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RESEARCH

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Effect of low-intensity muscle strength training on postoperative rehabilitation and adverse events in patients with knee osteoarthritis over 55 years of age: a meta-analysis

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Abstract

Background This study aimed to study the effect of low-intensity muscle strength training on postoperative rehabilitation of patients with knee osteoarthritis over 55 years of age and the incidence of adverse events by a meta-analysis.

Methods We searched China National Knowledge Infrastructure (CNKI), WanFang, China Science and Technology Journal Database (VIP), PubMed, Web of science, and Embase databases for articles on the effect of low-intensity muscle strength training on the recovery of patients with knee arthritis. And meta-analysis combined effect was performed in R 4.2.2 software. Quantitative analysis and risk of bias were assessed by Begg's and Eegger's test.

Results Meta-analysis showed that the effect of low-intensity muscle strength training on postoperative knee range of motion in patients with knee arthritis was mean difference (MD) = 5.20, *95% CI*=[4.00, 6.40], $\tau^2 = 0.43$, $P = 0.34$; the effect on postoperative muscle strength was standard mean difference (SMD) = 1.24, *95% CI*=[0.86, 1.61], $\tau^2 = 0.07$, $P < 0.01$; the effect on postoperative knee joint score was MD = 5.88, *95%CI*=[2.09, 9.67], $\tau^2 = 16.60$, $P < 0.01$; the effect on postoperative knee visual analogue scale (VAS) score was MD=-1.12, *95%CI* =[-1.43, -0.81], $\tau^2 = 0.09$, $P < 0.001$; the effect on the incidence of adverse events was RR = 0.85, *95%CI*= [0.52 1.39], $\tau^2 = 0.79$, $P = 0.04$.

Conclusion Low-intensity muscle strength training can improve the muscle strength of the affected limb and knee joint score, reduce the VAS score and the incidence of adverse events in patients with knee osteoarthritis over 55 years of age after surgery, but it has no effect on the postoperative knee range of motion, so it can be considered as appropriate in clinical selection.

Keywords Muscle strength training, Knee arthritis, Postoperative rehabilitation, Adverse events, Meta-analysis

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Introduction

Knee osteoarthritis (KOA) is a degenerative disease with high incidence in the elderly patients. With the rapid increase of population aging, KOA has become one of the most common chronic degenerative joint diseases in the world [1, 2]. KOA is characterized by articular cartilage degeneration, structural changes in subchondral bone, and osteophyte formation. This demographic transition underscores the critical demand for optimized rehabilitation strategies aimed at enhancing mobility, alleviating pain, and improving overall quality of life, especially in the elderly population. The main clinical manifestations are knee joint swelling, pain, stiffness, deformity, and increasingly severe mobility impairment [2, 3]. As the human body ages, proprioceptive disorders and movement disorders in patients can also lead to postural imbalance and decreased walking function, causing an increased risk of falls, which in turn leads to a deterioration in the patient's quality of life. Total knee arthroplasty (TKA) is currently the gold standard for the treatment of end-stage osteoarthritis [4]. The number of patients undergoing TKA surgery has increased globally in recent years. In the United States, there are more than 700,000 TKA procedures per year, and the number of TKA procedures is expected to increase significantly to 3.48 million by 2030 [5, 6]. However, the number of patients undergoing TKA surgery in China is less than half of that in the United States [7]. Although patients with KOA have less pain and improved quality of life after TKA surgery, there are still reports of decreased postoperative muscle mass, stride length, and walking speed [8]. Moreover, increased thigh muscle strength is associated with better performance in daily activities in patients with knee osteoarthritis [9], which suggest the importance of postoperative muscle strength training for patients. As a result, there is an increasing emphasis on postoperative rehabilitation techniques that prioritize muscle strength restoration to enhance long-term functional outcomes. Although plyometric training has demonstrated efficacy in improving muscle strength and joint function following TKA, the optimal intensity of such exercises for elderly patients remains a subject of ongoing debate. It has also been shown that the benefits of high-intensity plyometric training are not significantly improved compared to low-intensity plyometric training in patients after TKA, especially in patients over 55 years of age [10], so low-intensity plyometrics may be more appropriate. However, there is still some controversy about the applicability of plyometric training for postoperative rehabilitation of bone TKA patients over 55 years of age. Some studies believe that guided training can reduce the postoperative pain of TKA patients, improve the strength and range of motion of lower limb muscles, and shorten the hospital stay [11, 12]. Although some people support that muscle strength training in TKA patients can have a lasting effect on muscle strength [10], this does not necessarily mean that it can improve the functional performance of the patient's limbs [13] Therefore, in this study we used meta-analysis to retrieve Chinese and English databases on the effects of low-intensity plyometric training on postoperative recovery and the incidence of adverse effects in patients with knee osteoarthritis over 55 years of age, with a view to providing theoretical support for the postoperative plyometric rehabilitation of patients with osteoarthritis of the knee.

Methods

Data sources, search strategy, and screening

According to the PRISMA statement, Y ST and C FC systematically and comprehensively searched China National Knowledge Infrastructure (CNKI), Wanfang, China Science and Technology Journal Database (VIP), PubMed, Web of science, and Embase databases according to the combination of search keywords. The search time was updated from the establishment of the database to September, 2024. The following keywords were used for searching: Low intensity, strength training, exercise, sports, rehabilitation training, knee osteoarthritis, knee replacement, and TKA. Y ST and S HY worked together to formulate the search formula and the inclusion and exclusion criteria, and screened the literature according to this requirement. In case of disagreement between the two, a third researcher was added to adjudicate together. This systematic review has been performed and written in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Inclusion and exclusion criteria of literatures

Inclusion criteria: The type of study in the literature was a randomised controlled trial, cohort study or case-control study; the research objects were patients with clinical diagnosis of knee osteoarthritis, aged > 55 years; the intervention method of the experimental group is low-intensity muscle training, and the control group was routine exercise, including joint mobility training and muscle stretching training; included outcome measures were range of motion of the knee joint, muscle strength, knee joint score, knee Visual Analogue Scale/Score (VAS) score, and adverse events.

Exclusion criteria: the age of the patients in the study were ≤55 years old; the types of literature were review, case report, news, master's or doctoral dissertation; all outcomes in the literature were missing or cannot be extracted.

Included data extraction and literature quality evaluation

Two researchers independently reviewed the full text of the references and extracted the following data: study authors, year of publication, number of cases in the experimental and control groups, age, body mass index (BMI), intervention measures, and outcome measures. Literature quality assessment and risk of bias assessment were performed according to the methods recommended by the Cochrane Handbook. Specifically, it includes 7 aspects: random bias, allocation bias, blinding, measurement bias, result bias, reporting bias and other biases. For each indicator, "Low risk", "Unclear" and "High risk" are used to judge. Cohort and case-control studies are usually assessed for quality using the Newcastle-Ottawa Scale (NOS), which quantifies the quality of the study by assessing three dimensions: Selection, Comparability, and Outcome for cohort studies or Exposure for case-control studies.

Data extraction and quality assessment

After data extraction was completed, the GRADE framework was employed to systematically assess the quality of the evidence included in the study. This approach evaluates evidence across multiple dimensions. First, in terms of study design, randomized controlled trials (RCTs) are typically regarded as the gold standard for high-quality evidence, whereas observational studies are usually downgraded. Second, when assessing the risk of bias, studies with a high risk of bias are subject to a reduction in evidence quality.inconsistency refers to the presence of significant heterogeneity among study outcomes, which, if pronounced, can further degrade the quality of evidence. Indirectness examines whether the study outcomes directly address the research question; if indirect factors are present, evidence quality is downgraded. Precision evaluates the accuracy of the statistical results, particularly the width of the confidence intervals; imprecise results or overly wide confidence intervals can adversely affect evidence quality. other factors, such as publication bias, must also be considered, as they may further diminish the quality of evidence. By evaluating these dimensions, the GRADE method offers a systematic and objective framework for determining the overall quality of evidence.

Statistical analysis

Data analysis was performed using R4.2.2 and Meta package. Heterogeneity of studies was tested using chi-square test and I^2. If the heterogeneity between the literatures included in the study was less than $I^2 \leq 50\%$, the fixed effect model was used.

A pooled effect size analysis was performed; $I^2 > 50\%$ of the included studies had heterogeneity, and a random-effects model was used to analyze the possible causes of clinical and statistical heterogeneity. The Begg's and Eegger's tests were used to determine whether there was publication bias in the literature. The mean difference (MD) was used as the effect size for continuous variable data, and standard mean difference (SMD) was used as the effect size if the units of the included data were harmonised. The relative risk (RR) and 95% confidence interval (*CI*) were used for dichotomous variable data. $P < 0.05$ was the statistically significance.

Results

Study selection and study characteristics

A total of 532 related Chinese and English literatures were obtained through the search, including 56 Chinese and 476 English literatures. The titles and abstracts of the literatures were read after removing duplicate literatures using the software,376 literatures were excluded, and the full texts of the remaining 156 literatures were obtained for detailed reading. 5 papers were excluded from repeated publications, 56 papers without outcome indicators, and 22 papers related to non-patients over 55 years of age, or master's and doctoral dissertations, etc. Finally, 9 publications were included for a meta-analysis (see Fig. 1). The general data of the included studies had a good baseline and were comparable. However, the difference in training between the experimental group and the control group may lead to difficulties in interpreting the results. So, we do not consider the content of the training, but only use the intensity as the evaluation standard. Table 1 summarizes the demographic data and study characteristics of the 9 included RCTs.

Quality evaluation of the included literatures

9 articles were included in this study. 8 articles were randomised controlled studies and one article was a cohort study. Risk of bias evaluation was performed, and the results are shown in Figs. 2 and 3, with 1 cohort study scoring 7 on the NOS scale, all of which met the requirements of this article.

GRADE evidence quality evaluation

In this study, the GRADE framework was utilized to systematically evaluate the quality of evidence from the included studies. The assessment results indicated that several randomized controlled trials (RCTs) were classified as high-quality evidence due to their rigorous designs and consistent outcomes, providing preliminary support for the beneficial effects of low-intensity plyometric training on postoperative recovery in patients with knee osteoarthritis. However, some observational studies were downgraded to moderate-quality evidence, primarily due to the presence of bias and inconsistencies in their findings, suggesting that while these studies offer valuable insights, the reliability of their conclusions

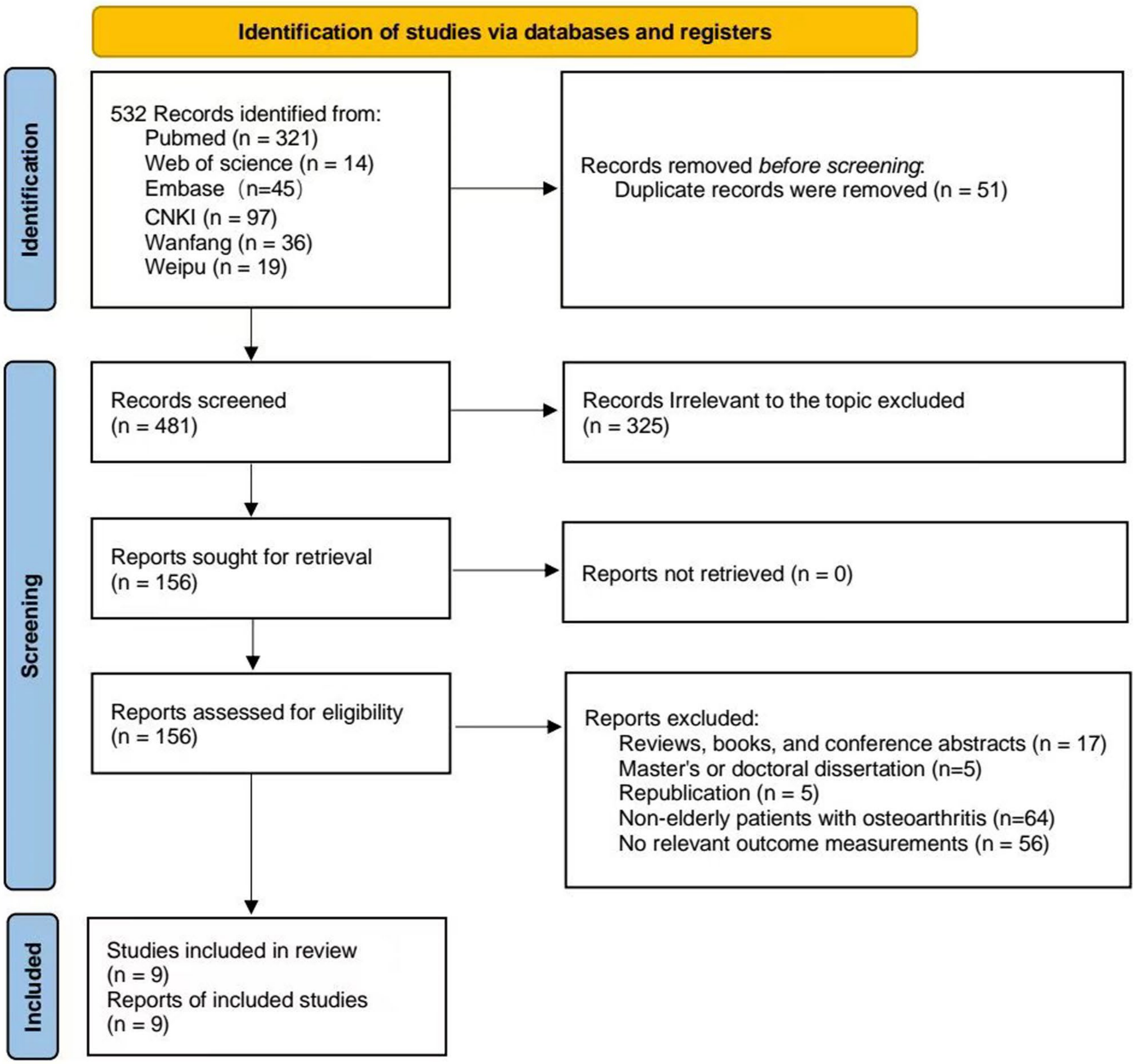

Fig. 1 The flowchart of literatures search

is somewhat constrained. Moreover, certain studies with small sample sizes and inadequate statistical precision were categorized as low-quality evidence, reflecting a weaker basis for the conclusions drawn. Table 2 Outcome measure GRADE evidence grading.

Meta-analysis of low-intensity muscle strength training on postoperative knee range of motion in patients with KOA

6 included studies reported the effect of low-intensity muscle strength training on postoperative knee range of motion in patients over 55 years of age with KOA. The results of heterogeneity test showed the heterogeneity of 6 studies were small (I^2=11%). There was no significant difference between the experimental group and the control group (MD=5.20 degrees, *95% CI* = [4.00, 6.40], τ^2=0.43, P=0.34). Low-intensity muscle strength training did not significantly improve the range of motion of the patient's knee (Fig. 4).

Meta-analysis of low-intensity muscle strength training on postoperative muscle strength in patients with KOA

4 included studies reported the effect of low-intensity muscle strength training on postoperative muscle strength in patients over 55 years of age with KOA. There was moderate heterogeneity among the 6 studies (I^2=80%>50%), then a random effects model SMD=1.24

Table 1 Summary of the characteristics of the included studies

Study (references)	Years	*N* (experiment group/control group)	Average BMI(Kg/m2)	Mean age (y)	Intervention of experiment group	Intervention of control group	Outcome indexes
An [14]	2021	17/18	26.25 /26.51	70.05/70.38	muscle strength training/knee stretch/flexible training	exercise routine	knee range of motion
Hsu [15]	2017	16/18	27.5/26.5	72.1/69.9	stretch/aerobic training/resistance training	exercise routine	knee range of motion; muscle strength
Jakobsen [16]	2017	32/35	29.8/29.4	66/63	progressive strength training/stretch	exercise routine	knee range of motion; Knee Score; adverse events
Moutzouri [17]	2019	26/25	29.9/30.5	71.3/72.3	Strengthening / muscle strength / lower body function training	exercise routine	knee range of motion; Knee Score; adverse events
Suzuki [18]	2019	28/24	23.88/23.54	60.1/58.3	Lower body strength training	exercise routine	Knee VAS Score; adverse events
Unver [19]	2016	30/30	31.82/31.17	69.53/69.8	Resistance straight leg raises and static lower body strength exercises	exercise routine	knee range of motion; Knee Score; Knee VAS Score; adverse events
Xia [20]	2022	62/62	/	64.21/64.37	Lower body resistance training/knee stretch	exercise routine	muscle strength; Knee Score; adverse events
Zhang [21]	2022	42/42	/	63.1/62.3	Lower body resistance training/knee stretch	exercise routine	knee range of motion; Knee Score; Knee VAS Score
Zhang [22]	2018	43/43	22.67/22.79	63.22/65.13	muscle strength standard guided functional training	exercise routine	Knee range of motion; Knee Score; adverse events

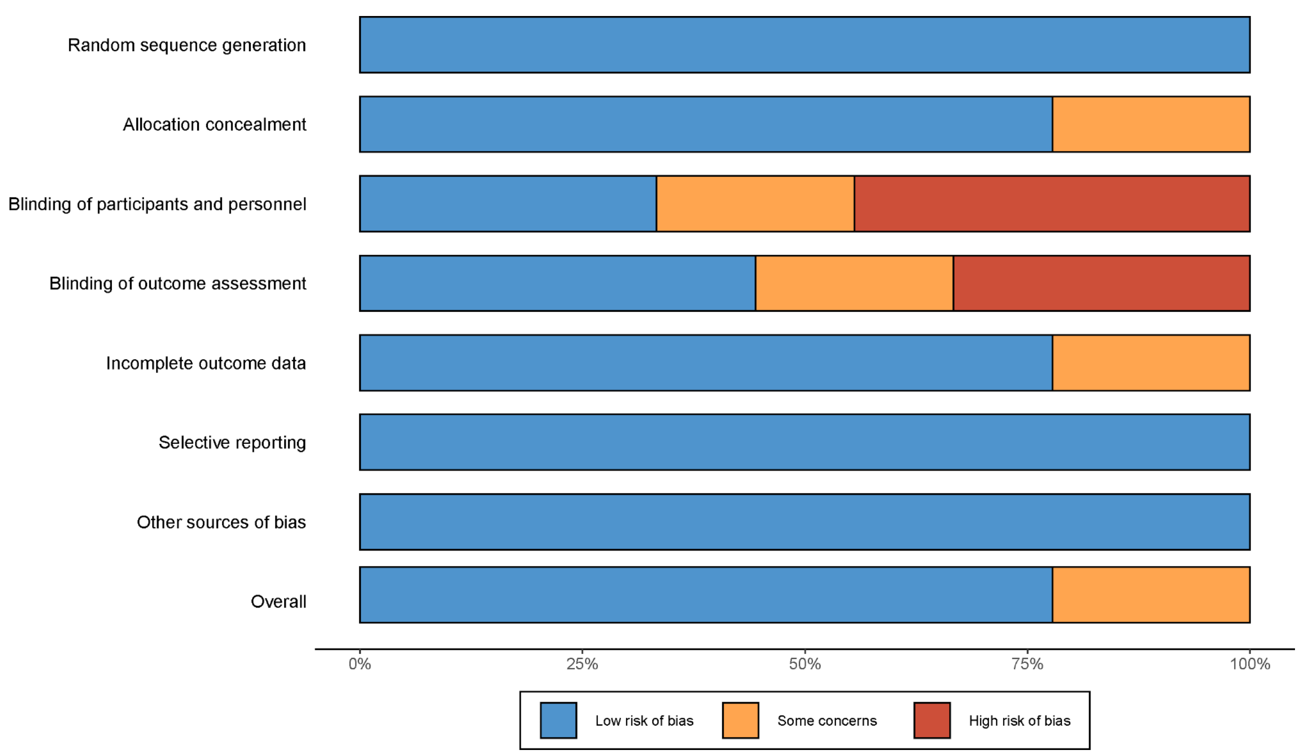

Fig. 2 Analysis of the proportion of various types of bias

with a *95% CI* of [0.86, 1.61] was used, and the combined effect sizes test τ^2=0.07, with a statistically significant difference between the two groups ($P<0.01$). The muscle strength of the patients in the experimental group was higher than that of the patients in the control group, suggesting that low-intensity muscle strength training can improve the postoperative muscle strength of patients (Fig. 5). Data-consolidated effect sizes for unit harmonisation use SMD and do not need to be followed by additional units.

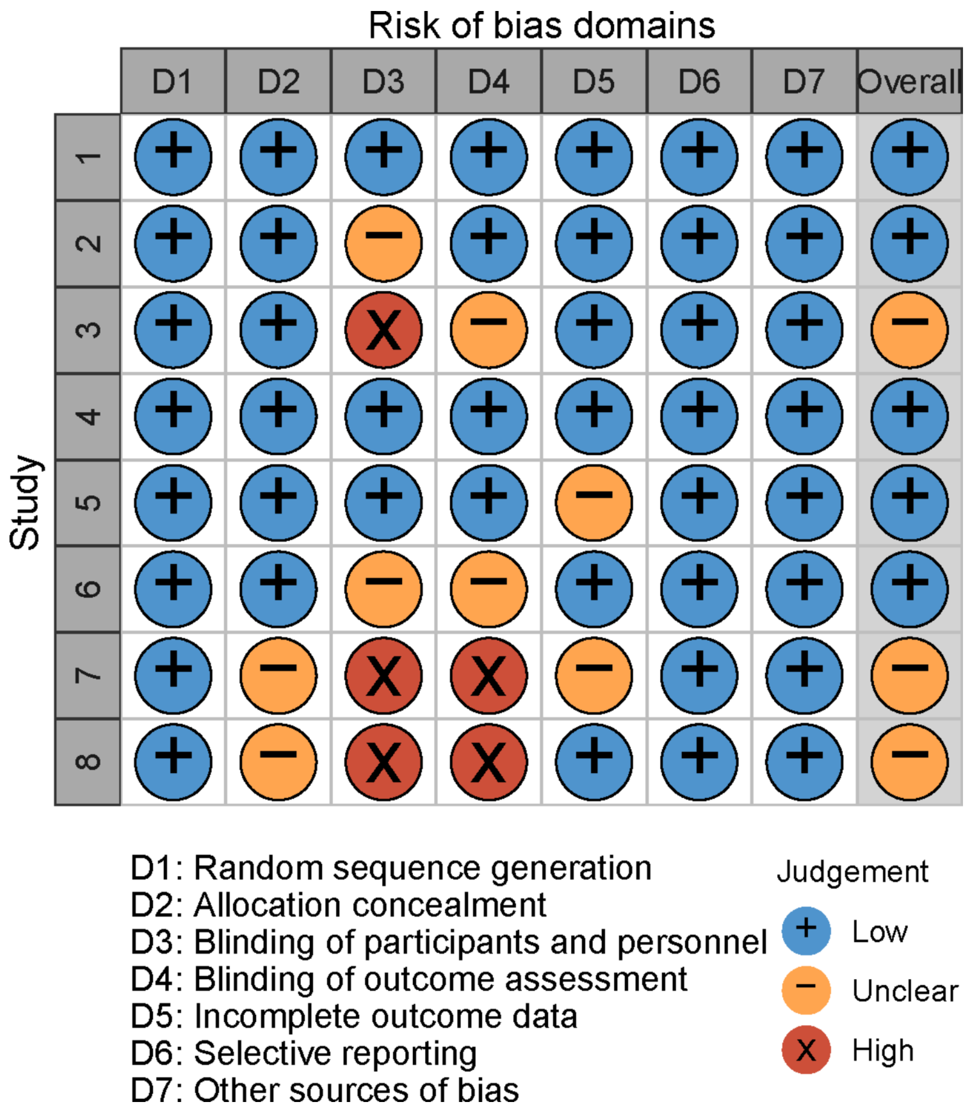

Fig. 3 Risk of bias analysis diagram

Table 2 Outcome measure GRADE evidence grading

No of study	**Quality assessment**					**No of patients**		**Effect**	**Quality**
	Risk of Bias	Inconsistency	Indirectness	Imprecision	Publication Bias	experiment	Control		
postoperative knee range of motion	-1	0	0	-1	0	164	169	MD = 5.20 degrees, 95% CI = [4.00, 6.40]	Low
postoperative muscle strength	-1	0	0	0	0	146	147	SMD = 1.24 with a 95% CI of [0.86, 1.61]	Low
postoperative knee score	-1	0	0	0	0	209	212	MD = 5.88, *95%CI*=[2.09, 9.67]	Moderate
postoperative knee VAS scores	-1	0	0	0	0	100	96	MD=-1.27, *95%CI* =[-1.76, -0.78]	Moderate
postoperative adverse reactions	-1	0	0	-1	0	218	225	RR = 1.14, 95% CI = [0.43, 3.02],	Low

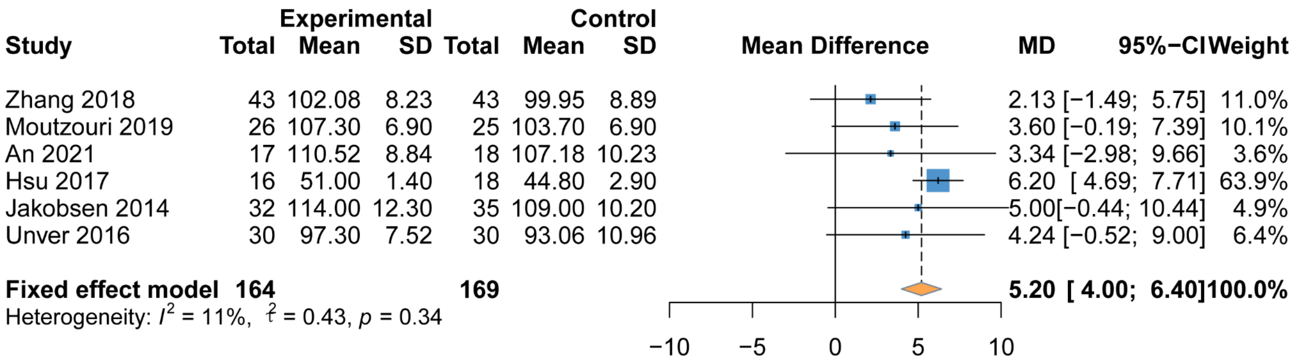

Fig. 4 Effect of low-intensity muscle strength training on postoperative knee range of motion in patients over 55 years of age with KOA

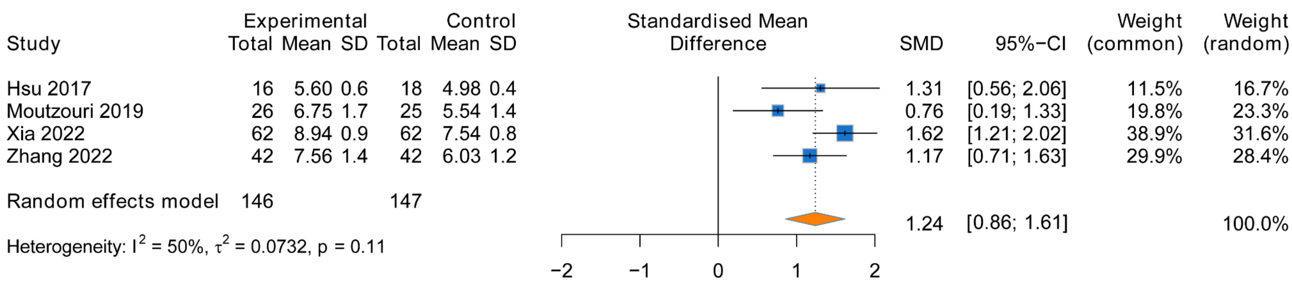

Fig. 5 Effect of low-intensity muscle strength training on postoperative muscle strength in patients over 55 years of age with KOA

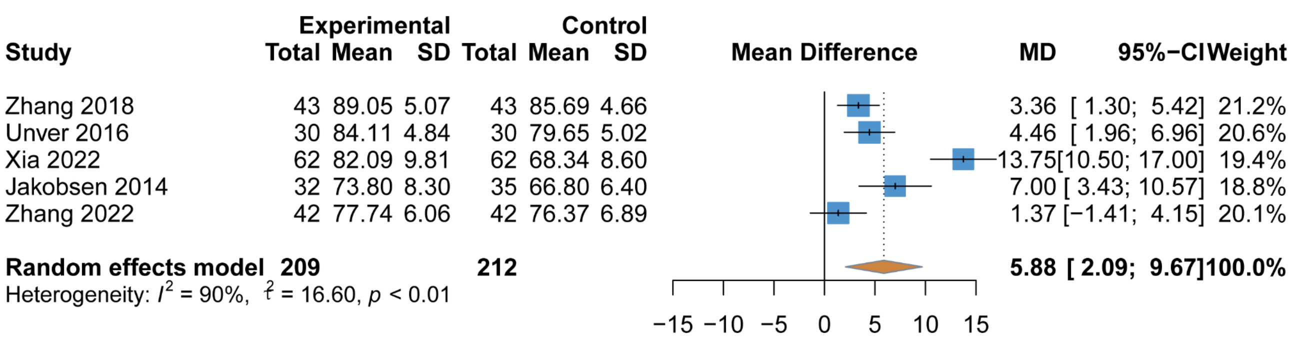

Fig. 6 Effects of low-intensity muscle strength training on postoperative knee score in patients over 55 years of age with KOA

Meta-analysis of low-intensity muscle strength training on postoperative knee score in patients with KOA

5 included studies reported the effect of low-intensity muscle strength training on postoperative knee score in patients over 55 years of age with KOA. There was high heterogeneity among the 5 studies (I^2=90%). There was a significant difference between the experimental group and the control group (MD=5.88, *95%CI*=[2.09, 9.67], τ^2=16.60, P<0.01). The knee joint score of the patients in the experimental group was higher than that of the patients in the control group, suggesting that low-intensity muscle training can improve the recovery of knee joint function in patients after surgery (Fig. 6).

Meta-analysis of low-intensity muscle strength training on postoperative knee VAS scores in patients with KOA

The 3 included studies reported the effect of low-intensity muscle strength training on postoperative knee VAS scores in patients over 55 years of age with KOA. There was low heterogeneity among the 3 studies (I^2=91.2%). There was no significant difference between the two groups (MD=-1.12, *95%CI* =[-1.43, -0.81], τ^2=0.09, P<0.001). Low-intensity muscle strength training had significant effect on the postoperative knee VAS score of the patients, as shown in Fig. 7.

Meta-analysis of low-intensity muscle strength training on the incidence of postoperative adverse reactions in patients with KOA

There are 5 literatures reporting the effect of low-intensity muscle strength training on the incidence of

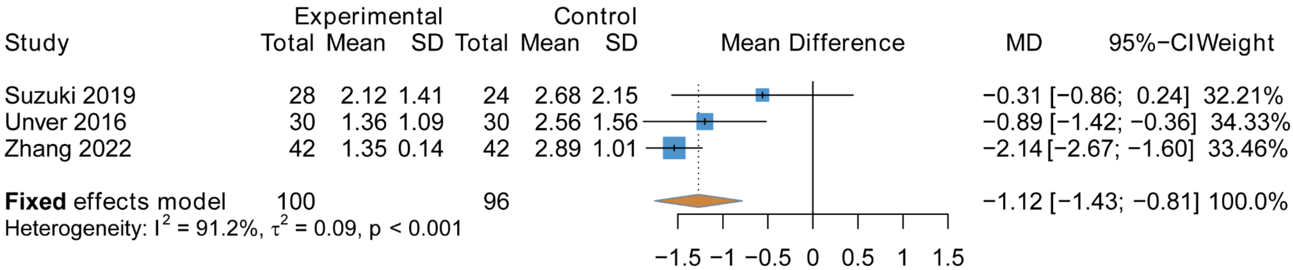

Fig. 7 Effect of low-intensity muscle strength training on postoperative knee VAS scores in patients over 55 years of age with KOA

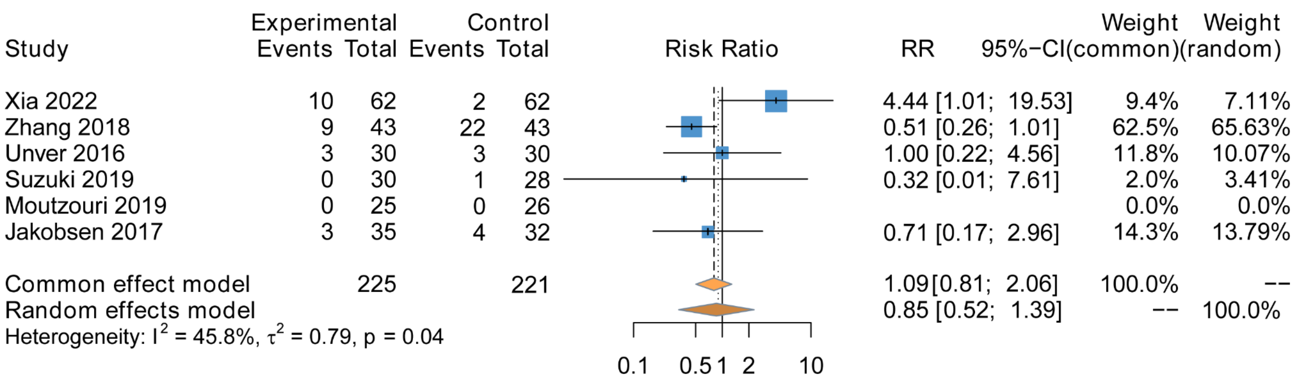

Fig. 8 Effect of low-intensity muscle strength training on the incidence of postoperative adverse reactions in patients over 55 years of age with KOA

Table 3 Publishing bias detection (Begg's和Eegger's test)

	Begg's test		Eegger's test	
Knee range of motion	z = 0.19	*p* = 0.85	t = -2.34	*p* = 0.08
Muscle strength	z = -0.68	*p* = 0.50	t = 0.37	*p* = 0.75
Knee Score	z = 0.98	*p* = 0.33	t = 1.31	*p* = 0.28
Knee VAS score	z = 1.57	*p* = 0.12	t = 4.66	*p* = 0.13
Adverse events	z = -0.49	*p* = 0.62	t = -0.93	*p* = 0.41

postoperative adverse reactions in patients over 55 years of age with KOA. There is a moderate degree of heterogeneity among the included studies (I^2=45.8%). The difference of adverse events between the two groups was statistically significant (RR=0.85, *95%CI*= [0.52 1.39], τ^2=0.79, *P*=0.04). The incidence was lower than that in the control group, suggesting that strength training may reduce the incidence of adverse reactions (Fig. 8).

Publishing bias

Since the literatures included in this study were relatively small, it was not suitable to use funnel plots for risk bias evaluation. Begg's and Eegger's methods were used. The results were found to be *P*>0.05 for all tests, thus there was less publication bias among the included studies, as shown in Table 3.

Discussion

In the process of rehabilitation after total knee replacement, the appropriate intensity of muscle strength training has always been a key clinical problem. Our meta-analysis study showed that although the low-intensity muscle strength training has no significant effect on the postoperative knee range of motion , but it has a significant effect on improving the patient's muscle strength and knee function score and knee pain (measured by VAS score) of the affected limb, and can effectively reduce the incidence of adverse reactions (*P*<0.05). Low-intensity training facilitates the activation of slow-twitch muscle fibers (Type I fibers), which are primarily responsible for endurance activities and play a key role in maintaining knee stability, particularly during the early stages of postoperative rehabilitation. Additionally, low-intensity repetitive training helps prevent excessive joint loading. Moreover, this type of training promotes neuromuscular adaptations, enhancing proprioception and neural control of muscles—both of which are critical for precise movement regulation and joint stabilization throughout the recovery process. These findings highlight the importance of muscle strength recovery for patients after TKA. And because of these postoperative complications, plyometric training has been recommended to patients as an important rehabilitation measure to promote the recovery of muscle strength, reduce pain and improve joint function [13, 18].

Thus, among the many rehabilitation methods, low-intensity plyometric training is often recommended for patients with osteoarthritis of the knee over 55 years of age due to its relatively low risk and good tolerability. There is also a strong correlation between increased muscle strength in patients and the improvement of patients' daily mobility and overall quality of life, especially in terms of restoring self-care abilities and independence in life [23]. In addition, the ability of low-intensity training to reduce adverse reactions is also of great clinical significance, because these complications may lead to prolonged recovery time and increased medical costs [24]. However, the limited effect of low-intensity training on knee joint flexibility and pain also points out the necessity of integrating other treatment methods into rehabilitation plan [16]. For example, combining physical therapy with specific stretching exercises may be more effective for comprehensively improving the rehabilitation effect of patients [16]. In addition, considering that the research mainly focuses on the early postoperative rehabilitation effect, future research needs to further explore the role of low-intensity muscle strength training in the long-term rehabilitation process, especially the long-term impact on maintaining and improving muscle strength and joint function.

There were the following shortcomings in our study. (i) Since the current attention to low-intensity muscle strength training to improve limb function and muscle weakness after knee arthritis is not enough, this study also has the problem of insufficient literature. It is necessary to further increase the sample size for analysis; (ii) the definition of strength training intensity is still unclear. There were certain differences in the identification of training intensity in different countries and regions, different age groups (e.g. training category differentiation and duration determination), which may bring some risk of bias.

In conclusion, low-intensity muscle strength training has been proven to improve postoperative knee function and limb muscle strength in patients over 55 years of age with KOA, and reduce the incidence of adverse events. It is a postoperative rehabilitation measure that can be promoted. As for the further research, we suggest: [1] strengthen the research on the improvement of postoperative function and muscle strength of knee arthritis by low-intensity strength training; [2] clarify the definition of strength training intensity in different backgrounds to reduce bias; [3] Explore ways to combine it with other rehabilitation treatments to further optimize the postoperative rehabilitation effect of patients with knee osteoarthritis, as well as the long-term impact on quality of life. These efforts will help advance the development and application of low-intensity strength training in clinical practice.

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

Author contributions

Conception and design: STY and FCCAdministrative support: STY, CQD and YLCollection and assembly of data: All authors. Data analysis and interpretation: HYSManuscript writing: All authors. Final approval of manuscript: All authors.

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Data availability

All data generated or analyzed during this study are included in this published article.

Declarations

Human ethics and consent to participate

Not applicable.

Consent for publication

No applicable.

Competing interests

The authors declare no competing interests.

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References

1. You Y, Liu J, Tang M, et al. Effects of Tai Chi exercise on improving walking function and posture control in elderly patients with knee osteoarthritis: a systematic review and meta-analysis. Medicine. 2021;100(16):e25655.
2. Jakobsen TL, Jakobsen MD, Andersen LL, et al. Quadriceps muscle activity during commonly used strength training exercises shortly after total knee arthroplasty: implications for home-based exercise-selection. J Experimental Orthop. 2019;6(1):29.
3. Zou L, Liu J, Lu H. Influence of protein kinase RIPK4 expression on the apoptosis and proliferation of chondrocytes in osteoarthritis. Mol Med Rep. 2018;17(2):3078–84.
4. Kim SA, Park HY, Shin YW, et al. Hemovac blood after total knee arthroplasty as a source of stem cells. Annals Translational Med. 2020;8(21):1406.
5. Xu T, Yang D, Liu K, et al. Efficacy and safety of a self-developed home-based enhanced knee flexion exercise program compared with standard supervised physiotherapy to improve mobility and quality of life after total knee arthroplasty: a randomized control study. J Orthop Surg Res. 2021;16(1):382.
6. Chiang CY, Chen KH, Liu KC, et al. Data Collection and Analysis Using Wearable Sensors for Monitoring Knee Range of Motion after total knee arthroplasty. Sensors. 2017;17(2):418.
7. Xu Z, Li H, Liu Z, et al. Robot-assisted surgery in total knee arthroplasty: trauma maker or trauma savior? A prospective, randomized cohort study. Burns Trauma. 2022;10:tkac034.
8. Bade MJ, Kohrt WM, Stevens-Lapsley JE. Outcomes before and after total knee arthroplasty compared to healthy adults. J Orthop Sports Phys Ther. 2010;40(9):559–67.
9. De Zwart A, Dekker J, Verberne S, et al. Association between Measures of Muscle Strength and performance of Daily activities in patients with knee osteoarthritis. J Rehabil Med. 2022;54:jrm00316.
10. Bade MJ, Struessel T, Dayton M, et al. Early high-intensity Versus Low-Intensity Rehabilitation after total knee arthroplasty: a Randomized Controlled Trial. Volume 69. Arthritis care & research; 2017. pp. 1360–8. 9.
11. Su W, Zhou Y, Qiu H, et al. The effects of preoperative rehabilitation on pain and functional outcome after total knee arthroplasty: a meta-analysis of randomized controlled trials. J Orthop Surg Res. 2022;17(1):175.

12. Husby VS, Foss OA, Husby OS, et al. Randomized controlled trial of maximal strength training vs. standard rehabilitation following total knee arthroplasty. Eur J Phys Rehabil Med. 2018;54(3):371–9.
13. Skoffer B, Maribo T, Mechlenburg I, et al. Efficacy of preoperative progressive resistance training in patients undergoing total knee arthroplasty: 12-month follow-up data from a randomized controlled trial. Clin Rehabil. 2020;34(1):82–90.
14. An J, Ryu HK, Lyu SJ, et al. Effects of Preoperative Telerehabilitation on muscle strength, Range of Motion, and functional outcomes in candidates for total knee arthroplasty: a single-blind randomized controlled trial. Int J Environ Res Public Health. 2021;18(11):6071.
15. Hsu WH, Hsu WB, Shen WJ, et al. Circuit training enhances function in patients undergoing total knee arthroplasty: a retrospective cohort study. J Orthop Surg Res. 2017;12(1):156.
16. Jakobsen TL, Kehlet H, Husted H, et al. Early progressive strength training to enhance recovery after fast-track total knee arthroplasty: a randomized controlled trial. Arthritis Care Res. 2014;66(12):1856–66.
17. Moutzouri M, Coutts F, Gliatis J, et al. Early initiation of home-based sensorimotor training improves muscle strength, activation and size in patients after knee replacement: a secondary analysis of a controlled clinical trial. BMC Musculoskelet Disord. 2019;20(1):231.
18. Suzuki Y, Iijima H, Tashiro Y, et al. Home exercise therapy to improve muscle strength and joint flexibility effectively treats pre-radiographic knee OA in community-dwelling elderly: a randomized controlled trial. Clin Rheumatol. 2019;38(1):133–41.
19. Unver B, Bakirhan S, Karatosun V. Does a weight-training exercise programme given to patients four or more years after total knee arthroplasty improve mobility: a randomized controlled trial. Arch Gerontol Geriatr. 2016;64:45–50.
20. Xia Yan QZ, Huang D. Application of Proprioception exercises combined with strength training in Rehabilitation after To- tal knee arthroplasty. Shanghai Nurs. 2022;22(1):5–9.
21. Zhang Xiaohe HY. Value of Isokinetic Muscle Strength Combined with Proprioception Training for Rehabilitation after total knee arthroplasty. Chin Foreign Med Res. 2022;20(7):42–5.
22. Zhang Yanguo YG. Effect of functional exercise guided by self-musclestrength standard combined with lower extremity muscle chains training on rehabilitation of knee osteoarthritis after total knee arthroplasty. Chin J Frontier Med. 2018;10(9):51–6.
23. Sakamoto R, Miura Y. The effect of exercise intervention on frail elderly in need of care: half-day program in a senior day-care service facility specializing in functional training. J Phys Ther Sci. 2016;28(7):1957–63.
24. Courage O, Strom L, Van Rooij F, et al. Higher rates of surgical and medical complications and mortality following TKA in patients aged ≥ 80 years: a systematic review of comparative studies. Efort Open Rev. 2021;6(11):1052–62.

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