 9 sSCT (F=78.085, p<0.001), and TUG test (F=64.286, p<0.001) within WBV and PRT groups. The ANOVA calculation of the baseline versus 10th postoperative week secondary outcomes in WOMAC-Pain (F=0.009, p=0.925, η^2:0.001), WOMAC-Total (F=0.693 p=0.411, η^2:0.021), knee flexion ROM (F=1.728, p=0.198, η^2:0.051), SF-36-Physical Function (F=0.502, p=0.424, η^2:0.015), SF-36- General Health (F=0.193, p=0.663, η^2:0.006), 40 mFPWT (F=0.072, p=0.790, η^2:0.002), 30STS test (F=0.040, p=0.842, η^2:0.001), 9 sSCT (F=0.075, p=0.876, η^2:0.002), and TUG test (F=2.285, p=0.140, η^2:0.167) indicated that WBV and PRT groups had comparable improvements. In addition, a comparison of change scores in baseline versus 10th postoperative week between WBV and PRT groups demonstrated a between-group difference of 0.06 (95%CI: -0.91:1.03) on the WOMAC-Pain, 1.65 (95%CI: -3.18:6.49) on the WOMAC-Total, 3.17 degree (95%CI: -3.98:10.33) on the knee flexion ROM, -3.52 (95%CI: -15.51:8.45) on the SF-36-Physical Function, 1.47 (95%CI: -3.88:6.82) on the SF-36-General Health, 0.86 second (95%CI: -3.73:5.45) on the 40 mFPWT, -0.05 second (95%CI: -0.67:0.55) 30STS test, 0.44 second (95%CI: -3.33:4.21) on the 9 sSCT, and 0.73 second (95%CI: -0.15:1.61) on the TUG test.

The mean Borg-RPE15 score during the 12 training sessions ranged from 13.71 to 14.94 (somewhat hard–hard) in the WBV group and 13.94 to 14.82 (somewhat hard-hard) in the PRT group. The groups showed no difference in Borg-RPE15 scores at the end of the 12 sessions during the six-week training period (p >0.05).

Discussion

This study compared the effects of six weeks of WBV or PRT on neuromuscular balance, quadriceps strength, pain and function, physical performance, and QoL in patients who underwent fast-track TKA. According to the current study's findings, six weeks of WBV or PRT improved neuromuscular balance, quadriceps strength, pain and function, physical performance, and QoL in

fast-track TKA patients. However, no superiority was observed between the PRT and WBV groups after six weeks of intervention in neuromuscular balance, quadriceps strength, pain and function, physical performance, or QoL.

Relieving pain and improving functions are the primary objectives of fast-track TKA (8,14). Evidence-based clinical features of the fast-track rehabilitation program enable the patients to recover and regain functionality earlier (21). Progressive resistance training initially increases pain, followed by a gradual reduction in pain intensity and improved function (7,10,13). Whole-body vibration studies (3 or 12 sessions) show pain and functional outcomes similar to control groups (1,22), while one study finds that PRT provides better pain relief and that WBV enhances function (6). This study's findings reveal that six weeks of WBV or PRT effectively alleviates pain and enhances function without adverse effects, with no superiority. The advantages of the fast-track rehabilitation program, including pain management, regular follow-up, personalized exercise, and high patient adherence to training, may have contributed to functional improvements in both groups.

The success rate of TKA in treating KOA is high (1), yet post-TKA quadriceps strength loss can range significantly, from 62% initially (23) to subsequent losses of 10.6% to 41% (7,8). Fast-track rehabilitation studies indicate similar quadriceps strength improvements in PRT groups at the first and second months, at the 10th week, and at the 6th month (8,11). In one study comparing a 4-week WBV or PRT intervention after TKA, quadriceps strength increased by 84.3% and 77.3% from pre-training, with no difference between groups (6). The current study's quadriceps strength outcomes showed a 26% increase in WBV and a 34% increase in PRT groups compared to baseline. These findings align with prior research supporting WBV and PRT for improving quadriceps strength.

Initiating early WBV or PRT post-TKA may enhance functional activities like sit-to-stand, mobility, and walking (1,10). Compared with traditional rehabilitation, PRT shows similar or superior effects on walking, stair climbing, sit-to-stand, and mobility (7,11,14). Low-frequency WBV may improve performance and reduce pain during physical activity (1). Recent studies, including WBV intervention post-TKA, show comparable or superior outcomes in TUG and stair-climbing performance compared to controls (1,22). The WBV and PRT interventions revealed comparable improvements in the TUG test (6). This study's results indicated that the 40 mFPWT, 9 sSCT, TUG test, and 30STS test improved from baseline, supporting the effectiveness of WBV and PRT in enhancing physical performance.

Balance is regarded as a critical determinant of functional recovery after TKA (13). While WBV may enhance balance via the tonic vibration reflex, prior studies report no significant difference in neuromuscular balance after TKA (1,24). Recent research on 6 and 12-week PRT interventions indicates improvements in neuromuscular balance (25,26). This study finds similar improvements in neuromuscular balance between the WBV and PRT groups after fast-track TKA, likely attributable to progressive neuromuscular balance training, quadriceps strength gains, and patient adherence to training programs.

One of the most critical objectives of TKA is to improve the patient's quality of life. Studies of 4–12 weeks of physical therapy after fast-track TKA report improved QoL at 1 (27,28), 3 (15), and 12 months (27,28). However, a 7-week PRT study found no QoL difference compared with the control group at 2 and 6 months (8). Adding WBV in quadriceps strengthening yields a higher QoL in patients with KOA at 4, 16, and 24 weeks compared to strengthening alone (12). This study's results showed improvements in the SF-36 physical function and general health subscales in both the WBV and PRT groups, but these improvements were not superior to each other. Therefore, these findings shed new light on QoL after fast-track TKA surgery, as no study has compared WBV and PRT to date.

The study's primary limitation is that the number of participants could have been higher due to participation challenges, particularly those arising from restrictions on individuals aged 65 and over during the coronavirus disease-19 pandemic. Additionally, both groups have a high proportion of female patients, which may limit generalizability. Conducting long-term follow-up after study completion would also have strengthened the results. Lastly, the lack of a control group limits the ability to attribute the observed improvements solely to WBV or PRT.

Conclusion

With its potential to significantly impact post-fast-track TKA rehabilitation, this study provides valuable insights into the effects of WBV and PRT interventions. However, contrary to our hypothesis, this study demonstrated that both WBV and PRT interventions were equally effective in improving neuromuscular balance, quadriceps strength, pain and function, physical performance, and quality of life. These findings emphasize the rapid rehabilitation effects and the comprehensive benefits of WBV and PRT training included in our research strategy. This study unveils new possibilities for research in early post-TKA rehabilitation, as this is the first study to compare neuromuscular balance and quality of life after fast-track TKA. While our study focused only on short-term effects, we strongly recommend that future research explore the long-term effects of WBV and PRT on neuromuscular balance, quality of life, and variations in WBV load.

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