Gao et al.
Journal of Orthopaedic Surgery and Research (2025) 20:384
https://doi.org/10.1186/s13018-025-05682-7

Journal of Orthopaedic Surgery and Research

SYSTEMATIC REVIEW

Open Access

Comparative efficacy of mind–body exercise for pain, function, quality of life in knee osteoarthritis: a systematic review and network meta-analysis

Kaixia Gao[1,2,4,5†], Jinmeng Tao[2,4,5†], Guangyuan Liang[3,4,5], Chen Gong[2,4,5], Lin Wang[1*] and Yuling Wang[2,4,5*]

Abstract

Introduction Knee osteoarthritis (KOA) is a prevalent chronic joint disease. Due to the risks of opioid use and limited pharmacological effectiveness, mind–body exercise (MBE) therapy and other non-pharmacological interventions have emerged as first-line treatments for this condition. However, the optimal MBE modes for KOA remain undetermined. This systematic review and network meta-analysis (NMA) aims to compare the efficacy of different MBE modes, including Pilates, Tai Chi, Yoga, and Qigong, in managing KOA.

Methods We searched PubMed, Embase, Cochrane Library, Web of Science, Scopus, China National Knowledge Infrastructure (CNKI), Wanfang Database from inception to 25 April 2024. Randomized clinical trials comparing MBE interventions for pain, physical function and quality of life (QoL) in KOA patients were eligible. The Cochrane Risk-of-Bias Tool 2.0 and Grading of Recommendations, Assessment, Development & Evaluation (GRADE) approach were used to assess literature quality and evidence certainty for each outcome.

Result A total of 38 studies (N = 2561) were included, with 38 for pain, 36 for physical function, and 12 for QoL in the NMA. With moderate-certainty, both Pilates and TC showed significant improvements in pain reduction [Pilates: standardized mean difference (SMD) = − 1.19, 95% confidence intervals (95% CI): − 1.92 to − 0.46; TC: SMD = − 0.78, 95% CI − 0.97 to − 0.59] and physical function (Pilates: SMD = − 1.37, 95% CI − 2.13 to − 0.50; TC: SMD = − 0.85, 95% CI − 1.08 to − 0.63) compared to the usual care group, while TC [SMD = − 0.57, 95% CI = (− 1.07 to − 0.06)] showed statistically significant efficacy in improving QoL compared to the usual care group.

Conclusion There is moderate-certainty evidence that Pilates and Tai Chi may be the most effective mind–body exercises for improving pain and physical function in knee osteoarthritis, while Tai Chi may be the best for improving quality of life. These findings may help clinicians guide their prescription of exercise types with respect to treatment outcomes. The limited number of large sample studies and the few studies with low bias risk are limitations.

Trial registration The protocol for NMA has been registered with PROSPERO (CRD42024531878).

Keywords Knee osteoarthritis, Mind–body exercises, Network meta-analysis, Systematic review

†Kaixia Gao and Jinmeng Tao share the first authorship.

*Correspondence:
Lin Wang
wanglin@sus.edu.cn
Yuling Wang
wangyul@mail.sysu.edu.cn
Full list of author information is available at the end of the article

Introduction

Knee osteoarthritis (KOA), a prevalent chronic joint disease, is a degenerative condition of the knee resulting from cartilage wear and loss [1]. KOA is characterized by intermittent weight-bearing pain, stiffness, swelling, and functional impairment, severely impacting quality of life (QoL). Individuals with KOA often suffer from depression and anxiety [2]. Observable anatomical changes, such as osteophyte formation and joint space narrowing, exacerbate these symptoms, evolving into a chronic condition [3]. Globally, KOA prevalence is 22.9% [4]. The Global Burden of Disease Study (GBD) identifies KOA significantly contributes to the age-standardized prevalence of osteoarthritis in most regions, except Central Asia and Eastern Europe. Projections indicate a 74.9% increase in the global KOA-affected population by 2050 from 2020 estimates, reaching about 642 million [5]. In China, KOA imposes substantial socioeconomic burdens, requiring effective management strategies [6, 7].

Current clinical guidelines acknowledge non-pharmacological interventions as core treatments appropriate for most KOA patients [8]. These interventions encompass patient education, self-management strategies, specific physical exercises, weight management [9], acupuncture [10, 11] and kinesio taping [12, 13]. Some interventions show promising results, like self-administered acupressure for pain and mobility improvement [14], and combined very low energy diet with exercise for weight management and functional improvement [15]. However, acupuncture is invasive with risks [10], and kinesio taping results are inconsistent due to method and duration variations [13]. In contrast, mind–body exercises (MBE) were recommended as core treatments in the 2019 OARSI guidelines due to their comprehensive and sustained efficacy [8]. MBE are low-impact activities integrating movement, breath control, and mental focus to promote mind–body coordination and health [16], such as Tai Chi (TC), Qigong [17], Yoga [18], and Pilates [19]. They enhance muscle strength, balance, flexibility, addressing KOA mechanical pain and functional issues, and provide psychological benefits by reducing anxiety and depression [6]. However, MBE requires professional instruction to proper technique, and the optimal frequency and duration of practice remain to be determined through further research [20].

While evidence supports the efficacy of MBE for managing pain, stiffness, physical function, and mental health in KOA patients [20], a significant research gap remains in understanding the comparative effectiveness of different MBE modalities. Most studies have compared MBE to conventional treatments or no intervention, rather than evaluating the specific benefits and differences between various MBE approaches such as Tai Chi, Qigong, Yoga, and Pilates. Only four RCTs directly compared TC with Qigong for KOA patients [21–25]. Few reviews and network meta-analysis (NMA) have focused on different exercise modalities for KOA [26–28]. Goh et al. [26] combined different MBE interventions, such as TC and Yoga, into a single treatment model, which may obscure individual effects and excluded Pilates studies. This approach of grouping various interventions is also evident in Mo et al. [27] and Li Jia et al. [28]. This limits determining the most effective MBE for KOA symptoms and QoL improvement.

Therefore, it is vital to conduct new systematic reviews and NMA that evaluate and compare the effects of various MBE on pain relief, functional improvement, and QoL enhancement in KOA patients, providing a clear, evidence-based guidelines for clinical application. Our results will help clinicians make evidence-based decisions when selecting MBE interventions. Researchers will be able to identify promising directions for future studies on optimizing MBE for KOA. Patients will benefit from more targeted and personalized MBE recommendations that consider their individual needs and preferences. Ultimately, this knowledge will enhance the non-pharmacological management of KOA, improving patient outcomes and QoL.

Materials and methods

Protocol and registration

We conducted a systematic review and network meta-analysis of RCTs to evaluate the comparative effectiveness of various mind–body exercises for KOA. We adhered to the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis for Network Meta-Analysis (PRISMA-NMA [29]) and the protocol for the NMA has been registered with PROSPERO (CRD42024531878).

Literature research

We searched PubMed, Web of Science, Cochrane Central Register of Controlled Trials, Embase, Scopus, Wanfang Database, and China National Knowledge Infrastructure (CNKI) for relevant literature from the inception of each database to April 2024. The included RCTs were conducted in diverse settings, including hospitals, clinics, and community centers. Reference lists from relevant systematic reviews published previously were reviewed to enrich the search. The search strategy included a combination of MeSH terms and free-text keywords related to mind–body exercises and knee osteoarthritis. The MeSH terms used were: “Tai Ji”, “Yoga”, “Qigong”, “Pilates”, “Mind–Body Therapies”, and “Osteoarthritis, Knee”. Additional free-text words, such as “mind–body exercise”, “tai chi”, “baduanjin”, and “knee osteoarthritis”, were also included to ensure a comprehensive search (eMethods in the Supplementary material 1). The search results from electronic database queries were transferred to EndNote X9 to remove duplicates. Study selection was performed by two reviewers (KXG and JMT). A third author (YLW) was involved if agreement could not be reached.

Eligibility criteria

Inclusion criteria

RCTs that compared MBE interventions with other types of interventions, including conventional therapeutic exercise (CTE), such as strengthening, aerobic, joint mobilization, neuromuscular, and balance exercises; usual care (UC), such as health education; and no treatment control (NT), were included. Participants (≥ 40 years) with clinically and/or radiographically diagnosed KOA were considered. Any structured MBE intervention classified as TC, Qigong (Baduanjin, Yijinjing, Wuqinxi, etc.), Yoga, or Pilates was included, provided that no additional active treatments (e.g., electrotherapy, manual therapy, or analgesics) were administered alongside the MBE interventions. The duration of the intervention had to exceed 7 weeks. Pain intensity, physical function, and QoL (all self-reported) were assessed, with pain as the primary outcome and the others as secondary outcomes.

Exclusion criteria

Studies were excluded if data could not be extracted from figures or tables, or if participants had received previous invasive treatments, such as knee surgery or corticosteroid injections, or had knee pain caused by rheumatic. Additionally, conference abstracts, case reports, secondary analyses, reviews, and protocols were excluded from the analysis.

Data extraction

Two reviewers (KXG and JMT) independently extracted five types of data using a standard information form: (1) basic publication details (first author, publication year, and country); (2) participant characteristics (mean age and sex); (3) study characteristics (parallel or crossover trial, two-arm or multi-arm parallel trial, sample size); (4) key components of the MBE and comparison interventions; and (5) outcomes (any measure of pain intensity, self-reported function and QoL). Inter-rater reliability was assessed using Cohen's kappa coefficient, which indicated excellent agreement between reviewers (kappa = 0.92). If an included RCT had multiple treatment arms, data from each arm were analyzed separately to evaluate the effect of each intervention. This approach ensures that each treatment arm is considered as an independent comparison in the NMA. Baseline characteristics and outcome data were extracted into a standardized form (mean ± SD). For studies that did not report data in a standard form, missing data were estimated using standard errors (SEs), confidence intervals (CIs), interquartile ranges (IQRs), or *P*-values through single or combined conversion. If a study reported multiple scales for pain intensity, physical function or QoL, the most sensitive scale was selected according to a predefined ranking order [30, 31]. In addition, when multiple time points were available, only data collected immediately after the intervention were extracted.

Outcome

The primary outcome was pain intensity, which was assessed using a hierarchical list of scales prioritizing instruments with higher sensitivity and comprehensive reporting [26, 32]. The scales, in order of priority, were: (1) Numeric Rating Scale (NRS); (2)Visual Analogue Scale (VAS); (3)Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) pain subscore; (4) Knee Injury and Osteoarthritis Outcome Score (KOOS) pain subscore; (5) Lequesne's index. The secondary outcomes included physical function and QoL. Physical function was evaluated using a hierarchical list of scales, prioritizing instruments that comprehensively evaluate the impact of knee osteoarthritis on daily activities [26, 32]. The scales, in order of priority, were: (1) WOMAC function subscore; (2) Activities of Daily Living (ADL); (3) KOOS ADL subscore; (4) Lower Extremity Functional Scale (LEFS); (5) Lysholm Knee Scoring Scale; (6) Lequesne's index. QoL was measured by (1) Short Form (SF)−36; (2) SF-12; (3) KOOS QoL subscore; (4) AQoL-6D assessment scales [26].

Data synthesis and analysis

For continuous outcomes (pain intensity, physical function, and QoL), the standardized mean difference (SMD) and 95% confidence interval (95% CI) were used to normalize the results to a consistent scale. The SMD of the change score (end-point minus baseline score) was calculated to estimate the effect size (ES). When the SDs of the change score were unavailable, we estimated the missing SDs using the following formula from the Cochrane Handbook [33]:

$$\text{SD\_change} = \sqrt{\left(\text{SD}^2\text{\_baseline} + \text{SD}^2\text{\_end\_point} - (2 \times 0.5 \times \text{SD\_baseline} \times \text{SD\_end\_point})\right)}.$$

Clinically, effect sizes were categorized as small (< 0.40), moderate (0.40–0.70), or large (> 0.70) based on the SMD [34]. A 95% CI for the SMD that does not include zero signifies a statistically significant difference between the two interventions [35]. Given that different instruments interpret outcome measures differently, when studies used a reverse scale (where higher values represented better outcomes instead of worse ones), the group means were multiplied by − 1, following the guidance outlined in the Cochrane Handbook [36]. The variables used for assessing the transitivity assumption are detailed in the Supplementary material 2 [37]. NMA was performed using the frequentist approach in Stata/MP statistical software version 17.0 [38–40]. To visualize network geometry and connectivity between nodes, network plots were generated for each outcome, with node sides representing the number of participants in each trial and edge widths reflecting the number of trials evaluating each treatment. The assumption that direct and indirect evidence in NMA is equivalent (i.e., consistency) may lead to inaccurate conclusions when statistically significant inconsistencies exist [41]. Therefore, to ensure the consistency of the entire NMA, we applied both consistency and inconsistency models and employed the Wald test to evaluate inconsistency outcomes. Locally, we used the node-splitting approaches. Considering the potential for heterogeneity across studies, a random-effects model was selected for conducting the NMA. League tables were subsequently constructed to summarize the outcomes across various indicators, integrating both direct and indirect comparisons. To assess the most effective MBE therapy for pain relief, functional improvement, and QoL enhancement, we used the surface under the cumulative ranking curve analiysis (SUCRA), and cumulative ranking plots across all outcomes. The SUCRA values were expressed as percentages, ranging from 0 (the least effective) to 100% (the most effective). Rankings and probabilities indicate preferred treatments for the average patient, as determined by clinicians and policymakers. However, a higher rank does not always mean a clinically significant effect, as the actual treatment impact is what matters most [42]. We assessed publication bias by visually inspecting comparison-adjusted funnel plots based on symmetry criteria [38]. Additionally, Egger's test was conducted in R statistical software version 4.3.2, and RStudio statistical software version 22,023.09.1–494 [43], with $P > 0.05$ indicating no significant publication bias. Sensitivity analyses were performed by excluding RCTs with high risk of bias. To further explore the sources of heterogeneity, we conducted meta-regression analyses using duration, session frequency, percentage of female participants, Body Mass Index (BMI), age, and disease duration as covariates for the primary outcome.

Risk of bias assessment and GRADE

Two researchers assessed the methodological quality of the included RCTs using the Cochrane tool for assessing the risk of bias (RoB 2) at the outcome level during post-treatment follow-ups [44]. The assessment domains included randomization process (D1), deviations from intended interventions (D2), missing outcome data (D3), measurement of the outcome (D4), and selection of the reported result (D5). The risk level for each domain was divided into three categories, namely, low, high, and some concerns. If all domains were rated as "low", the overall risk of bias was "low". If any domain was rated as "some concerns" and no domains were "high", the overall risk was "some concerns". If at least one domain was rated as "high", the overall risk was "high". In cases of discrepancy, consensus was reached through a third author. The GRADE (Grading of Recommendations Assessment, Development, and Evaluation) framework was used to assess the quality of evidence [45], with ratings ranging from high (best) to very low (worst), and to assist in drawing conclusions from an NMA using a minimally contextualized framework [46].

Results

Search results

We initially searched seven databases, identifying 624 records. After removing 364 duplicates, 260 records remained. In accordance with the eligibility criteria, the first screening round excluded 199 articles based on their titles and abstracts. In the subsequent screening phase, 23 of the remaining 61 articles were excluded after a full-text review. Ultimately, 38 studies were selected for inclusion. The search and selection process is illustrated in Fig. 1.

Study characteristics

Table 1 summarizes the key characteristics of all included studies. This NMA incorporated 38 eligible RCTs, involving 2561 participants diagnosed with KOA. The studies included were published between 2003 and 2024. The majority of the studies were two-arm trials (32), with the remainder being three-arm trials (1) and four-arm trials (5). Most studies were conducted in China (25/38), with the remaining studies distributed among the United States (7/38), South Korea (2/38), Canada (1/38), Australia (1/38), Iran (1/38), and Brazil (1/38). Of these, 15 studies were written in Chinese and 23 studies were written in English. Moreover, the included studies involved

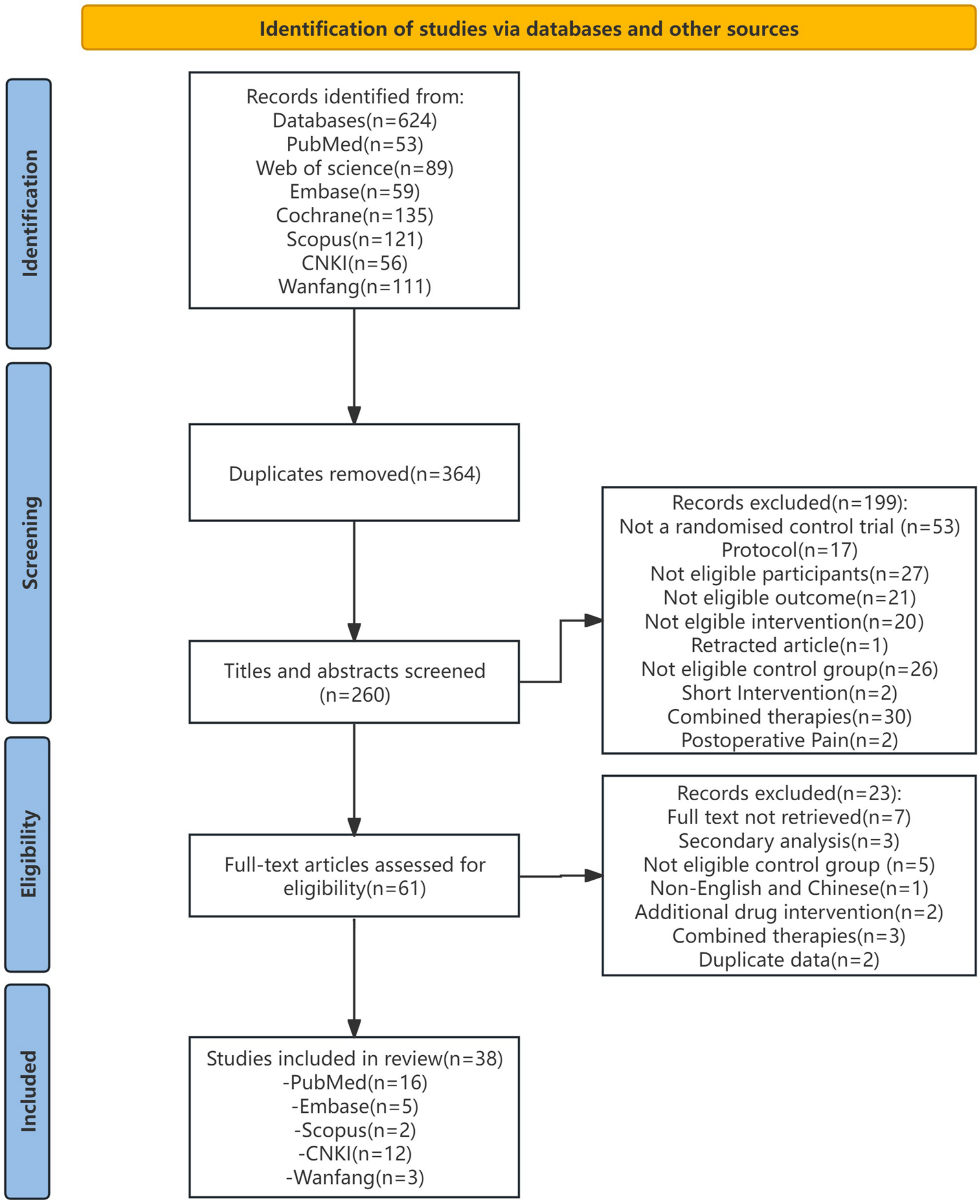

Fig. 1 PRISMA flow diagram of the search process for studies examining the efficacy of mind–body exercise in patients with KOA

various MBE: TC (22/38), Qigong (15/38), Yoga (4/38), and Pilates (2/38). The studies on Qigong included the Baduanjin and Wu Qin Xi forms. Four studies did not provide gender distribution information, and 15 studies recruited only female subjects. There were three control groups: CTE (6/38), UC (19/38), and NT (13/38). The MBE interventions varied in duration from 7 to 48 weeks, with the number of sessions ranging from 14 to 144. Pain intensity was evaluated in all 38 studies, physical function was measured in 36 studies, and QoL was assessed in 12 studies. Participants in these studies were aged between 50 and 80 years.

Pain intensity

A total of 2533 subjects across 38 studies assessed the effectiveness of MBE modes in reducing pain intensity,

Table 1 Principal characteristics of included studies

References	Country	Sample size (F/M)	Age, mean (SD)	Duration (weeks)	Follow-up weeks	Outcome measures	Experimental group intervention	Control group intervention
Liu et al. [21]	China	81 (60/21)	59.2 (7.5)	12	–	KOOS (pain)/KOOS (ADL)/KOOS (QoL)	Tai Chi (60 min/60 sessions)/qigong (60 min/60 sessions)	UC
Tu et al. [22]	China	75 (58/17)	58.8 (7.1)	12	–	KOOS (pain)	Tai Chi (60 min/60 sessions)/qigong (60 min/60 sessions)	UC
Wang et al. [23]	China	78 (57/21)	58.6 (7.1)	12	–	KOOS (pain)	Tai Chi (60 min/60 sessions)/qigong (60 min/61 sessions)	UC
Hu et al. [24]	China	83 (–/–)	58 (7.6)	12	–	WOMAC (pain)/WOMAC (function)/SF-36	Tai Chi (60 min/60 sessions)/qigong (60 min/60 sessions)	UC
Hu et al. [47]	China	92 (–/–)	66.0 (3.9)	24	–	VAS/WOMAC (function)	Tai Chi (60 min/72 sessions)	UC
Lin et al. [25]	China	72 (54/18)	59.0 (7.3)	12	–	WOMAC (pain)/WOMAC (function)	Tai Chi (60 min/60 sessions)/qigong (60 min/60 sessions)	UC
Wang et al. [48]	USA	204 (143/61)	60.2 (10.5)	12	40	WOMAC (pain)/WOMAC (function)	Tai Chi (60 min/24 sessions)	CTE
Zhu et al. [49]	China	46 (46/0)	64.6 (3.4)	24	–	WOMAC (pain)/WOMAC (function)	Tai Chi (60 min/72 sessions)	UC
Tsai et al. [50]	USA	55 (40/0)	78.9 (7.6)	20	–	WOMAC (pain)/WOMAC (function)	Tai Chi (20/40 min/60 sessions)	UC
Lee et al. [51]	Korea	44 (41/3)	69.1 (5.4)	8	–	WOMAC (pain)/WOMAC (function)/SF-12	Tai Chi (60 min/16 sessions)	NT
Brismée et al. [52]	USA	41 (34/7)	69.9 (9.3)	12	6	VAS/WOMAC (function)	Tai Chi (40 min/36 sessions)	UC
Zhou et al. [53]	China	30 (20/10)	64.1 (1.0)	16	–	VAS/KOOS (ADL)/KOOS (QoL)	Tai Chi (60–90 min/32 sessions)	NT
Song et al. [54]	Korea	43 (43/0)	63.7 (5.9)	12	–	WOMAC (pain)/WOMAC (function)	Tai Chi (20 min/36 sessions)	CTE
Huang et al. [55]	China	40 (40/0)	64.3 (3.3)	24	–	VAS/WOMAC (function)	Tai Chi (60 min/75 sessions)	UC
Wortley et al. [56]	USA	18 (13/5)	68.9 (5.2)	10	–	WOMAC (pain)/WOMAC (function)	Tai Chi (60 min/20 sessions)	NT
Li et al. [57]	China	61 (23/38)	65.9 (5.9)	16	–	WOMAC (pain)/WOMAC (function)	Tai Chi (60 min/64 sessions)	NT
Wang et al. [58]	USA	40 (33/7)	65 (7.8)	12	36	VAS/WOMAC (function)/SF-36	Tai Chi (60 min/24 sessions)	UC
Song et al. [59]	China	40 (40/0)	64.2 (8.6)	12	24	WOMAC (pain)/WOMAC (function)/SF-36	Tai Chi (60 min/36 sessions)	UC
Zhang et al. [60]	China	32 (32/0)	62.9 (3.3)	24	–	WOMAC (pain)/WOMAC (function)	Tai Chi (60 min/72 sessions)	UC

Table 1 (continued)

References	Country	Sample size (F/M)	Age, mean (SD)	Duration (weeks)	Follow-up weeks	Outcome measures	Experimental group intervention	Control group intervention
Zhang et al. [61]	China	50 (50/0)	60.8 (9.2)	48	–	VAS/LEFS (Lower Extremity Functional Scale)	Tai Chi (60 min/144 sessions)	NT
Cao et al. [62]	China	41 (34/7)	70.0 (9.3)	12	6	VAS/WOMAC (function)	Tai Chi (60 min/16–26 sessions)	UC
Zhu et al. [63]	China	46 (46/0)	64.6 (3.4)	24	–	WOMAC (pain)/WOMAC (function)	Tai Chi (60 min/72 sessions)	UC
An et al. [64]	China	28 (28/0)	65 (7.4)	8	–	WOMAC (pain)/WOMAC (function)/SF-36	Qigong (30 min/40 sessions)	NT
Ye et al. [65]	China	50 (30/20)	63.8 (6.1)	12	–	WOMAC (pain)/WOMAC (function)	Qigong (40 min/36 sessions)	NT
Jiang et al. [66]	China	23 (–)	63.5 (4.6)	12	–	VAS/WOMAC (function)	Qigong (45 min/60 sessions)	UC
Yin et al. [67]	China	118 (118/0)	69.1 (2.3)	24	–	WOMAC total	Qigong (–)	NT
Tian et al. [68]	China	40 (40/0)	62.5 (3.9)	24	–	WOMAC (pain)/WOMAC (function)	Qigong (60 min/144 sessions)	NT
Xiao et al. [69]	China	266 (266/0)	70.0 (3.5)	24	–	WOMAC (pain)/WOMAC (function)/SF-36	Qigong (60 min/144 sessions)	NT
Chun et al. [70]	China	68 (45/23)	70.5 (9.8)	12	–	WOMAC (pain)/WOMAC (function)	Qigong (60 min/48 sessions)	CTE
Xiao et al. [71]	China	98 (61)	70.4 (9.7)	24	–	WOMAC (pain)/WOMAC (function)	Qigong (60 min/ 96 sessions)	CTE
Yang et al. [72]	China	148 (112/36)	50–75	12	–	VAS/LKSS	Qigong (50 min/72 sessions)	NT
Wang et al. [73]	China	28 (16/12)	65.4 (5.2)	12	–	VAS/WOMAC (total)	Qigong (60 min/36 sessions)	NT
Bennell et al. [74]	Australia	212 (148/64)	62.3 (7.7)	12	12	Knee pain during walking (NRS)/WOMAC (function)/AQoL-6D	Yoga (30 min/36 sessions)	UC
Cheung et al. [75]	USA	36 (36/0)	71.9 (5.6)	8	12	WOMAC (pain)/WOMAC (function)/SF-12	Yoga (30 min/60 min/40 sessions)	UC
Cheung et al. [76]	USA	55 (–)	70.1 (7.9)	8	–	VAS/WOMAC (function)/SF-12	Yoga (45 min/8 sessions, 30/24 sessions)	UC
Kuntz et al. [77]	Canada	21 (21/0)	64.6 (7.4)	12	–	KOOS-pain/ADL/KOOS (QoL)	Yoga (60 min/36 sessions)	CTE
Rego et al. [78]	Brazil	17 (17/0)	65.2 (2.4)	7	–	WOMAC (pain)/WOMAC (function)/SF-36	Pilates (60 min/14 sessions)	NT
Mazloum et al. [79]	Iran	41 (13/28)	52.1 (8.9)	8	–	Lequesne's index	Pilates (60 min/24 sessions)	CTE/NT

M, Male; F, Female; VAS, Visual numerical scale; NRS, Numerical pain scale; WOMAC, Western Ontario & McMaster Universities Osteoarthritic Index; KOOS, Knee injury and Osteoarthritis Outcome Score; ADL, Activity of daily living; AQoL, Assessment of Quality of Life; KOOS, Knee injury and Osteoarthritis Outcome Score, LKSS: Lysholm Knee Scoring Scale; n, Sample size; QoL, Quality of life, SF-12, 12-item short form survey; SF-36, 36-Item short form survey; UC, Usual care; NT, No treatment; CTE, Conventional therapeutic exercises

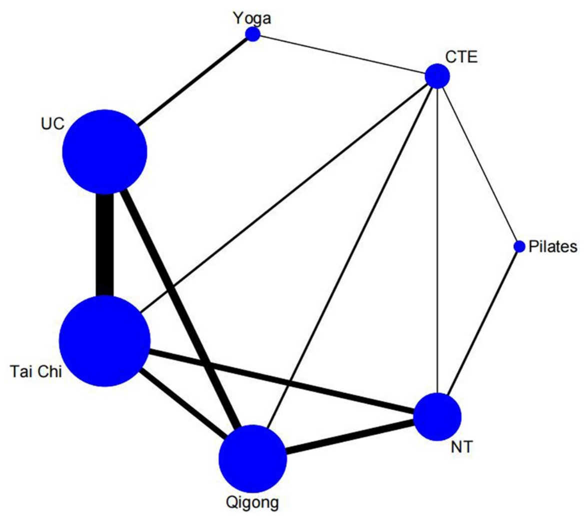

Fig. 2 Network of evidence of pain intensity and the size of the nodes relates to the number of participants in that intervention type and the thickness of lines between interventions relates to the number of studies for that comparison

with the network plot depicted in Fig. 2. The Wald test for global inconsistency was not significant ($\chi^2 = 4.24$, $P = 0.75$), and the node-splitting method showed no statistically significant differences ($P > 0.05$) in local inconsistency between indirect and direct comparisons for each segmented node (refer to Supplementary Table 1). Pilates (SMD: −1.19, 95% CI −1.92 to −0.46), TC (SMD: −0.78, 95% CI −0.97 to −0.59), Yoga (SMD: −0.76, 95% CI −1.15 to −0.36), and Qigong (SMD: −0.70, 95% CI −0.94 to −0.47) all outperformed usual care (no-treatment) in reducing pain intensity, indicating a large clinical effect. Additionally, compared to CTE, Pilates (SMD: −0.76, 95% CI −1.47 to −0.04) showed a large clinical effect, and TC (SMD: −0.35, 95% CI −0.67 to −0.03) showed a small clinical effect; further details are presented in Supplementary Table 2. The SUCRA analysis revealed that Pilates (SUCRA = 92.9%) and TC (SUCRA = 74.1%) were among the most effective MBE interventions for pain relief, followed by Yoga (SUCRA = 68.3%) and Qigong (SUCRA = 61.6%). Usual care (SUCRA = 12.5%) was ranked lower, with no-treatment group projected as the least effective (SUCRA = 4.4%). For further details, refer to Fig. 3. Table 2 summarizes the effect estimates of pain intensity compared to usual care and their quality. With moderate certainty, Pilates and TC were the most effective interventions, while Yoga and Qigong demonstrated moderate

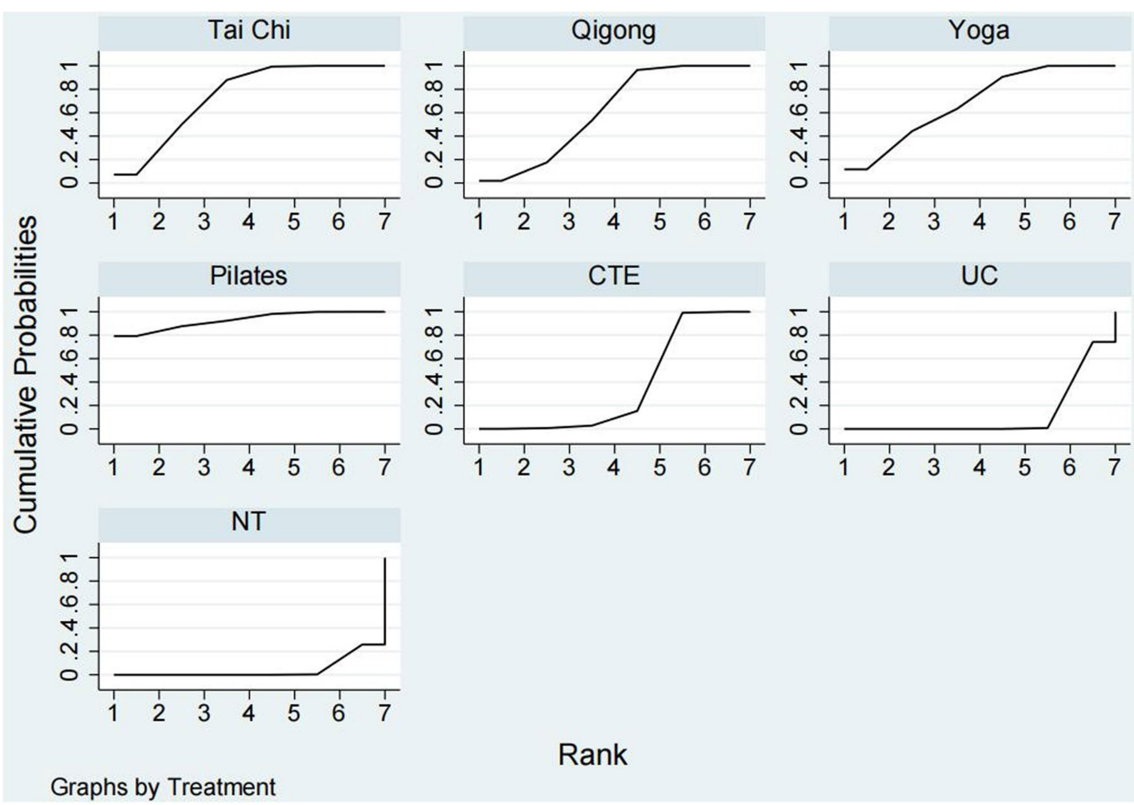

Fig. 3 The rank probability of pain intensity various interventions based on the SUCRA. The SUCRA metric was used to rank the effectiveness of each treatment and identify the best treatment

Table 2 Summary of results for pain intensity

Certainty on the evidence	Classification	Intervention	Intervention versus usual care SMD (95% CI)	SUCRA (%)
Moderate certainty (moderate-certainty evidence)	Category 1: Among the most effective	Pilates	−1.19 (−1.92, −0.46)	92.9
		Tai Chi	−0.78 (−0.97, −0.59)	74.1
	Category 2: Inferior to the best/better than the worst interventions	Yoga	−0.76 (−1.15, −0.36)	68.3
		Qigong	−0.70 (−0.94, −0.47)	61.6
		Conventional therapeutic exercise	−0.43 (−0.78, −0.09)	36.3
	Category 0: Among the least effective	–	–	–
Low certainty (low- to very low-certainty evidence)	Category 1:May be among the most effective	–	–	–
	Category 2: Inferior to the best/Better than the worst interventions	–	–	–
	Category 0: May be among the least effective	Usual care	–	12.5
		No treatment	−0.10 (−0.39,0.20)	4.4

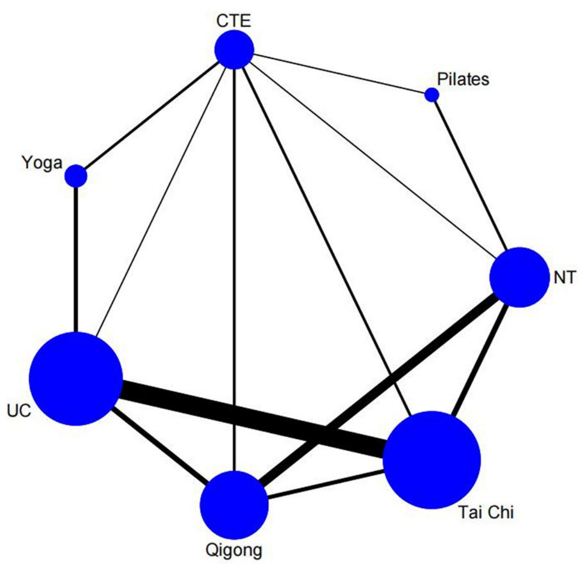

Fig. 4 Network of evidence of physical function and the size of the nodes relates to the number of participants in that intervention type and the thickness of lines between interventions relates to the number of studies for that comparison

efficacy, outperforming the least effective options (usual care and no-treatment).

Physical function

A total of 36 studies, encompassing 2408 subjects and seven interventions, examined the impact of MBE interventions on physical function in KOA patients, with the network plot shown in Fig. 4. The Wald test for global inconsistency was not significant ($\chi^2=8.14$, $P=0.32$); no local inconsistencies were found through the node-splitting method ($P>0.05$, refer to Supplementary Table 3). Pilates (SMD: −1.31, 95% CI −2.13 to −0.50), TC (SMD: −0.85, 95% CI −1.08 to −0.63), Yoga (SMD: −0.80, 95% CI −1.24 to −0.36), and Qigong (SMD: −0.75, 95% CI −1.08 to −0.42) outperformed usual care (no-treatment) in enhancing physical function, indicating a large clinical effect. Further details can be found in Supplementary Table 4. The SUCRA analysis revealed that Pilates (SUCRA = 93.2%) and TC (SUCRA = 74.0%) were the most effective MBE interventions for improving physical function, with Yoga (SUCRA = 66.2%) and Qigong (SUCRA = 60.0%) following closely behind. Usual care (SUCRA = 10.7%) and the no-treatment group were ranked as the least effective (SUCRA = 6.1%). Refer to Fig. 5 for more details. Table 3 summarizes the effect estimates of physical function compared to usual care and their quality. With moderate certainty, Pilates and TC were the most effective interventions, while the remaining interventions showed low certainty.

QoL

In the examination of MBE interventions' impact on enhancing QoL, 12 studies involving 922 participants were analyzed, with the network plot shown in Fig. 6. The Wald test for global inconsistency was not significant ($\chi^2=0.56$, $P=0.75$), and no local inconsistencies were detected within the network ($P>0.05$, refer to Supplementary Table 5). The League table result revealed that only TC intervention (SMD = −0.57, 95% CI = −1.07 to −0.06) showed superiority over usual care in improving QoL, indicating a moderate

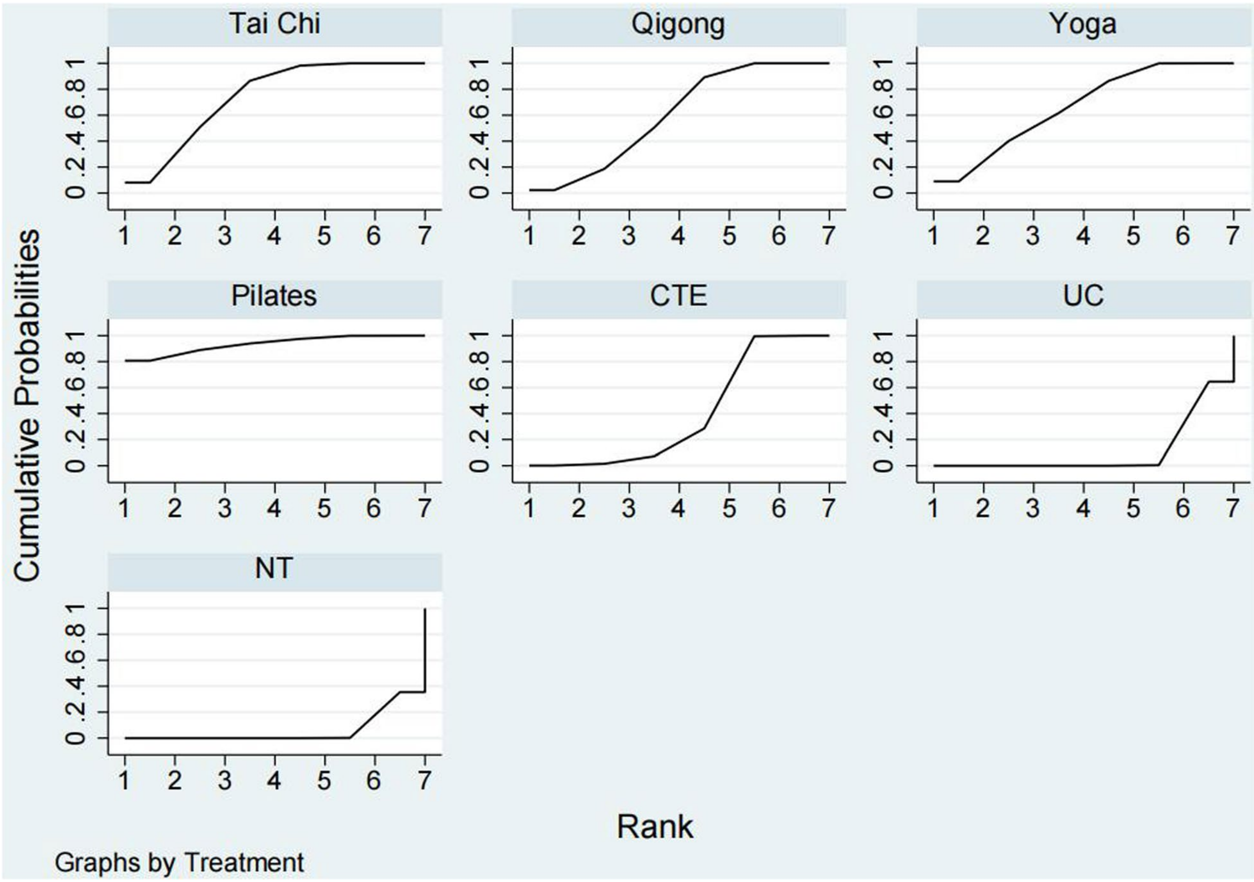

Fig. 5 The rank probability of physical function various interventions based on the SUCRA. The SUCRA metric was used to rank the effectiveness of each treatment and identify the best treatment

Table 3 Summary of results for physical function

Certainty on the evidence	Classification	Intervention	Intervention versus usual care SMD (95% CI)	SUCRA (%)
Moderate certainty (moderate-certainty evidence)	Category 1: Among the most effective	Pilates	− 1.31 (− 2.13, − 0.50)	93.2
		Tai Chi	− 0.85 (− 1.08, − 0.63)	74.0
	Category 0: Among the least effective	–	–	–
Low certainty (low- to very low-certainty evidence)	Category 1: May be among the most effective	Yoga	− 0.80 (− 1.24, − 0.36)	66.2
		Qigong	− 0.75 (− 1.08, − 0.42)	60.0
		Conventional therapeutic exercise	− 0.55 (− 0.92, − 0.17)	39.5
	Category 0: May be among the least effective	Usual care	–	10.7
		No treatment	− 0.07 (− 0.44, 0.30)	6.1

clinical effect. Compared to the no-treatment group, TC (SMD: − 1.14, 95% CI − 1.77 to − 0.51) and Yoga (SMD: − 0.95, 95% CI − 1.87 to − 0.03) demonstrated a large clinical effect, while Qigong intervention (SMD: − 0.68, 95% CI − 1.21 to − 0.09) showed a moderate clinical effect. Detailed findings are provided in Supplementary Table 6. The SUCRA analysis revealed that TC (81.7%) was the most effective intervention for

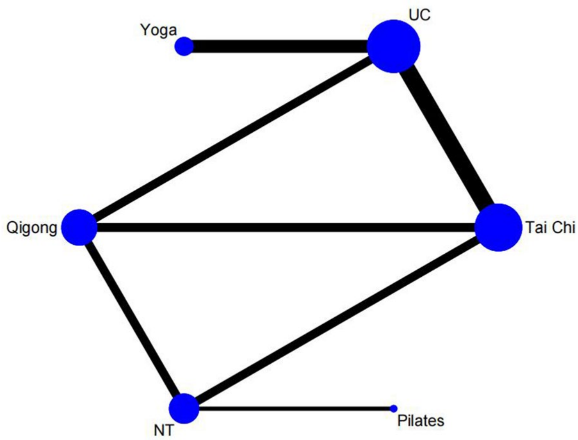

Fig. 6 Network of evidence of QoL and the size of the nodes relates to the number of participants in that intervention type and the thickness of lines between interventions relates to the number of studies for that comparison

improving QoL. The no-treatment group was likely the least effective, with a SUCRA value of 3.0%. For further information, refer to Fig. 7. Table 4 summarizes the effect estimates of QoL compared to usual care and their quality. With moderate certainty, TC was the most effective intervention, while the remaining interventions showed low certainty.

Risk of bias assessment and GRADE

For the primary outcome (pain intensity), bias due to the randomization process: a detailed analysis showed that 10 studies (26.3%) used computer-generated randomization methods (including computer software and web-based tools), 21 studies (55.3%) used random number tables or random sequence generation, one study (2.6%) used inappropriate randomization methods (allocation based on patient preference), and six studies (15.8%) did not clearly describe their randomization procedures. Overall, 21 studies raised some concerns, with 18 studies lacking adequate information on randomization methods and allocation concealment, and three studies showing baseline characteristic difference

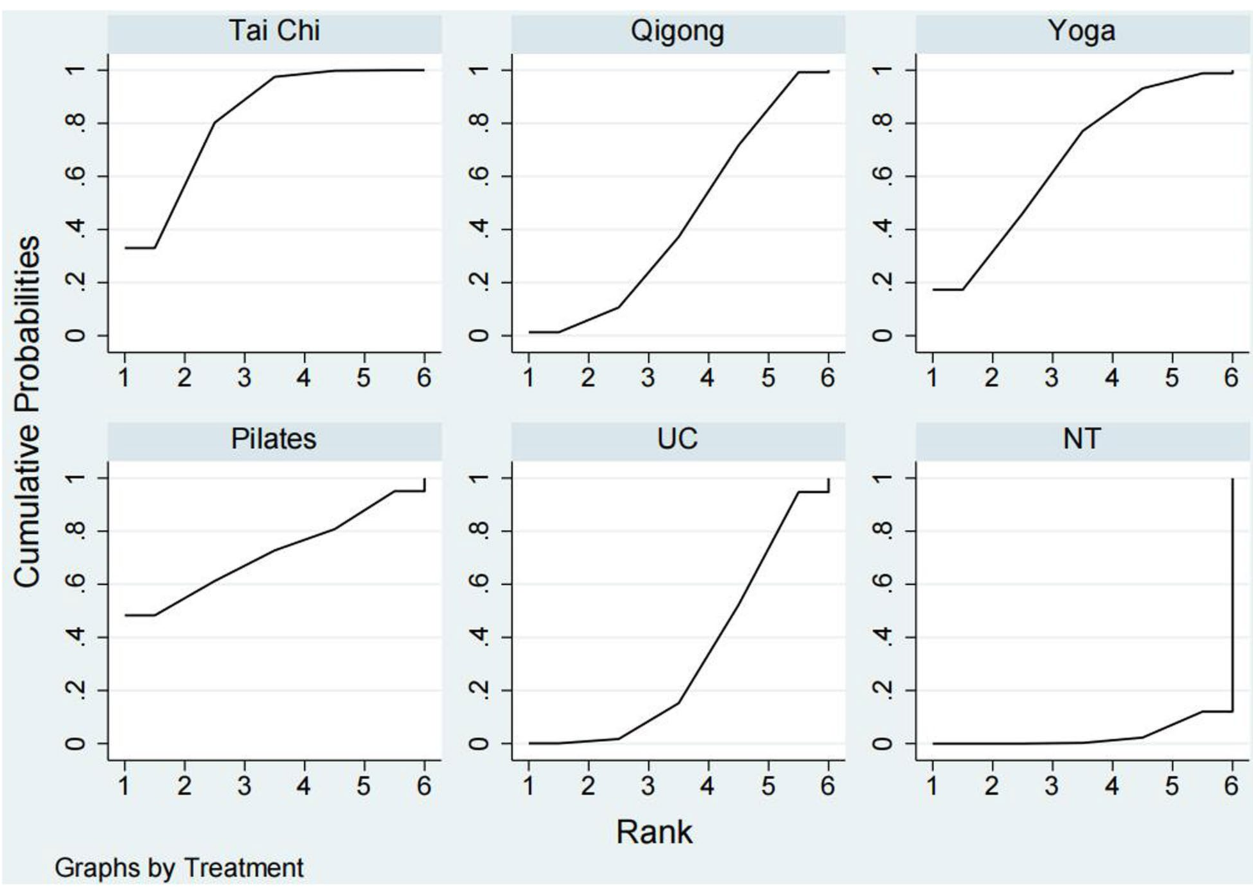

Fig. 7 The rank probability of QoL various interventions based on the SUCRA. The SUCRA metric was used to rank the effectiveness of each treatment and identify the best treatment

Table 4 Summary of results for QoL

Certainty on the evidence	Classification	Intervention	Intervention versus usual care SMD (95% CI)	SUCRA (%)
Moderate certainty (moderate-certainty evidence)	Category 1: Among the most effective	Tai Chi	− 0.57 (− 1.07, − 0.06)	82.1
	Category 2: Inferior to the best/Better than the worst interventions	–	–	–
	Category 0: Among the least effective	–	–	–
Low certainty (low- to very low-certainty evidence)	Category 1: May be among the most effective	–	–	–
	Category 2: Inferior to the best/Better than the worst interventions	Pilates	− 0.61 (− 2.23, 1.01)	71.6
		Yoga	− 0.38 (− 0.94, 0.19)	66.5
		Qigong	− 0.11 (− 0.72, 0.51)	44.0
	Category 0: May be among the least effective	Usual care	–	–
		No treatment	− 0.57 (− 1.31, 0.16)	4.4

Fig. 8 Risk of bias for included studies (pain intensity)

between intervention groups. Bias in measurement of the deviations from intended interventions: three studies were at high risk due to a high dropout rate and the lack of intention-to-treat analyses. Given the nature of the exercise interventions in these trials, 18 studies had some concerns due to challenges in blinding. Bias arising from outcome measurement: eight studies had some concerns due to inadequate blinding of outcome assessors. Consequently, nine studies were at low risk of bias, 25 studies had some concerns, and four studies were at high risk of bias (refer to Fig. 8). Supplementary material 3 presents the RoB 2 assessment for physical function and QoL. Supplementary material 4 shows the GRADE results for pairwise comparisons of studies examining the efficacy of MBE interventions in patients with KOA.

Sensitivity analysis

To assess the impact of risk of bias on our findings, we conducted sensitivity analyses by excluding RCTs with a high risk of bias. The results were consistent with those obtained from the main analyses (see Supplementary material 5), supporting the robustness of our finding.

Meta-regression analysis

Meta-regression was conducted separately for different MBE types (TC, Qigong, Yoga, and Pilates) with age, BMI, duration, session frequency, percentage of female participants, and disease duration as covariates. The results suggested that BMI might be a potential moderator affecting the intervention effects, particularly in TC interventions (see Supplementary material 6). Although several potential moderators were identified for yoga interventions, the limited number of included yoga studies precluded drawing definitive conclusions about these associations.

Public bias

We plotted comparison-adjusted funnel plots for pain, physical function and QoL as outcome indicators

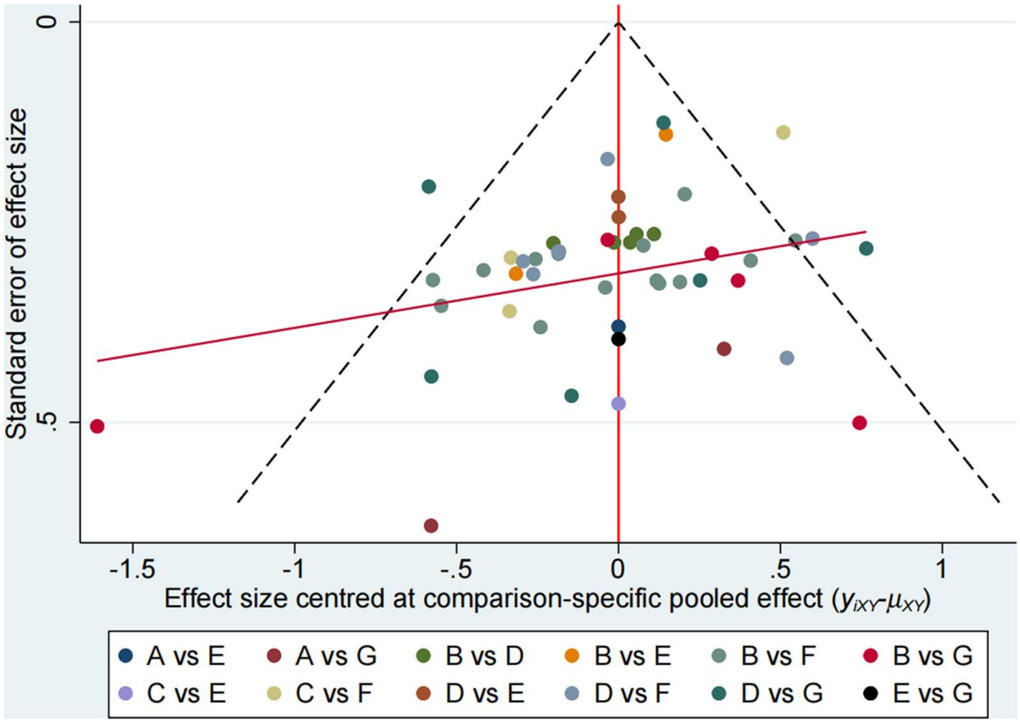

Fig. 9 Pain intensity: comparison-adjusted funnel plot showing the publication bias of the included randomized controlled trials. The red line represents the null hypothesis that independent effect size estimates do not differ from the comparison-specific pooled estimates. **A** Pilates, **B** Tai Chi, **C** Yoga, **D** Qigong, **E** control group (conventional therapeutic exercises), **F** control group (usual care), **G** control group (no treatment)

separately to identify potential publication bias. The funnel plots displayed a symmetrical distribution of scattered points, suggesting that our results are robust without significant publication bias. More details are shown in Figs. 9, 10 and 11. Additionally, the results of Egger's test indicated no significant publication bias: pain ($P=0.07$), physical function ($P=0.36$), and QoL ($P=0.40$); refer to Supplementary material 7.

Discussion

In this first NMA of MBE for KOA, we explored a comprehensive ranking of four widely practiced MBE techniques (Pilates, TC, Yoga, and Qigong) to identify the most effective intervention for alleviating pain, enhancing physical function and improving QoL. Given that TC and Qigong have their origins in China, we included studies in all languages to ensure a comprehensive review. There is moderate-certainty evidence that Pilates and TC may be the most effective MBEs for improving pain and physical function in KOA, while TC may be the best for improving QoL. The remaining interventions showed low certainty. These findings provide valuable insight for clinicians considering MBE therapies as complementary or alternative treatments for KOA patients.

The results from the league table showed no significant inter-group differences in these outcome measures, indicating that, statistically, these MBE modes have similar effects in improving KOA symptoms. This may be attributed to the shared mechanisms of body awareness, relaxation, and physical regulation common to all four MBE modes. Additionally, the limited sample size may have reduced the statistical power to detect inter-group differences. While one intervention may consistently achieve a higher rank, excessive focus on the rankings (derived from SUCRA) may lead to misleading interpretations [46]. However, the GRADE approach to drawing conclusions from a NMA using a minimally contextualized framework can assist in deriving valid conclusions [46].

Pilates exercise therapy is well-known for its effectiveness in improving flexibility and overall physical condition, utilizing a method that emphasizes core stability, proper posture, controlled breathing, flexibility, strength, and muscle coordination [19]. Muscle loss contributes to the pain, disability, and morbidity associated with KOA [80]. In KOA patients, thigh muscle weakness is a major issue and a contributing factor in the progression of degenerative changes [81, 82]. Previous studies comparing conventional therapeutic exercise with Pilates for managing pain and function in KOA patients found that

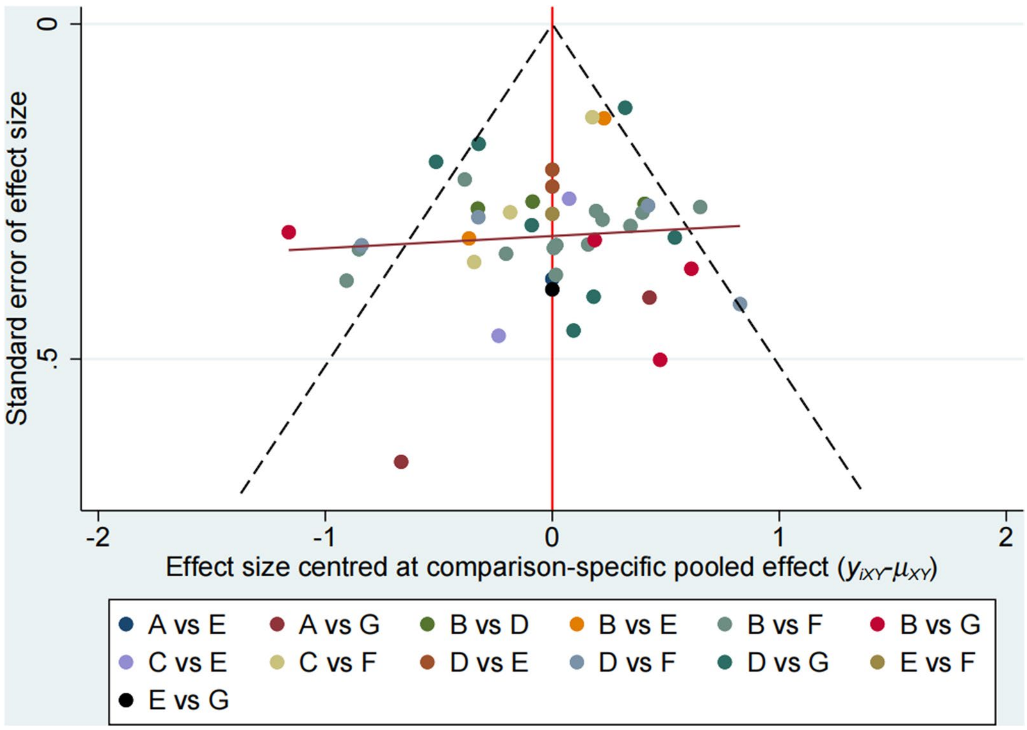

Fig. 10 Physical function: comparison-adjusted funnel plot showing the publication bias of the included randomized controlled trials. The red line represents the null hypothesis that independent effect size estimates do not differ from the comparison-specific pooled estimates. **A** Pilates, **B** Tai Chi, **C** Yoga, **D** Qigong, **E** control group (conventional therapeutic exercises), **F** control group (usual care), **G** control group (no treatment)

those who adhered to the Pilates regimen experienced notable symptomatic improvements. These improvements may be associated with increased strength in the quadriceps and hamstring muscles [79]. A meta-analysis also provides strong evidence of enhanced lower limb strength following Pilates training in older adults [83]. Strengthening muscles provides better support and stability for the knee, reducing stress and wear on the knee joint, and thereby alleviating pain [84]. Consequently, Pilates may reduce pain intensity by enhancing the strength of the muscles in the lower limbs. Additionally, Pilates emphasizes correct posture and movement patterns, which can evenly distribute the burden on the knee joints and reduce pain caused by improper posture. Rego et al. found that after 7 weeks of Pilates training, participants showed significant improvements in WOMAC (function) scores [78]. Pilates exercises that incorporate eccentric and stretching movements can activate muscle spindles [79, 85], which are instrumental in sensing the motion and position of the limb [86]. The coordinated activation of the muscles of the lower limbs is essential for the knee joint stabilization. Pilates includes static isometric and dynamic isotonic contractions of the muscles. Changes in the center of gravity contribute to improvements in postural control, enhanced coordinated contraction of agonist and antagonist muscles, improved activation of knee muscles, and the stabilization of the knee joint. The flexibility training in Pilates reduces stiffness and improves joint motion by increasing knee flexibility and subsequent progression in pain and function conditions [87, 88]. Furthermore, Pilates' focus on breathing contributes to improving body homeostasis and enhances physiological conditions [89], which is closely linked to greater functional improvement in KOA. The use of pain neuroscience education (PNE) in chronic pain management has grown in recent years [90], and it is now being used in conjunction with Pilates for KOA patients. Rabiei et al. [91] concluded that combining PNE with Pilates could have superior effects on psychological characteristics, though not on pain and function, compared to Pilates alone. The combined use of Pilates with other therapies is a worthy direction for future research. Current studies have primarily examined the short-term effects of Pilates on KOA treatment [78, 79], and the therapeutic effects of long-term training are still lacking. While current studies support the analgesic effect of Pilates for KOA patients, there is still a lack of objective neurophysiological studies to clarify the underlying mechanisms. Further extensive experimentation

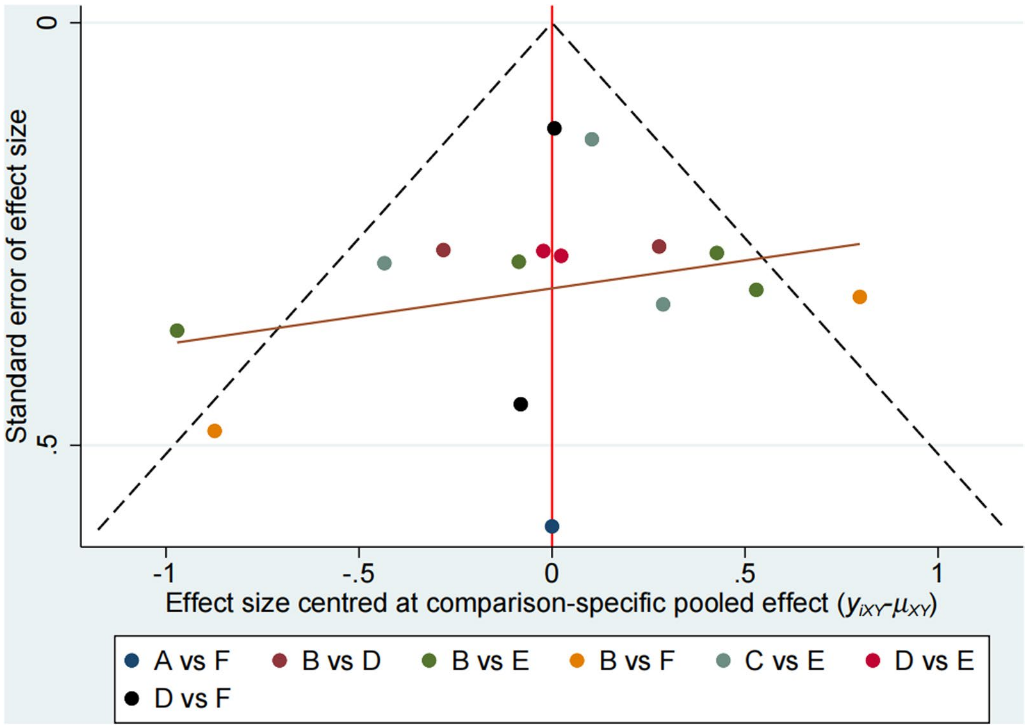

Fig. 11 QoL: comparison-adjusted funnel plot showing the publication bias of the included randomized controlled trials. The red line represents the null hypothesis that independent effect size estimates do not differ from the comparison-specific pooled estimates. **A** Pilates, **B** Tai Chi, **C** Yoga, **D** Qigong, **E** control group (usual care), **F** control group (no treatment)

and research are necessary to comprehensively understand the potential mechanisms of Pilates for KOA.

TC is an ancient multicomponent MBE therapy derived from traditional Chinese medicine, integrating physical, psychosocial, spiritual, and behavioral components to enhance health and fitness [92]. Wang et al. conducted a 12-week TC study that showed a significant increase in SF-36 scores and a substantial improvement in QoL in KOA patients [48]. Song et al. also demonstrated that TC training is effective in improving the QoL of elderly women [59]. The effects of TC on QoL appear to be associated with improved mental well-being, including reduced stress, anxiety, depression, mood disorders, and enhanced self-confidence [93]. Previous studies have suggested that the efficacy of TC in enhancing QoL may be linked to its ability to diminish sympathetic nervous system activity. TC has been shown to mitigate psychological stress, as measured by salivary cortisol, and enhance QoL by stimulating the production of regulatory T-cell mediators such as transforming growth factor-beta and Interleukin-10 (IL-10) through targeted antigenic stimuli [94]. The primary pathological mechanism causing pain in KOA is increased inflammation in the knee joint, with elevated levels of Interleukin-1β (IL-1β), Interleukin-6 (IL-6), and Tumor Necrosis Factor-α (TNF-α) [95, 96]. TC exercises have shown potential in modulating inflammatory markers, providing significant analgesic benefits. In a meta-analysis involving nine TC studies, it was found that TC significantly reduced serum TNF-α and decreased IL-6 [97]. Additionally, a RCT involving breast cancer survivors demonstrated a sustained decrease in IL-6 and IL-1β after 12 months, highlighting the enduring anti-inflammatory effects of TC exercise [98]. Moreover, the gut microbiota has been increasingly recognized as closely linked to KOA development due to its intricate interplay with joint health [99, 100]. Studies have shown that gut microbiota damage may damage joints through the involvement of their metabolites in the inflammatory response, potentially contributing to the pathogenesis of KOA [101]. On the one hand, TC exercises reduce the generation of Lipopolysaccharide (LPS) through the gut microbiota, exerting a regulatory effect on inflammation [102]; on the other hand, TC can increase the production of Short-Chain Fatty Acid (SCFA) via the gut mucrobiota, reducing inflammatory factors [103], thus alleviating the inflammatory response in KOA from two perspectives. Additionally, KOA is often associated with irregularities in both structural and functional connectivity across different brain regions [104, 105], particularly those related to pain perception. Consistent TC practice has the potential to prompt localized alterations in the precentral gyrus, insular sulcus, and middle frontal sulcus [106]. Previous RCTs have revealed significant associations between pre- and post-TC variations in the functional connectivity of regions such as the Basolateral Amygdala (BA)-temporal pole, BA-medial prefrontal cortex [21, 107], periaqueductal grey-ventral tegmental area [108], and dorsolateral prefrontal cortex pathways [109]. Therefore, regular TC practice may modulate pain and physical function by directly impacting cerebral cortex activity.

Yoga and Qigong (Baduanjin, Wuqinxi) have demonstrated benefits for KOA. However, based on our GRADE results, their therapeutic effects on pain, physical function, and QoL are not superior to those of other MBE therapies. Yoga, originating in ancient India, is a low-impact MBE. With styles like Iyengar and Hatha Yoga, it requires minimal equipment and has gained widespread popularity. In a meta-analysis of eight studies on Yoga interventions, it was found that Yoga is effective in improving pain, stiffness and physical function in KOA patients [110]. Moreover, a sensitivity analysis excluding studies with low-frequency or short-duration treatments indicated that Yoga significantly improved the QoL in KOA patients. Hatha yoga offers a comprehensive approach that engages both the body and mind, utilizing postures, breath control, and meditation to help manage KOA symptoms [111]. In comparison, chair yoga is better suited for individuals with KOA, as it provides low-impact, gentle, and highly adaptable exercises designed to minimize stress on the knee joint, improve range of motion and flexibility, relieve pain, and enhance joint function and overall comfort [112]. Regarding Qigong, which, similar to TC, also originates in China and is part of a broader system of "health cultivation" practices. Numerous studies have demonstrated the benefits of Baduanjin [113] and Wuqinxi [114] in improving pain and function in KOA. These practices enhance blood circulation in the joints, increase flexibility and mobility in the lower limbs, support the smooth flow of qi (vital energy) and blood through the meridians, and promote the execution of precise, controlled movements.

The primary clinical manifestations of KOA include joint pain, stiffness, and dysfunction. KOA also leads to alterations in muscle coordination and contraction, reduced quadriceps muscle strength, impaired balance, gait abnormalities, psychological distress, collectively contributing to a significant decline in patients' QoL. A substantial body of evidence from clinical trials indicates that MBE therapy is an effective and safe intervention for treating KOA. The therapeutic mechanism may include enhancing lower extremity muscle strength, modulating inflammatory mediators and gut microbiota, improving ligament flexibility, coordinating and activating lower limb muscles, promoting mental health, and influencing the cerebral cortex. Compared to non-pharmacological therapies, such as kinesio taping, acupuncture, massage, and traditional exercises that primarily target muscle strength and the cardiovascular and respiratory systems, MBE therapy offers distinct advantages. These include additional physiological, psychological, and clinical effects [115]. Furthermore, MBE generally exhibits a high safety profile, with minimal to no adverse effects [116, 117]. Once patients receive initial guidance, they can continue exercising independently over the long term, reducing the economic burden associated with ongoing treatments.

There are limitations to this NMA. First, the limited research on Pilates and the generally modest sample sizes in most of the included studies may have restricted data availability, possibly leading to an underestimation of MBE interventions. Further studies on the effects of Pilates for KOA are needed, particularly RCTs with high quality and large sample sizes. Second, the inherent challenge of exercise interventions makes it difficult to blind both subjects and physiotherapists, potentially leading to deviations from intended interventions and affecting the precision of effect size estimates. However, this limitation is generally accepted and often addressed in meta-analyses assessing the efficacy of exercise interventions. Third, there was an imbalance in gender representation, with a significantly higher number of female participants compared to male participants. This gender imbalance may limit the generalizability of the findings to the broader KOA population, while female is an important risk factors for knee osteoarthritis in middle-older aged [118]. Thus, caution is needed when interpreting the findings for male KOA patients. Fourth, due to the limited number of studies on indicator such as Six-Minute Walk Test, Time Up and Go Test, and depression, as well as insufficient long-term outcome data, we were unable to assess the effects of different MBEs on these indicators or their sustained effects. Future studies should prioritize these indicators and focus on long-term follow-up to comprehensively evaluate the effects of MBEs on KOA patients. Finally, due to the limited number of studies and the scarcity of direct comparative evidence between interventions, these findings should be interpreted with caution, highlighting the need for more high-quality, large-scale, multicenter research.

Conclusion

There is moderate-quality evidence that Pilates and Tai Chi may be the most effective mind–body exercises for improving pain and physical function in knee osteoarthritis, while Tai Chi may be the best for improving quality of life. These findings provide important insights for clinical practice and may help clinicians guide their prescription of exercise types based on treatment outcomes. Further high-quality, large-scale, multicenter, long-term follow-up RCTs are needed to confirm whether our findings are consistent across all patients with knee osteoarthritis.

Abbreviations

CTE	Conventional therapeutic exercise
CI	Confidence interval
KOOS	Knee Injury and Osteoarthritis Outcome Score
KOA	Knee osteoarthritis
MBE	Mind–body exercise
NMA	Network meta-analysis
NT	No treatment
QoL	Quality of life
RCT	Randomized controlled trial
SMD	Standardized mean difference
SUCRA	Surface under the cumulative ranking analysis
TC	Tai chi
UC	Usual care
WOMAC	Western Ontario and McMaster Universities Arthritis Index

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13018-025-05682-7.

Supplementary file 1.
Supplementary file 2.
Supplementary file 3.

Acknowledgements

We express sincerely gratitude to Jian Shi and Haozhi Zhao for their guidance in data analysis. We further acknowledge Jian Shi and Beibei Feng for their guidance on essay writing.

Author contributions

KX-G and JM-T wrote the manuscript. KX-G, JM-T, C-G, L-W and YL-W contributed to the conception. KX-G and JM-T searched the literature. KX-G, JM-T, and GY-L were involved in the data analysis. KX-G, JM-T, GY-L, and YL-W contributed to the acquisition of data. C-G checked the language. YL-W and L-W contributed to writing, reviewing and editing. All authors contributed to the article and approved the submitted version.

Funding

This study was supported by the program of Guangdong Provincial Clinical Research Center for Rehabilitation Medicine (2023B110003), the Research Foundation of Traditional Chinese Medicine Bureau of Guangdong Province (20231067), and the Guangdong Hopson-Pearl River Education Development Foundation (No. H20190116202012724). The sponsor and funder had no role in study design, and writing this manuscript as well as collection, analysis, decision to publish or preparation of this manuscript.

Availability of data and materials

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Author details

[1]Department of Sport Rehabilitation, Shanghai University of Sport, Shanghai 200000, China. [2]Department of Rehabilitation Medicine, the Sixth Affiliated Hospital, Sun Yat-Sen University, Guangzhou 510655, China. [3]Postgraduate Research Institute, Guangzhou Sport University, Guangzhou, China. [4]Guangdong Provincial Clinical Research Center for Rehabilitation Medicine, Guangzhou, China. [5]Biomedical Innovation Center, the Sixth Affiliated Hospital, Sun Yat-Sen University, Guangzhou, China.

Received: 28 November 2024 Accepted: 4 March 2025
Published online: 17 April 2025

References

1. Sharma L. Osteoarthritis of the knee. N Engl J Med. 2021;384(1):51–9.
2. Kolasinski SL, Neogi T, Hochberg MC, Oatis C, Guyatt G, Block J, Callahan L, Copenhaver C, Dodge C, Felson D, et al. 2019 American college of rheumatology/arthritis foundation guideline for the management of osteoarthritis of the hand, hip, and knee. Arthritis Care Res (Hoboken). 2020;72(2):149–62.
3. Mahmoudian A, Lohmander LS, Mobasheri A, Englund M, Luyten FP. Early-stage symptomatic osteoarthritis of the knee—time for action. Nat Rev Rheumatol. 2021;17(10):621–32.
4. Cui A, Li H, Wang D, Zhong J, Chen Y, Lu H. Global, regional prevalence, incidence and risk factors of knee osteoarthritis in population-based studies. EClinicalMedicine. 2020;29–30:100587.
5. Steinmetz JD, Culbreth GT, Haile LM, Rafferty Q, Lo J, Fukutaki KG, Cruz JA, Smith AE, Vollset SE, Brooks PM, Cross M. Global, regional, and national burden of osteoarthritis, 1990–2020 and projections to 2050: a systematic analysis for the Global Burden of Disease Study 2021. Lancet Rheumatol. 2023;5(9):e508–22.
6. Chinese society of physical medicine and rehabilitation, west China hospital of sichuan university. Chinese guideline for the rehabilitation treatment of knee osteoarthritis (2023 edition). Chin J Evid Based Med 2024;24(01):1–14. https://doi.org/10.7507/1672-2531.202306145.
7. Long H, Zeng X, Liu Q, Wang H, Vos T, Hou Y, Lin C, Qiu Y, Wang K, Xing D, et al. Burden of osteoarthritis in China, 1990–2017: findings from the Global Burden of Disease Study 2017. Lancet Rheumatol. 2020;2(3):e164–72.
8. Bannuru RR, Osani MC, Vaysbrot EE, Arden NK, Bennell K, Bierma-Zeinstra SMA, Kraus VB, Lohmander LS, Abbott JH, Bhandari M, et al. OARSI guidelines for the non-surgical management of knee, hip, and polyarticular osteoarthritis. Osteoarthr Cartil. 2019;27(11):1578–89.
9. Arden NK, Perry TA, Bannuru RR, Bruyère O, Cooper C, Haugen IK, Hochberg MC, McAlindon TE, Mobasheri A, Reginster JY. Non-surgical management of knee osteoarthritis: comparison of ESCEO and OARSI 2019 guidelines. Nat Rev Rheumatol. 2021;17(1):59–66.
10. Lee CJ, Luo WT, Tam KW, Huang TW. Comparison of the effects of acupotomy and acupuncture on knee osteoarthritis: a systematic review and meta-analysis. Complement Ther Clin Pract. 2023;50:101712.
11. Ughreja RA, Prem V. Effectiveness of dry needling techniques in patients with knee osteoarthritis: a systematic review and meta-analysis. J Bodyw Mov Ther. 2021;27:328–38.
12. Abolhasani M, Halabchi F, Afsharnia E, Moradi V, Ingle L, Shariat A, Hakakzadeh A. Effects of kinesiotaping on knee osteoarthritis: a literature review. J Exerc Rehabil. 2019;15(4):498–503.
13. Melese H, Alamer A, Hailu Temesgen M, Nigussie F. Effectiveness of kinesio taping on the management of knee osteoarthritis: a systematic review of randomized controlled trials. J Pain Res. 2020;13:1267–76.
14. Yeung WF, Chen SC, Cheung DST, Wong CK, Chong TC, Ho YS, Suen LKP, Ho LM, Lao L. Self-administered acupressure for probable knee osteoarthritis in middle-aged and older adults: a randomized clinical trial. JAMA Netw Open. 2024;7(4):e245830.
15. Allison K, Jones S, Hinman RS, Pardo J, Li P, DeSilva A, Quicke JG, Sumithran P, Prendergast J, George E, et al. Alternative models to support weight loss in chronic musculoskeletal conditions: effectiveness of a physiotherapist-delivered intensive diet programme for knee

osteoarthritis, the POWER randomised controlled trial. Br J Sports Med. 2024;58(10):538–47.
16. Kwok JY, Choi KC, Chan HY. Effects of mind–body exercises on the physiological and psychosocial well-being of individuals with Parkinson's disease: a systematic review and meta-analysis. Complement Ther Med. 2016;29:121–31.
17. Lee SH, Jeon Y, Huang CW, Cheon C, Ko SG. Qigong and tai chi on human health: an overview of systematic reviews. Am J Chin Med. 2022;50(8):1995–2010.
18. Barnes PM, Bloom B, Nahin RL. Complementary and alternative medicine use among adults and children: United States, 2007. Natl Health Stat Rep. 2008;12:1–23.
19. Wells C, Kolt GS, Bialocerkowski A. Defining Pilates exercise: a systematic review. Complement Ther Med. 2012;20(4):253–62.
20. Qiao H, Hao X, Wang G. Effects of mind–body exercise on knee osteoarthritis: a systematic review and meta-analysis of randomized controlled trials. BMC Musculoskelet Disord. 2024;25(1):229.
21. Liu J, Liu W, Huang J, Wang Y, Zhao B, Zeng P, Cai G, Chen R, Hu K, Tu Y, et al. The modulation effects of the mind–body and physical exercises on the basolateral amygdala-temporal pole pathway on individuals with knee osteoarthritis. Int J Clin Health Psychol. 2024;24(1):100421.
22. Tu YX. The white matter fiber changes under different exercise in patients with knee osteoarthritis: a DTI-TBSS study. Fujian: Fujian Univ of Traditional Chinese Medicine; 2017. Available at: https://kns.cnki.net/kns8s/?classid=LSTPFY1C.
23. Wang ZP. Explore the neural mechanism of exercise rehabilitation of knee osteoarthritis. Fujian: Fujian Univ of Traditional Chinese Medicine, 2017. Available at: https://kns.cnki.net/kns8s/?classid=LSTPFY1C.
24. Hu K. Effects of different exercises on middle-aged and elderly community adults with knee osteoarthritis: a randomized controlled trial. Fujian: Fujian Univ of Traditional Chinese Medicine, 2017. Available at: https://kns.cnki.net/kns8s/?classid=LSTPFY1C.
25. Lin MQ. The effect of different exercise modes on serum immune indexes in patients with knee osteoarthritis. Fujian: Fujian Univ of Traditional Chinese Medicine, 2017. Available at: https://kns.cnki.net/kns8s/?classid=LSTPFY1C.
26. Goh SL, Persson MSM, Stocks J, Hou Y, Welton NJ, Lin J, Hall MC, Doherty M, Zhang W. Relative efficacy of different exercises for pain, function, performance and quality of life in knee and hip osteoarthritis: systematic review and network meta-analysis. Sports Med. 2019;49(5):743–61.
27. Mo L, Jiang B, Mei T, Zhou D. Exercise therapy for knee osteoarthritis: a systematic review and network meta-analysis. Orthop J Sports Med. 2023;11(5):23259671231172772.
28. Li J, Liu QR, Xing MN, Chen B, Jiao W, Meng ZX. A network meta-analysis on therapeutic effect of different types of exercise on knee osteoarthritis patients. Chin J Tissue Eng Res. 2024;29(03):608–16.
29. Hutton B, Salanti G, Caldwell DM, Chaimani A, Schmid CH, Cameron C, Ioannidis JP, Straus S, Thorlund K, Jansen JP, et al. The PRISMA extension statement for reporting of systematic reviews incorporating network meta-analyses of health care interventions: checklist and explanations. Ann Intern Med. 2015;162(11):777–84.
30. Fransen M, McConnell S, Harmer AR, Van der Esch M, Simic M, Bennell KL. Exercise for osteoarthritis of the knee. Cochrane Database Syst Rev. 2015;1(1):Cd004376.
31. Regnaux JP, Lefevre-Colau MM, Trinquart L, Nguyen C, Boutron I, Brosseau L, Ravaud P. High-intensity versus low-intensity physical activity or exercise in people with hip or knee osteoarthritis. Cochrane Database Syst Rev. 2015;2015(10):Cd010203.
32. da Costa BR, Pereira TV, Saadat P, Rudnicki M, Iskander SM, Bodmer NS, Bobos P, Gao L, Kiyomoto HD, Montezuma T, et al. Effectiveness and safety of non-steroidal anti-inflammatory drugs and opioid treatment for knee and hip osteoarthritis: network meta-analysis. BMJ. 2021;375:n2321.
33. Higgins JPT GSe: Cochrane handbook for systematic reviews of interventions version 5.1.0 [updated March 2011]. The Cochrane Collaboration; 2011.
34. Higgins JPT TJ, Chandler J, Cumpston M, Li T, Page MJ, Welch VA (editors). Cochrane handbook for systematic reviews of interventions version 6.2 (updated February 2021). Cochrane 2021.
35. Cohen J. Statistical power analysis for the behavioral sciences. 2nd ed. Lawrence Erlbaum Associates; 1988.
36. Higgins JP, Li T, Deeks JJ. Choosing effect measures and computing estimates of effect. In: Cochrane handbook for systematic reviews of interventions. 2019, pp. 143–176.
37. Belavý DL, Kaczorowski S, Saueressig T, Owen PJ, Nikolakopoulou A. How to conduct and report checking transitivity and inconsistency in network-meta-analysis: a narrative review including practical worked examples, code and source data for sports and exercise medicine researchers. BMJ Open Sport Exerc Med. 2024;10(4):e002262.
38. Chaimani A, Higgins JP, Mavridis D, Spyridonos P, Salanti G. Graphical tools for network meta-analysis in STATA. PLoS ONE. 2013;8(10):e76654.
39. Chaimani A, Salanti G. Visualizing assumptions and results in network meta-analysis: the network graphs package. Stata J. 2015;15(4):905–50.
40. Mavridis D, White IR, Higgins JP, Cipriani A, Salanti G. Allowing for uncertainty due to missing continuous outcome data in pairwise and network meta-analysis. Stat Med. 2015;34(5):721–41.
41. White IR, Barrett JK, Jackson D, Higgins JP. Consistency and inconsistency in network meta-analysis: model estimation using multivariate meta-regression. Res Synth Methods. 2012;3(2):111–25.
42. Rücker G, Schwarzer G. Ranking treatments in frequentist network meta-analysis works without resampling methods. BMC Med Res Methodol. 2015;15:58.
43. Shim SR, Kim SJ. Intervention meta-analysis: application and practice using R software. Epidemiol Health. 2019;41:e2019008.
44. Sterne JAC, Savović J, Page MJ, Elbers RG, Blencowe NS, Boutron I, Cates CJ, Cheng HY, Corbett MS, Eldridge SM, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. BMJ. 2019;366:l4898.
45. Salanti G, Del Giovane C, Chaimani A, Caldwell DM, Higgins JP. Evaluating the quality of evidence from a network meta-analysis. PLoS ONE. 2014;9(7):e99682.
46. Brignardello-Petersen R, Florez ID, Izcovich A, Santesso N, Hazlewood G, Alhazanni W, Yepes-Nuñez JJ, Tomlinson G, Schünemann HJ, Guyatt GH. GRADE approach to drawing conclusions from a network meta-analysis using a minimally contextualised framework. BMJ. 2020;371:m3900.
47. Hu X, Lai Z, Wang L. Effects of Taichi exercise on knee and ankle proprioception among individuals with knee osteoarthritis. Res Sports Med. 2020;28(2):268–78.
48. Wang C, Schmid CH, Iversen MD, Harvey WF, Fielding RA, Driban JB, Price LL, Wong JB, Reid KF, Rones R, et al. Comparative effectiveness of tai chi versus physical therapy for knee osteoarthritis: a randomized trial. Ann Intern Med. 2016;165(2):77–86.
49. Zhu Q, Huang L, Wu X, et al. Effects of Tai Ji Quan training on gait kinematics in older Chinese women with knee osteoarthritis: a randomized controlled trial. J Sport Health Sci. 2016;5(3):297–303.
50. Tsai PF, Chang JY, Beck C, Kuo YF, Keefe FJ. A pilot cluster-randomized trial of a 20-week Tai Chi program in elders with cognitive impairment and osteoarthritic knee: effects on pain and other health outcomes. J Pain Symptom Manag. 2013;45(4):660–9.
51. Lee HJ, Park HJ, Chae Y, et al. Tai Chi Qigong for the quality of life of patients with knee osteoarthritis: a pilot, randomized, waiting list controlled trial. Clin Rehabil. 2009;23(6):504–11.
52. Brismée JM, Paige RL, Chyu MC, et al. Group and home-based tai chi in elderly subjects with knee osteoarthritis: a randomized controlled trial. Clin Rehabil. 2007;21(2):99–111.
53. Zhou ZF. The effect of Tai Chi on influence in patients with Osteoarthritis of the knee. Chin J Geriatric care. 2019;17(06):15–8.
54. Song R, Lee EO, Lam P, Bae SC. Effects of tai chi exercise on pain, balance, muscle strength, and perceived difficulties in physical functioning in older women with osteoarthritis: a randomized clinical trial. J Rheumatol. 2003;30(9):2039–44.
55. Huang LY. Effects of innovative tai chi rehabilitation strategies on clinic effect and gait of elderly patients wih knee osteoarthritis [dissertation]. Shanghai: Shanghai Univ of sport; 2015. Available at: https://kns.cnki.net/kns8s/?classid=LSTPFY1C.
56. Wortley M, Zhang S, Paquette M, et al. Effects of resistance and Tai Ji training on mobility and symptoms in knee osteoarthritis patients. J Sport Health Sci. 2013;2:209–14.
57. Li JY, Cheng L. The effect of Taichi and resistance training on osteoarthritis symptoms of the elderly and the exercise capacity. Chin J Rehabil Med. 2019;34(11):1304–9.

58. Wang C, Schmid CH, Hibberd PL, et al. Tai Chi is effective in treating knee osteoarthritis: a randomized controlled trial. Arthritis Rheum. 2009;61(11):1545–53.
59. Song J, Wei L, Cheng K, Lin Q, Xia P, Wang X, Wang X, Yang T, Chen B, Ding A, et al. The effect of modified tai chi exercises on the physical function and quality of life in elderly women with knee osteoarthritis. Front Aging Neurosci. 2022;14:860762.
60. Zhang ZW. Effect on plantar pressure of innovative tai chi for elderly women with knee osteoarthritis during walking [thesis]. Shanghai: Shanghai Univ of sport; 2014. Available at: https://kns.cnki.net/kns8s/?classid=LSTPFY1C.
61. Zhang X. Effect of taijiquan "Xiaojiutian" in middle-aged and old female of lower limb function in patients with knee osteoarthritis [thesis]. Beijing: Capital Univ of Physical Education And Sports; 2016. Available at: https://kns.cnki.net/kns8s/?classid=LSTPFY1C.
62. Cao X. The effects of tai chi practice in elderly subjects with knee osteoarthritis [thesis]. Guangxi: Guangxi Univ of Chinese Medicine; 2018. Available at: https://kns.cnki.net/kns8s/?classid=LSTPFY1C.
63. Zhu Q, Huang L, Wu X, et al. Effect of Taijiquan practice versus wellness education on knee proprioception in patients with knee osteoarthritis: a randomized controlled trial. J Tradit Chin Med. 2017;37(6):774–81.
64. An B, Dai K, Zhu Z, et al. Baduanjin alleviates the symptoms of knee osteoarthritis. J Altern Complement Med. 2008;14(2):167–74.
65. Ye J, Simpson MW, Liu Y, et al. The effects of baduanjin qigong on postural stability, proprioception, and symptoms of patients with knee osteoarthritis: a randomized controlled trial. Front Med (Lausanne). 2019;6:307.
66. Jiang Y, Lai ZQ, Fan KY, et al. Effects of 12-week health qigong baduanjin on lower limb body compositions in knee osteoarthritis patients. J Liaoning Univ Tradit Chin Med. 2020;22(08):90–3.
67. Yin XJ, Li HF. Influence of wuqinxi on proprioceptive sensation and body balance function of female patients with knee osteoarthritis. J Jianghan Univ (Nat Sci Edition). 2017;45(04):355–8.
68. Tian BW. A study on the effect of wuqinxi exercise on the proprioception and balance function of elderly female patients with KOA [dissertation]. Beijing: Beijing Sport University; 2012. Available at: https://kns.cnki.net/kns8s/?classid=LSTPFY1C.
69. Xiao Z, Li G. The effect of Wuqinxi exercises on the balance function and subjective quality of life in elderly, female knee osteoarthritis patients. Am J Transl Res. 2021;13(6):6710–6.
70. Xiao CM, Li JJ, Kang Y, Zhuang YC. Follow-up of a Wuqinxi exercise at home programme to reduce pain and improve function for knee osteoarthritis in older people: a randomised controlled trial. Age Ageing. 2021;50(2):570–5.
71. Xiao C, Zhuang Y, Kang Y. Effects of Wu Qin xi Qigong exercise on physical functioning in elderly people with knee osteoarthritis: a randomized controlled trial. Geriatr Gerontol Int. 2020;20(10):899–903.
72. Yang SZ. Experimental study on the effect of Baduanjin on knee stability and balance function in patients with knee osteoarthritis [thesis]. Liaoning: Liaoning Univ of Traditional Chinese Medicine; 2019. Available at: https://kns.cnki.net/kns8s/?classid=LSTPFY1C.
73. Wang D. The rehabilitation effect and influencing factors of 12-week five-poultry exercise on patients with knee osteoarthritis [thesis]. Tianjin: Tianjin Univ of Sport; 2019. Available at: https://kns.cnki.net/kns8s/?classid=LSTPFY1C.
74. Bennell KL, Schwartz S, Teo PL, et al. Effectiveness of an unsupervised online yoga program on pain and function in people with knee osteoarthritis : a randomized clinical trial. Ann Intern Med. 2022;175(10):1345–55.
75. Cheung C, Wyman JF, Resnick B, Savik K. Yoga for managing knee osteoarthritis in older women: a pilot randomized controlled trial. BMC Complement Altern Med. 2014;14:160.
76. Cheung C, Wyman JF, Bronas U, Mccarthy T, Rudser K, Mathiason MA. Managing knee osteoarthritis with yoga or aerobic/strengthening exercise programs in older adults: a pilot randomized controlled trial. Rheumatol Int. 2017;37(3):389–98.
77. Kuntz AB, Chopp-Hurley JN, Brenneman EC, et al. Efficacy of a biomechanically-based yoga exercise program in knee osteoarthritis: a randomized controlled trial. PLoS ONE. 2018;13(4):e0195653.
78. Rêgo TAM, Ferreira APL, Villela DW, Shirahige L, Xavier AB, Braz RRS, Guerino MR, Araújo M. Effects of mat Pilates on older adult women with knee osteoarthritis: a randomized controlled trial. J Bodyw Mov Ther. 2023;33:136–41.
79. Mazloum V, Rabiei P, Rahnama N, Sabzehparvar E. The comparison of the effectiveness of conventional therapeutic exercises and Pilates on pain and function in patients with knee osteoarthritis. Complement Ther Clin Pract. 2018;31:343–8.
80. Krishnasamy P, Hall M, Robbins SR. The role of skeletal muscle in the pathophysiology and management of knee osteoarthritis. Rheumatology (Oxford). 2018;57(suppl_4):iv22–33.
81. Santos ML, Gomes WF, Pereira DS, Oliveira DM, Dias JM, Ferrioli E, Pereira LS. Muscle strength, muscle balance, physical function and plasma interleukin-6 (IL-6) levels in elderly women with knee osteoarthritis (OA). Arch Gerontol Geriatr. 2011;52(3):322–6.
82. Øiestad BE, Juhl CB, Culvenor AG, Berg B, Thorlund JB. Knee extensor muscle weakness is a risk factor for the development of knee osteoarthritis: an updated systematic review and meta-analysis including 46 819 men and women. Br J Sports Med. 2022;56(6):349–55.
83. Bueno de Souza RO, Marcon LF, Arruda ASF, Pontes Junior FL, Melo RC. Effects of mat pilates on physical functional performance of older adults: a meta-analysis of randomized controlled trials. Am J Phys Med Rehabil. 2018;97(6):414–25.
84. Hall M, Hinman RS, Wrigley TV, Kasza J, Lim BW, Bennell KL. Knee extensor strength gains mediate symptom improvement in knee osteoarthritis: secondary analysis of a randomised controlled trial. Osteoarthritis Cartilage. 2018;26(4):495–500.
85. Queiroz BC, Cagliari MF, Amorim CF, Sacco IC. Muscle activation during four Pilates core stability exercises in quadruped position. Arch Phys Med Rehabil. 2010;91(1):86–92.
86. Subasi SS, Gelecek N, Aksakoglu G. Effects of different warm-up periods on knee proprioception and balance in healthy young individuals. J Sport Rehabil. 2008;17(2):186–205.
87. Saleem N, Zahid S, Mahmood T, Ahmed N, Maqsood U, Chaudhary MA. Effect of Pilates based exercises on symptomatic knee osteoarthritis: a randomized controlled trial. J Pak Med Assoc. 2022;72(1):8–12.
88. Segal NA, Hein J, Basford JR. The effects of Pilates training on flexibility and body composition: an observational study. Arch Phys Med Rehabil. 2004;85(12):1977–81.
89. Haouzi P, Bell HJ. Control of breathing and volitional respiratory rhythm in humans. J Appl Physiol (1985). 2009;106(3):904–10.
90. Watson JA, Ryan CG, Cooper L, Ellington D, Whittle R, Lavender M, Dixon J, Atkinson G, Cooper K, Martin DJ. Pain neuroscience education for adults with chronic musculoskeletal pain: a mixed-methods systematic review and meta-analysis. J Pain. 2019;20(10):1140.e1141-1140.e1122.
91. Rabiei P, Sheikhi B, Letafatkar A. Examining the influence of pain neuroscience education followed by a Pilates exercises program in individuals with knee osteoarthritis: a pilot randomized controlled trial. Arthritis Res Ther. 2023;25(1):94.
92. Wang C, Schmid CH, Fielding RA, Harvey WF, Reid KF, Price LL, Driban JB, Kalish R, Rones R, McAlindon T. Effect of tai chi versus aerobic exercise for fibromyalgia: comparative effectiveness randomized controlled trial. BMJ. 2018;360:k851.
93. Wang C, Bannuru R, Ramel J, Kupelnick B, Scott T, Schmid CH. Tai Chi on psychological well-being: systematic review and meta-analysis. BMC Complement Altern Med. 2010;10:23.
94. Esch T, Duckstein J, Welke J, Braun V. Mind/body techniques for physiological and psychological stress reduction: stress management via Tai Chi training—a pilot study. Med Sci Monit. 2007;13(11):Cr488–97.
95. Dainese P, Wyngaert KV, De Mits S, Wittoek R, Van Ginckel A, Calders P. Association between knee inflammation and knee pain in patients with knee osteoarthritis: a systematic review. Osteoarthr Cartil. 2022;30(4):516–34.
96. Miller RE, Miller RJ, Malfait AM. Osteoarthritis joint pain: the cytokine connection. Cytokine. 2014;70(2):185–93.
97. Shu C, Feng S, Cui Q, Cheng S, Wang Y. Impact of Tai Chi on CRP, TNF-alpha and IL-6 in inflammation: a systematic review and meta-analysis. Ann Palliat Med. 2021;10(7):7468–78.
98. Irwin MR, Hoang D, Olmstead R, Sadeghi N, Breen EC, Bower JE, Cole S. Tai Chi compared with cognitive behavioral therapy and the reversal of systemic, cellular and genomic markers of inflammation in breast cancer survivors with insomnia: a randomized clinical trial. Brain Behav Immun. 2024;120:159–66.

99. Arora V, Singh G, InSug O, Ma K, Natarajan Anbazhagan A, Votta-Velis EG, Bruce B, Richard R, van Wijnen AJ, Im HJ. Gut-microbiota modulation: the impact of the gut-microbiota on osteoarthritis. Gene. 2021;785:145619.
100. Liu L, Tian F, Li GY, Xu W, Xia R. The effects and significance of gut microbiota and its metabolites on the regulation of osteoarthritis: close coordination of gut-bone axis. Front Nutr. 2022;9:1012087.
101. Ricciuto A, Sherman PM, Laxer RM. Gut microbiota in chronic inflammatory disorders: a focus on pediatric inflammatory bowel diseases and juvenile idiopathic arthritis. Clin Immunol. 2020;215:108415.
102. Zhou T, Qiu ZZ, Liu W. Correlational research on the effect of Taijiquan exercise on intestinal probiotics and blood lipid of obese old people. J Shandong Sport Univ. 2012;28(01):62–6.
103. Zheng Z, Luo Y, Yan XM, Du JT. Effects of a tai chi rehabilitation program of differing duration on the function of intestinal flora. J Pathog Biol. 2020;15(09):1071–4.
104. Cheng S, Zeng F, Zhou J, Dong X, Yang W, Yin T, Huang K, Liang F, Li Z. Altered static and dynamic functional brain network in knee osteoarthritis: a resting-state functional magnetic resonance imaging study: Static and dynamic FNC in KOA. Neuroimage. 2024;292:120599.
105. Salazar-Méndez J, Cuyul-Vásquez I, Viscay-Sanhueza N, Morales-Verdugo J, Mendez-Rebolledo G, Ponce-Fuentes F, Lluch-Girbés E. Structural and functional brain changes in people with knee osteoarthritis: a scoping review. PeerJ. 2023;11:e16003.
106. Wei GX, Xu T, Fan FM, Dong HM, Jiang LL, Li HJ, Yang Z, Luo J, Zuo XN. Can Taichi reshape the brain? A brain morphometry study. PLoS ONE. 2013;8(4): e61038.
107. Shen CL, Watkins BA, Kahathuduwa C, Chyu MC, Zabet-Moghaddam M, Elmassry MM, Luk HY, Brismée JM, Knox A, Lee J, et al. Tai Chi improves brain functional connectivity and plasma lysophosphatidylcholines in postmenopausal women with knee osteoarthritis: an exploratory pilot study. Front Med (Lausanne). 2021;8:775344.
108. Liu J, Chen L, Chen X, Hu K, Tu Y, Lin M, Huang J, Liu W, Wu J, Qiu Z, et al. Modulatory effects of different exercise modalities on the functional connectivity of the periaqueductal grey and ventral tegmental area in patients with knee osteoarthritis: a randomised multimodal magnetic resonance imaging study. Br J Anaesth. 2019;123(4):506–18.
109. Liu J, Chen L, Tu Y, Chen X, Hu K, Tu Y, Lin M, Xie G, Chen S, Huang J, et al. Different exercise modalities relieve pain syndrome in patients with knee osteoarthritis and modulate the dorsolateral prefrontal cortex: a multiple mode MRI study. Brain Behav Immun. 2019;82:253–63.
110. Lu J, Kang J, Huang H, Xie C, Hu J, Yu Y, Jin Y, Wen Y. The impact of Yoga on patients with knee osteoarthritis: a systematic review and meta-analysis of randomized controlled trials. PLoS ONE. 2024;19(5):e0303641.
111. Wieland LS, Skoetz N, Pilkington K, Vempati R, D'Adamo CR, Berman BM. Yoga treatment for chronic non-specific low back pain. Cochrane Database Syst Rev. 2017;1(1):Cd010671.
112. Sivaramakrishnan D, Fitzsimons C, Kelly P, Ludwig K, Mutrie N, Saunders DH, Baker G. The effects of yoga compared to active and inactive controls on physical function and health related quality of life in older adults-systematic review and meta-analysis of randomised controlled trials. Int J Behav Nutr Phys Act. 2019;16(1):33.
113. Zeng ZP, Liu YB, Fang J, Liu Y, Luo J, Yang M. Effects of Baduanjin exercise for knee osteoarthritis: a systematic review and meta-analysis. Complement Ther Med. 2020;48:102279.
114. Guo J, Peng C, Hu Z, Guo L, Dai R, Li Y. Effect of Wu Qin Xi exercises on pain and function in people with knee osteoarthritis: a systematic review and meta-analysis. Front Med (Lausanne). 2022;9:979207.
115. Brosseau L, Taki J, Desjardins B, Thevenot O, Fransen M, Wells GA, Imoto AM, Toupin-April K, Westby M, Gallardo I, et al. The Ottawa panel clinical practice guidelines for the management of knee osteoarthritis. Part one: introduction, and mind–body exercise programs. Clin Rehabil. 2017;31(5):582–95.
116. Li X, Si H, Chen Y, Li S, Yin N, Wang Z. Effects of fitness qigong and tai chi on middle-aged and elderly patients with type 2 diabetes mellitus. PLoS ONE. 2020;15(12):e0243989.
117. Siu PM, Yu AP, Chin EC, Yu DS, Hui SS, Woo J, Fong DY, Wei GX, Irwin MR. Effects of tai chi or conventional exercise on central obesity in middle-aged and older adults : a three-group randomized controlled trial. Ann Intern Med. 2021;174(8):1050–7.
118. Dong Y, Yan Y, Zhou J, Zhou Q, Wei H. Evidence on risk factors for knee osteoarthritis in middle-older aged: a systematic review and meta-analysis. J Orthop Surg Res. 2023;18(1):634.

Publisher's Note