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Impact of preoperative balance training on postoperative functional recovery of patients after total knee arthroplasty: a systematic review and meta-analysis

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Abstract. – OBJECTIVE: Previous studies' results on the impact of preoperative balance training on postoperative functional recovery after total knee arthroplasty (TKA) appeared to be ambiguous. Thus, this systematic review and meta-analysis were performed to investigate the effects of preoperative balance training on walking ability, balance-specific performance, and other functional indicators in elderly patients post-TKA.

MATERIALS AND METHODS: Patient data were obtained from databases including PubMed, Physiotherapy Evidence Database (PEDro), CINAHL, SPORTDiscus, and Scopus. The inclusion criteria followed the Population-Intervention-Comparison-Outcome (PICO) principle. The assessment process involved meticulous screening, judicious data extraction, and rigorous evaluation of trial method quality, conducted by two independent researchers. Based on standardized mean differences and 95% confidence intervals, meta-analysis was performed employing a random-effects model or fixed-effects model.

RESULTS: Preoperative balance training appears to be a potentially effective intervention for enhancing the knee osteoarthritis (KOA) patients' knee joint function (RR = 1.16, 95% CI: -2.58, 4.91), isometric knee flexion (RR = 2.49, 95% CI: -2.53, 7.50), knee extension (RR = -0.13, 95% CI: -0.45, 0.18), knee society score (KSS) (RR = 2.18, 95% CI: -1.51, 5.88), stair test (RR = -0.73, 95% CI: -1.84, 0.37), and timed up and go (RR = -1.18, 95% CI: -1.60, -0.76).

CONCLUSIONS: Compared to interventions with less emphasis on balance training, rehabilitation programs highly emphasizing balance training significantly enhance the walking ability, balance specificity, and functional indicators of elderly patients post-TKA. This includes rehabilitation programs for senior TKA patients, with a focus on activities meant to improve the sensory system, balance in particular.

Key Words:
Preoperative balance training, Total knee arthroplasty, Stroke, Systematic review, Meta-analysis.

Introduction

Knee osteoarthritis (KOA) is a chronic, degenerative, and deformative joint disease characterized by knee pain, limited joint flexion and extension, and joint deformity. Risk factors of KOA include age, gender, body mass index (BMI), and overuse of knee joints[1]. With the increasing aging of the population in China, the prevalence of KOA has shown[2] a rising trend in recent years. Currently, clinical management of KOA commonly involves drug therapy such as intra-articular injection or oral administration of non-steroidal anti-inflammatory drugs, analgesics, and chondroprotective agents, with knee arthroplasty performed when necessary. However, these treatment approaches are costly and associated with various adverse events. Some patients experience difficulties tolerating the treatment, which can lead to poor long-term therapeutic outcomes. This often manifests as knee joint pain, swelling, stiffness, and functional impairment. In severe cases, it can even result in joint deformities and a loss of function, significantly impacting the patient's daily life and ability to work[3].

Total knee arthroplasty (TKA) is effective for restoring joint function and range of motion, mitigating pain and stiffness, and improving the overall physical performance in individuals with severe KOA[4]. Nevertheless, greater postural sway has been reported in pa-

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tients after TKA, potentially due to weakened muscle strength and proprioception, which is common in KOA patients[5]. Though total knee arthroplasty is usually performed in the late stage of KOA to ameliorate the compromised physical performance caused by altered proprioception, the improvement is limited, and the deficits persist[6]. Thus, quadriceps strength on the affected side is 30% lower than that on the healthy side[7], resulting in imbalanced weight-bearing of the limbs, impaired body balance, altered movement patterns, and decreased function. It has been reported[8] that post-TKA patients exhibit over 80% of pressure velocity centers in anterior-posterior and medial-lateral sway compared to the control group. This physical limitation results in TKA patients having difficulty engaging in daily activities. It reduces their walking ability, and evidence[9] suggests that TKA patients have an increased risk of falls compared to healthy, age-matched individuals. Additionally, falls in elderly individuals after TKA can lead to fear and activity avoidance, severe injuries, and even death, imposing a significant economic burden on the healthcare system[10]. Interventions that prioritize improving walking ability and balance play a crucial role in successful rehabilitation after TKA. These interventions are essential for mitigating the risk of falls and promoting optimal recovery[10].

With the continuous advancement of rehabilitation concepts, rehabilitation of knee proprioception and balance ability after TKA has received increasing attention as an important part of the overall rehabilitation process. Neuromuscular training can improve movement patterns by enhancing neuromuscular control[11]. Recently, there has been a growing body of clinical evidence[12] highlighting the significance of proprioception and balance training in post-TKA knee rehabilitation. These reports[12] emphasize the positive impact of such training on the overall recovery and functional outcomes of patients undergoing TKA. Its effectiveness in improving postoperative balance and postural control ability and reducing the risk of falls has been recognized[12]. A recent systematic review[13] studied the impact of balance training on individual balance performance measurements following TKA. The findings revealed that functional capacity and balance improved versus the control group. Despite valuable insight provided by these studies into the availability of individual balance training after TKA, no related meta-analysis methods, which allow for statistical comparisons and critical evaluation of limited comparable studies, are available[14]. To this end, this study analyzed the impact of preoperative balance training on post-TKA functional outcomes, comparing relevant randomized controlled trials.

Materials and Methods

Search Strategy

Computer searches were conducted in databases including Cochrane Library, Embase, Web of Science, PubMed, China National Knowledge Infrastructure (CNKI), Chinese Biomedical Literature Service System (CBM), and Wanfang Database. The English search terms used were "proprioception training," "balance training," "sensorimotor training," "neuromuscular training," and "total knee arthroplasty." Additionally, disease-related keywords included "knee joint" and "knee Osteoarthritis". Taking the PubMed database as an example, the search strategy is outlined in Table I. Furthermore, we manually explored the titles and content of the included studies, along with objective abstract assessments, to ultimately identify other relevant literature. Figure 1 illustrates the literature screening process. This study follows PRISMA guidelines. Our study has been registered in INPLASY (International Platform of Registered Systematic Review and Meta-analysis Protocols). Our registration number is INPLASY202410122 (10.37766/inplasy2024.1.0122).

Inclusion Criteria

To enhance the quality and reliability of the analysis, a stringent academic excellence threshold was established for literature selection. Stud-

Table I. PubMed search strategy.

#1	(proprioception training[Title/Abstract]) OR (balance training[Title/Abstract]) OR (sensorimotor training[Title/Abstract]) OR (neuromuscular training[Title/Abstract]) OR (total knee arthroplasty[Title/Abstract])
#2	(knee joint[Title/Abstract]) OR (knee Osteoarthriris[Title/Abstract])
#3	#1 AND #2

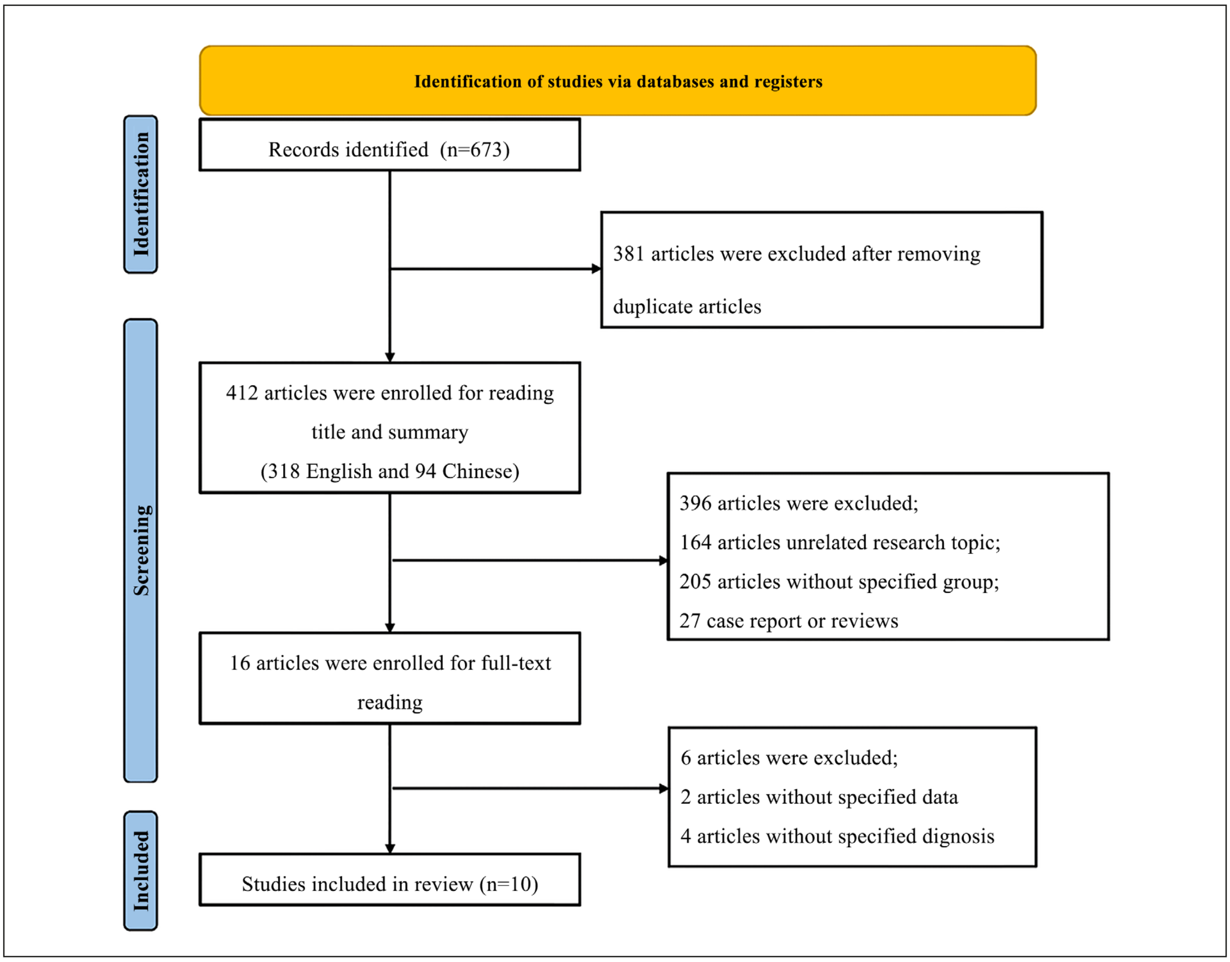

Figure 1. The flowchart of the literature selection process.

ies meeting the following criteria were included in the analysis: (1) Clinical randomized controlled trials; (2) Control group receiving routine rehabilitation training or no specific intervention, while the experimental group received proprioception/balance and neuromuscular training on top of the control group; (3) Elderly individuals (65 years and older) undergoing TKA due to osteoarthritis; (4) Intervention or exposure randomized controlled trials (RCTs) and pilot RCTs examining the effects of implementing balance training after TKA. Training interventions encompassed a range of exercises, including balance exercises, as well as interventions referred to as "sensorimotor training" as defined by Beinert and Taube[14]. These interventions aimed to improve proprioception, enhance sensory feedback, and enhance the coordination of sensory and motor responses in individuals undergoing knee rehabilitation after TKA. When authors did not provide such categorization, these were defined as "balance exercises" as they appeared to challenge the primary sensory systems for balance (i.e., visual, vestibular, and/or proprioceptive), or to restore neuromuscular function and motor efficiency. (5) Comparisons between groups combining balance training with routine rehabilitation training in the control group *vs.* groups completing only routine rehabilitation training, or comparisons between groups performing only balance training *vs.* groups completing only routine rehabilitation training.

Exclusion Criteria

(1) Case reports; (2) Inability to extract relevant outcome measures such as incidence rates; (3) Patients with comorbidities. (4) History of surgical treatment in the intervention or control group. (5) Use of other types of treatments in the intervention or control group. (6) No other

restrictions on patient age, gender, ethnicity, time post-stroke, baseline function, publication date, or language.

Quality Assessment Criteria and Data Extraction

Two independent reviewers (RYF, WRR) conducted literature screening, data extraction, and quality assessment, with any discrepancies resolved by a third reviewer (JTB). Data extracted in this study included study design, study population, inclusion and exclusion criteria, intervention measures, treatment methods in the control group, and outcomes. Mean values and standard deviations (SD) were extracted for quantitative data. For randomized controlled trials, the Jadad scale was used for quality assessment, while cohort studies and case-control studies were assessed for quality using the NOS scale.

Statistical Analysis

RevMan 5.3 (The Cochrane Centre, Oxford, UK) was used for analysis: (1) Binary variables were analyzed using odds ratios (OR) with 95% confidence intervals (CI). (2) Heterogeneity was assessed through Q and I^2 tests; when heterogeneity was low, a fixed-effects model was used for analysis. When heterogeneity was high, a random-effects model (RE) was employed for analysis, and the literature was re-evaluated to identify and analyze the source of heterogeneity. Subgroup analysis was conducted if there was substantial heterogeneity with statistically significant differences. Descriptive analysis was performed when the source of heterogeneity could not be explained. $p < 0.05$ was considered significantly different.

Results

Characteristics of Included Studies

From 2010 to October 2023, 673 relevant articles were identified through thorough research. After eliminating duplicate literature, a total of 381 articles were selected, comprising 318 in English and 94 in Chinese. Upon initial screening of titles and abstracts, 396 articles were excluded, with 164 unrelated to the research topic, 205 being case reports and reviews, and 27 being single-group studies. Sixteen articles were initially included after the first round of screening. After reading the full text, six articles were subsequently excluded, with two not containing the specified data and four having discrepancies in participant diagnosis. Eventually, 10 articles[15-24] were included. The observation group consisted of a total of 312 participants, and data from 313 patients in the control group were collected. Additionally, the identification of publication bias risk provided a multifaceted perspective on component heterogeneity. The flowchart of the literature selection process is shown in Figure 1. The basic information of the included literature is outlined in Table II.

Quality Assessment of Included Studies

All 10 studies were randomized controlled trials[15-24]. The quality of the randomized controlled trials was assessed using the Jadad scale.

Table II. Basic information of included literature.

Authors	Research type	n	Intervention	Outcome measures
Sun et al[15] 2023	Randomized Control Study	100	Preoperative balance training + TKA *vs.* TKA	a, b, d, e, f
Domínguez-Navarro et al[16] 2021	Randomized Control Study	35	Preoperative balance training + TKA *vs.* TKA	a, b, c, d, e
Pournajaf et al[17] 2022	Randomized Control Study	56	Preoperative balance training + TKA *vs.* TKA	a, b, c, d, e, f
Bruun et al[18] 2014	Randomized Control Study	57	Preoperative balance training + TKA *vs.* TKA	a, f
Karaman et al[19] 2017	Randomized Control Study	34	Preoperative balance training + TKA *vs.* TKA	d
Roig-Casasus et al[20] 2018	Randomized Control Study	43	Preoperative balance training + TKA *vs.* TKA	d, f
Piva et al[21] 2017	Randomized Control Study	41	Preoperative balance training + TKA *vs.* TKA	a, e
Liao et al[22] 2015	Randomized Control Study	130	Preoperative balance training + TKA *vs.* TKA	f
Johnson et al[23] 2011	Randomized Control Study	16	Preoperative balance training + TKA *vs.* TKA	f
Liao et al[24] 2013	Randomized Control Study	113	Preoperative balance training + TKA *vs.* TKA	f

(a) Knee range of motion (ROM); (b) Isometric knee flexion; (c) Knee extension; (d) KSS; (e) Stair test; (f) Timed up-and-go. Total knee arthroplasty (TKA).

Table III. Jadad scores of included studies.

Authors	Case selection	Comparability	Outcome	NOS score
Sun et al[15] 2023	4	2	1	7
Domínguez-Navarro et al[16] 2021	3	2	1	6
Pournajaf et al[17] 2022	3	2	1	6
Bruun et al[18] 2014	3	1	1	5
Karaman et al[19] 2017	4	2	1	7
Roig-Casasus et al[20] 2018	3	2	1	6
Piva et al[21] 2017	3	1	1	5
Liao et al[22] 2015	4	1	1	6
Johnson et al[23] 2011	3	2	1	6
Liao et al[24] 2013	4	2	1	7

(a) Knee range of motion (ROM); (b) Isometric knee flexion; (c) Knee extension; (d) KSS; (e) Stair test; (f) Timed up-and-go. Total knee arthroplasty (TKA).

Criteria for scoring included appropriate generation of random sequences (2 points), unclear randomization concealment (1 point), absence of blinding (0 points), and failure to describe the number or reasons for withdrawals or dropouts (0 points). The Jadad scores for the randomized controlled trials ranged from 0 to 3, indicating low-quality literature, as shown in Table III and Figure 2.

Meta-Analysis Results

Knee ROM

A detailed study of knee range of motion (ROM) was conducted in five articles[15-18,21], and significant heterogeneity was identified (I^2 = 62%, p = 0.03), so a RE model was used. Results showed that preoperative balance training may be an effective treatment for improving knee function in KOA patients (RR = 1.16, 95% CI: -2.58, 4.91), as illustrated in Figure 3.

Isometric knee flexion

Three articles[15-17] conducted a detailed study of isometric knee flexion. The heterogeneity test revealed significant heterogeneity (I^2 = 97%, p < 0.0001), so a RE model was employed. Results suggested that preoperative balance training appeared to contribute to improving the isometric knee flexion in KOA patients (RR = 2.49, 95% CI: -2.53, 7.50), as shown in Figure 4.

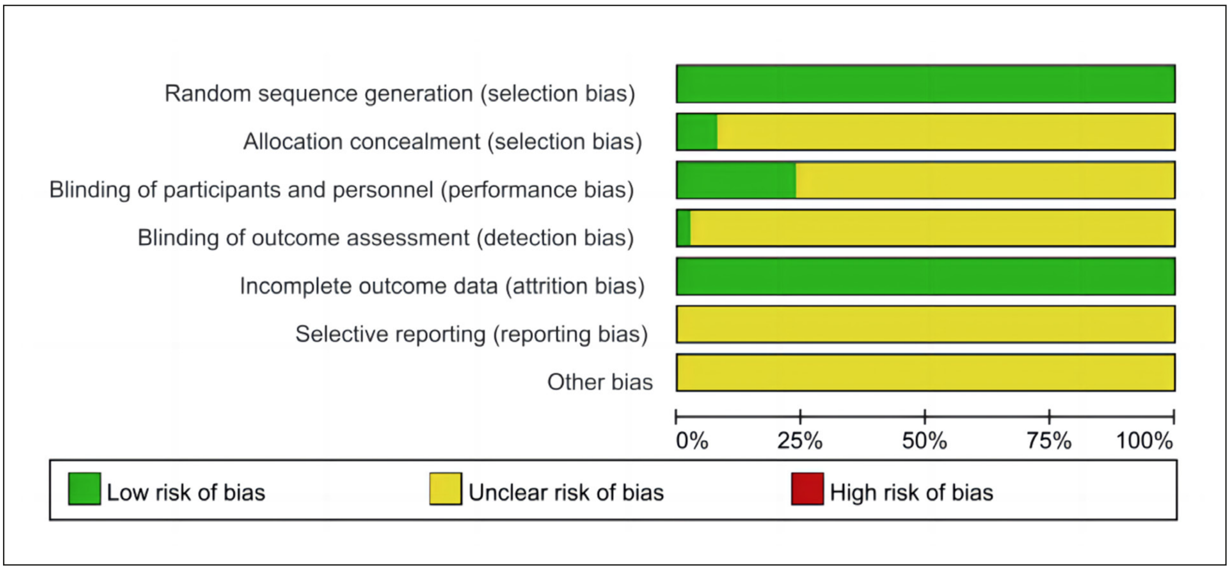

Figure 2. Quality evaluation chart of the included studies.

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
Bruun 2014[18]	81	18	29	75	21	28	10.3%	6.00 [-4.17, 16.17]
Domínguez-Navarro 2021[16]	28.9	13.3	16	38.3	14.1	19	12.2%	-9.40 [-18.49, -0.31]
Piva 2017[21]	13.2	27.5	18	11.1	23	17	4.5%	2.10 [-14.66, 18.86]
Pournajaf 2022[17]	22.19	8.72	29	21.77	3.95	27	31.2%	0.42 [-3.09, 3.93]
Sun 2023[15]	24.8	2.5	50	21.3	2.3	50	41.8%	3.50 [2.56, 4.44]
Total (95%CI)			**142**			**141**	**100.0%**	**1.16 [-2.58, 4.91]**

Heterogeneity: Tau² = 8.51; Chi² = 10.49, df = 4 (P = 0.03); I² = 62%
Test for overall effect: Z= 0.61 (P = 0.54)

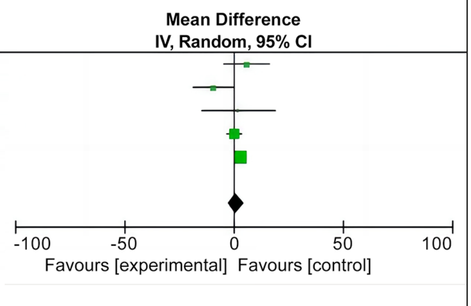

Figure 3. Forest plot of knee ROM.

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
Domínguez-Navarro 2021[16]	104.1	104.1	19	112.1	11.5	19	0.9%	-8.00 [-59.27, 43.27]
Pournajaf 2022[17]	3.65	0.44	29	3.62	0.53	27	50.1%	0.03 [-0.23, 0.29]
Sun 2023[15]	14.2	3.9	50	9	0.9	50	49.0%	5.20 [4.09, 6.31]
Total (95%CI)			**95**			**96**	**100.0%**	**2.49 [-2.53, 7.50]**

Heterogeneity: Tau² = 13.04; Chi² = 79.30, df = 2 (P = 0.00001); I² = 97%
Test for overall effect: Z= 0.97 (P = 0.33)

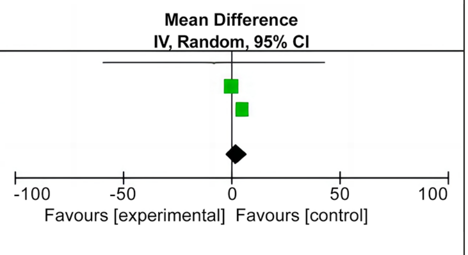

Figure 4. Forest plot of isometric knee flexion.

Knee extension

Two articles[16,17] carried out a detailed study of knee extension. No significant heterogeneity was found among the studies (I^2 = 0%, p = 0.34), so a fixed-effects model was used. The result suggested that preoperative balance training provides potential benefits for enhancing knee extension in KOA patients (RR = -0.13, 95% CI: -0.45, 0.18), as depicted in Figure 5.

Knee society score

Knee society score analysis was analyzed in 5 articles[15-17,19,20]. The heterogeneity test showed significant heterogeneity (I^2 = 88%, p < 0.0001), resulting in the use of a RE model. The meta-analysis indicated that preoperative balance training may be effective in improving knee society score (KSS) in KOA patients (RR = 2.18, 95% CI: -1.51, 5.88), as illustrated in Figure 6.

Stair test

Four articles[15-17,21] analyzed the stair test. Significant heterogeneity was found in the heterogeneity test (I^2 = 76%, p = 0.006), so an RE model was used. The result suggested that preoperative

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
Domínguez-Navarro 2021[16]	4.3	5.1	16	3	3.5	19	1.1%	1.30 [-1.65, 4.25]
Pournajaf 2022[17]	3.17	0.58	29	3.32	0.63	27	98.9%	-0.15 [-0.47, 0.17]
Total (95%CI)			**45**			**46**	**100.0%**	**-0.13 [-0.45, 0.18]**

Heterogeneity: Tau² = 0.00; Chi² = 0.92, df = 1 (P = 0.34); I² = 0%
Test for overall effect: Z= 0.83 (P = 0.41)

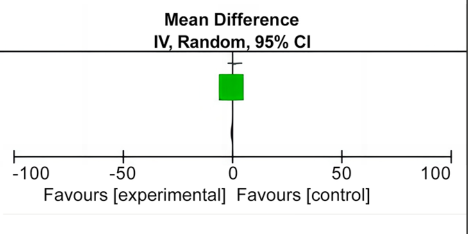

Figure 5. Forest plot of knee extension.

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
Domínguez-Navarro 2021[16]	51.3	11.7	16	62.4	10.1	19	12.5%	-11.10 [-18.40, -3.79]
Kararnan 2017[19]	50.6	3.9	17	41.1	5.1	17	20.9%	9.50 [6.45, 12.55]
Pournajaf 2022[17]	67.38	4.91	29	65.72	3.99	27	22.2%	1.66 [-0.68, 4.00]
Roig-Casasus 2018[20]	51.8	2.7	19	49.7	3.8	24	22.8%	2.10 [0.15, 4.05]
Sun 2023[15]	46.8	7.4	50	43.4	5.7	50	21.7%	3.40 [0.81, 5.99]
Total (95%CI)			**131**			**137**	**100.0%**	**2.18 [-1.51, 5.88]**

Heterogeneity: Tau² = 14.61; Chi² = 33.88, df = 4 (P < 0.00001); I² = 88%
Test for overall effect: Z= 1.16 (P = 0.25)

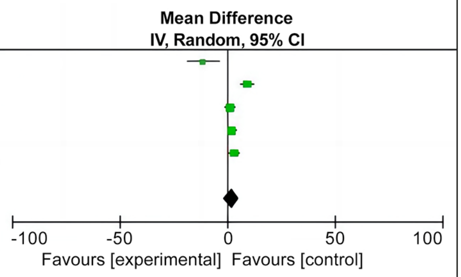

Figure 6. Forest plot of KSS.

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
Domínguez-Navarro 2021[16]	28	5.8	16	30.8	5.4	19	7.3%	-2.80 [-6.54, 0.94]
Piva 2017[21]	0.1	0.15	21	0.06	0.15	20	46.7%	0.04 [-0.05, 0.13]
Pournajaf 2022[17]	17.08	6.09	29	18.2	7.58	27	7.8%	-1.12 [-4.74, 2.50]
Sun 2023[15]	7.5	2.4	50	8.7	1.4	50	38.2%	-1.20 [-1.97, -0.43]
Total (95%CI)			**116**			**116**	**100.0%**	**-0.73 [-1.84, 0.37]**

Heterogeneity: Tau² = 0.68; Chi² = 13.39, df = 3 (P = 0.006); I² = 76%
Test for overall effect: Z= 1.30 (P = 0.19)

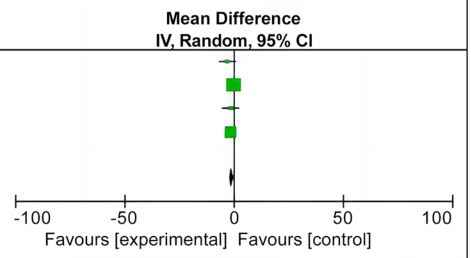

Figure 7. Forest plot of stair test.

balance training may enhance the stair test in KOA patients (RR = -0.73, 95% CI: -1.84, 0.37), as shown in Figure 7.

Timed up-and-go

Eight articles[15-18,20,22-24] performed the timed up-and-go test. No significant heterogeneity was detected (I^2 = 31%, p = 0.18), so a fixed-effect model was employed. The result suggested that preoperative balance training appeared to enhance the results of the timed up-and-go test in KOA patients (RR = -1.18, 95% CI: -1.60, -0.76), as shown in Figure 8.

Publication bias

Figure 9 shows the meta-analysis funnel plots for the six indicators. These funnel plots exhibit significant asymmetry, suggesting a potential presence of publication bias in this study.

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
Bruun 2014[18]	12	13	29	14	14	28	0.4%	-2.00 [-9.02, 5.02]
Domínguez-Navarro 2021[16]	15.7	6.1	16	13.4	7.6	19	0.8%	2.30 [-2.24, 6.84]
Johnson 2011[23]	7.8	1.8	8	8.8	1.4	8	6.2%	-1.00 [-2.58, 0.58]
Liao 2015[22]	9.89	0.92	58	10.73	0.99	55	37.5%	-0.84 [-1.19, -0.49]
Liao 2013[24]	8.9	1.2	65	10.3	1.7	65	29.3%	-1.40 [-1.91, -0.89]
Pournajaf 2022[17]	25.54	9.38	29	23.61	11.11	27	0.6%	1.93 [-3.48, 7.34]
Roig-Casasus 2018[20]	14.4	4.3	17	17.3	3.6	20	2.5%	-2.90 [-5.48, -0.32]
Sun 2023[15]	7.8	2.1	50	9.3	1.1	50	22.7%	-1.50 [-2.16, -0.84]
Total (95%CI)			**272**			**272**	**100.0%**	**-1.18 [-1.60, -0.76]**

Heterogeneity: Tau² = 0.09; Chi² = 10.17, df = 7 (P = 0.18); I² = 31%
Test for overall effect: Z= 5.50 (P < 0.00001)

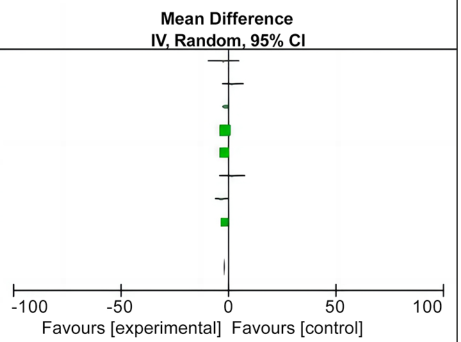

Figure 8. Forest plot of timed up-and-go test.

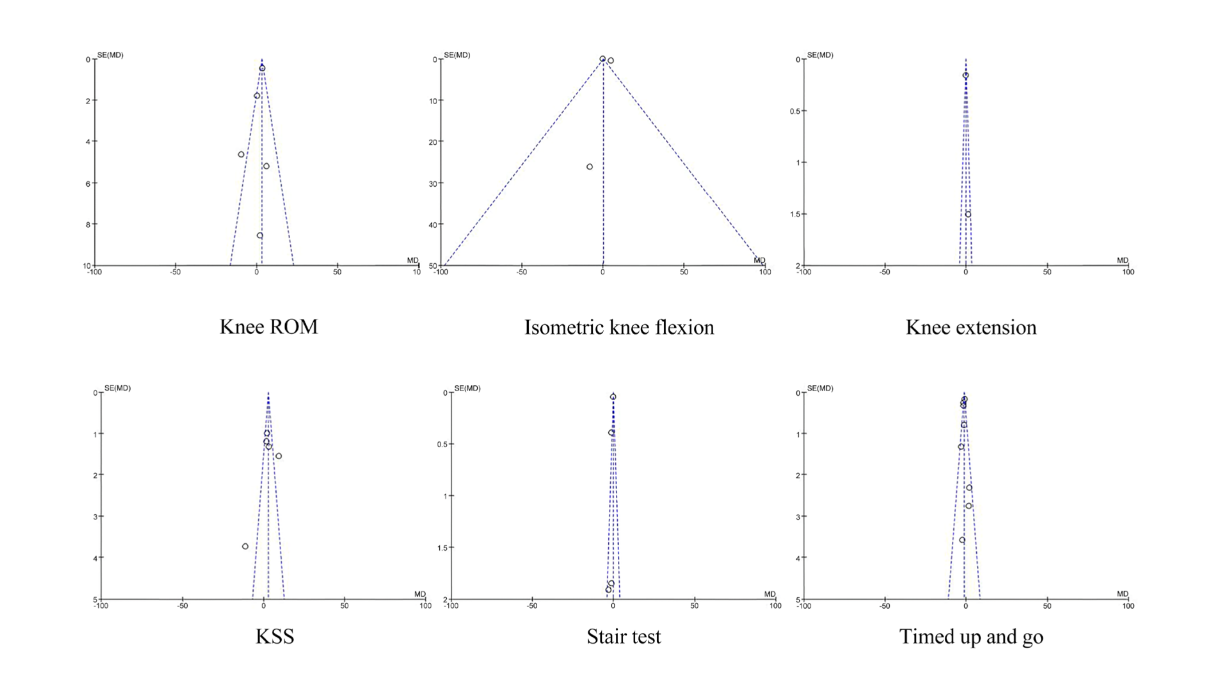

Figure 9. Funnel plot of publication bias.

Discussion

Knee osteoarthritis is primarily caused by factors such as overexertion and excessive weight-bearing, leading to degenerative joint disease. Its main manifestations include joint pain, swelling, and reduced range of motion[25]. Following knee injuries, patients often experience reduced activity levels, leading to varying degrees of muscle weakness and decreased joint stability. This may cause vulnerability to acute injuries during movement, thus creating a vicious cycle[26]. Total knee arthroplasty has demonstrated excellent effectiveness in the management of end-stage knee osteoarthritis, alleviating the pain for countless patients worldwide[27]. Postoperative rehabilitation is a crucial factor in the outcome of TKA. While early pain relief, muscle strengthening, and joint range of motion restoration have been the focus of rehabilitation, a significant number of patients still experience knee instability and an increased risk of falls after surgery, seriously compromising their quality of life. This suggests that, in addition to the aforementioned aspects, other potential factors that affect post-TKA knee stability require consideration[28]. With the development of rehabilitation medicine, researchers[29] have found that deficits in proprioception and balance ability after surgery are also significant factors affecting postoperative function.

Therefore, we conducted this study using rigorous scientific methods and insightful analysis to assess the impact of preoperative balance training on walking ability, balance specificity, and functional indicators in KOA patients undergoing total knee arthroplasty. This study included 10 research articles[15-24] involving 625 patients, and the results showed that compared to traditional rehabilitation, balance training improved the walking ability and balance performance of post-TKA patients. Similarly, the experimental group showed significantly greater improvement in subjective measurements of physical function than the control group. When preoperative balance training was combined with measurements of walking ability, balance specificity, and subjective measurements of physical function, the improvement was even more pronounced. According to the consensus in the literature, traditional rehabilitation programs alone are sufficient to enhance balance. Nevertheless, this current meta-analysis indicates that individuals undergoing around six weeks of balance training, either as an adjunct to conventional rehabilitation or different from conventional rehabilitation, exhibited notably greater improvements in tasks specific to balance compared to those undergoing only conventional rehabilitation. It is currently challenging to compare these findings with previous review articles due to a lack of such reviews in this area. Moutzouri et al[30] conducted a systematic review of six studies, revealing enhanced functional capacity and balance in patients after TKA through rehabilitation focused on proprioception, postural control, and coordination. Doma[31] conducted a systematic review and meta-analysis involving 12 studies, concluding that clinicians should contemplate the implementation of rehabilitation programs for elderly patients after TKA, underscoring the advantages of exercises targeting balance. They concluded that clinicians should consider implementing rehabilitation programs for elderly patients after TKA and emphasized the benefits of exercise targeting balance.

Modern medical research[32] has found that the development of KOA is a long-term and irreversible process. With increasing age, patients with KOA experience a decline in knee extensor muscle strength, diminished proprioceptive function, and reduced central integration ability. These factors often interact with each other, forming a vicious cycle that leads to a decrease in balance ability[33]. Impaired balance ability in patients with KOA increases the risk of falls, significantly affecting the patient's quality of life. There are abundant proprioceptors in the tissues surrounding the knee joint, including tendons, ligaments, joint capsules, and menisci. The central nervous system receives joint motion sensation, position sensation, and vibration sensation from these proprioceptors and uses efferent nerves to mobilize the limb movement system, adjusting the body's posture and maintaining the flexibility of movement to prevent falls[34]. After TKA, inevitable damage to joint cartilage, menisci, and cruciate ligaments, as well as partial damage to the joint capsule and surrounding ligaments, further diminishes proprioceptive and balance abilities[35]. Targeted training for proprioception and balance is known as proprioception and balance training[36].

Balance training can improve the interrupted sensory pathways and neuromuscular conduction velocity around the knee joint, thereby promoting the recovery of proprioception and improving the functional symptoms of the knee joint. Biomechanically, balance training can promote the restoration of muscle strength, thereby improving the mechanical characteristics of the coronal plane of the knee joint. When the knee joint contacts the ground, the vertical impact on the ground is reduced, thereby decreasing the occurrence of knee valgus[37]. These biomechanical changes play a positive role in preventing repeated twisting injuries of the knee joint. In summary, balance training is an important part of the rehabilitation of chronic knee instability. The choice of exercise program is key to improving exercise efficiency, and this study provides strong evidence support for balance training programs[38,39]. It is recommended that in the future, the intervention plan provided by this article be used for rehabilitation training for chronic knee instability.

However, our meta-analysis has the following limitations. First, this study lacks some key data, which has an impact on the analysis of these results. Second, there is a lack of comprehensive reporting on the effect of preoperative balance training on the function of patients after TKA. Third, there are inherent subtle differences between prospective and retrospective studies. In this study, heterogeneity stems from various aspects. It can be the variability in outcome measurement and the difference in method rigor, especially in RCTs, which might be a potential source of such differences. Fourth, due to inconsistent follow-up in the included literature, this study only focused on the early impact of training, lacking in-depth research on the medium to long-term effectiveness. Furthermore, some studies included in the literature were preoperative interventions, while others were postoperative interventions. It has been reported[18] that both preoperative and postoperative interventions can improve patients' proprioception and balance after surgery. However, due to the relatively small number of studies included in this study, a subgroup analysis of the effects of preoperative and postoperative training is unavailable. Moreover, it is important to note that the training techniques employed in each study varied. Therefore, it is valuable to further explore which training method yields the most optimal outcomes.

Conclusions

This study, through systematic review and meta-analysis, establishes that preoperative balance training significantly improves knee joint function and quality of life in patients after TKA. By comparing relevant literature and analyzing results with statistical significance, this study identifies the potential of preoperative balance training as an essential component. However, the safety and incidence of complications of preoperative balance training for TKA are currently unknown. Therefore, further high-level, multicenter, large-sample randomized controlled trials are still required to further accurately and comprehensively verify the effectiveness and safety of preoperative balance training in the management of TKA.

Data Availability

The datasets generated during and/or analyzed during the current study are available in the manuscript.

Ethics Approval and Informed Consent

This manuscript is not a clinical study; hence, the ethical approval and consent to participate are not applicable.

Conflict of Interest

The authors declare that they have no conflict of interest.

Authors' Contributions

J.-F. Yang conceived the study design and conceived the content concept; Y.-Q. Wang performed the data collection, extraction and analyzed the data. G.-B. Qu interpreted and reviewed the data and drafts. All authors were involved in the literature search, writing the paper, and had final approval of the submitted and published versions. All authors contributed to data analysis, drafting or revising the article, have agreed on the journal to which the article will be submitted, gave final approval of the version to be published, and agreed to be accountable for all aspects of the work.

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