





Interventional Effects of Small Needle-Knife Combined with Exercise Therapy in the Treatment of Knee Osteoarthritis: A Systematic Review and Meta-Analysis

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Background: Knee osteoarthritis (KOA) is a common degenerative disease. Small needle-knife (SNK) therapy combined with exercise therapy has attracted increasing attention. However, its effectiveness requires further evaluation.

Objective: To systematically evaluate the clinical efficacy of SNK combined with exercise therapy in KOA patients.

Methods: Randomized controlled trials (RCTs) comparing small needle-knife (SNK) plus exercise with exercise alone were identified from major databases (PubMed, EMBASE, Cochrane Library and others) from inception to March 14, 2025. Primary outcomes included overall treatment efficacy, pain measured by the visual analogue scale (VAS), function assessed by the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) and the Lequesne Index, and knee stability assessed by the Lysholm score. Meta-analyses were performed using fixed- or random-effects models according to heterogeneity (I^2 and Q test). Risk of bias was assessed with the Cochrane Risk of Bias 2.0 tool (RoB 2), and the certainty of evidence with the GRADE approach. The protocol was prospectively registered in PROSPERO.

Results: Ten RCTs were included. Results showed that SNK combined with exercise significantly improved clinical efficacy (RR = 1.30; 95% CI [1.19, 2.42]). Compared with exercise alone, combination therapy significantly relieved pain (VAS: MD = -1.64; 95% CI [-2.20, -1.05]), improved function (WOMAC: MD = -14.65; 95% CI [-19.48, -9.83]; Lequesne index: MD = -2.23; 95% CI [-3.59, -0.86]), and enhanced knee stability (Lysholm score: MD = 9.20; 95% CI [1.67, 16.74]). ROB2 assessment showed that 60% of studies had low risk, and 40% had some concerns. All outcome measures were supported by high-quality evidence according to the GRADE framework.

Conclusion: The combination of SNK and exercise shows clinically significant improvements in KOA. Nevertheless, additional high-quality studies are required to corroborate these findings.

Keywords: knee osteoarthritis, small needle-knife, sports therapy, systematic review, meta-analysis

Introduction

Knee osteoarthritis (KOA) is a highly prevalent, chronic disabling disease and one of the most severe forms of degenerative joint disease, affecting over 654 million individuals worldwide.^{1,2} It predominantly affects older adults, with an incidence of 30–50% among people aged 65 years and above.³ In addition to aging, major risk factors include obesity (BMI \geq 30 kg/m², associated with a 4.7-fold increased risk),⁴ previous joint injuries, and genetic susceptibility.⁵ With population aging and rising obesity rates, the incidence of KOA is expected to further increase.⁶ KOA commonly



leads to chronic pain and functional limitation; approximately 85% of patients experience persistent pain that restricts daily activities such as walking and stair climbing.⁷ Moreover, muscle weakness around the knee and proprioceptive impairments contribute to joint instability and an increased risk of falls.⁸

Currently, the Osteoarthritis Research Society International (OARSI) recommends conservative management as the first-line treatment for KOA,⁹ including pharmacological therapies, exercise, education, weight loss, acupuncture, and small needle-knife (SNK) therapy.¹⁰ Commonly used pharmacological treatments consist of analgesics, nonsteroidal anti-inflammatory drugs (NSAIDs), and steroid injections. Nonetheless, long-term use of these drugs carries significant side effects, such as gastrointestinal adverse reactions, cardiovascular diseases, and liver toxicity.^{11,12}

As non-pharmacological therapies gain prominence in osteoarthritis (OA) management, Small Needle-Knife (SNK) therapy has emerged as a clinical focus. SNK integrates traditional Chinese acupuncture principles with modern minimally invasive techniques and is widely used for musculoskeletal disorders by releasing soft tissue adhesions, modulating fascia tension, improving local circulation, and reducing inflammation.¹³ As a minor surgical technique, SNK must be performed by certified practitioners, such as traditional Chinese medicine (TCM) or orthopedic physicians, who have received standardized training in its application.

Studies indicate that SNK significantly reduces pain and enhances function in KOA patients.^{14,15} Exercise therapy is also widely recognized as a safe, effective, and cost-efficient non-pharmacological intervention that can alleviate KOA symptoms by optimizing joint biomechanics.¹⁶ Accordingly, the Osteoarthritis Research Society International (OARSI) recommends both aerobic and strength-training exercises as core components of conservative management.⁹ However, exercise therapy alone may have limited efficacy in reducing joint pain and swelling,¹⁷ making it a supplementary or adjunctive physical therapy for KOA.¹⁸ Combining SNK with therapeutic exercise may offer synergistic benefits by addressing both pain management and functional improvement in KOA.

With the growing clinical application of SNK and exercise therapy, their combined use has attracted increasing research interest. However, standardized protocols and optimal exercise regimens for SNK-exercise therapy remain undefined. While their combination shows synergistic benefits in clinical practice, some controversies persist.¹⁹

Despite the growing clinical use of SNK and exercise therapy for KOA, previous systematic reviews and meta-analyses have not specifically quantified the potential synergistic effect of SNK combined with exercise therapy compared with monotherapy, nor have they examined how different exercise prescriptions (eg, type, frequency, and duration) may influence this effect. Therefore, this study aims to systematically evaluate and quantify the superiority of SNK combined with exercise therapy in reducing pain, improving joint function, and enhancing overall clinical outcomes in KOA patients compared to monotherapy. Additionally, subgroup analyses will explore dose-response relationships across exercise types (active/passive/mixed), treatment frequency (high ≥ 2 sessions/week vs low ≤ 1 session/week), and duration (short-term ≤ 8 weeks vs long-term > 8 weeks) to identify the most effective therapeutic combination.

Methods

This meta-analysis was conducted as per the recommendations of the PRISMA 2020 guidelines²⁰ ([Supplementary Appendix 1](#)). The systematic review and meta-analysis have been prospectively registered in the International Prospective Register of Systematic Reviews (PROSPERO) database, with the registration number CRD42024577027.

Search Strategy

PubMed, EMBASE, Cochrane Library, Web of Science, China National Knowledge Infrastructure (CNKI), VIP, China Biomedical Literature (CBM), and Wanfang databases were retrieved to find relevant English- and Chinese-language studies published from the inception of the databases up to August 2025. The keywords used in the search encompassed (knee osteoarthritis OR femorotibial arthrosis OR gonarthrosis) AND (needle knife OR acupuncture therapy OR acupotomy OR zimmon OR cutting needle) AND (exercise OR fitness OR kinesiotherapy OR sport OR kineses OR movement*). Additionally, researchers manually reviewed the reference lists of the literature obtained to identify other potentially eligible studies. All search strategies are provided in [Supplementary Appendix 2](#).

Inclusion and Exclusion Criteria

The inclusion criteria were designed as per the PICOS principle: Participants (P): Adults diagnosed with KOA to ensure sample consistency and diagnostic reliability.

Intervention (I): The intervention of interest was the combination of SNK and exercise. In the included trials, SNK was performed using a blade-tipped needle with a diameter of 0.8–1.0 mm and a flat blade width of 0.4–0.6 mm. This combination was intended to relieve symptoms and enhance joint function through the soft-tissue release and local analgesic effects of SNK, together with the muscle-strengthening effects of exercise therapy. Comparator (C): The control group received exercise therapy alone, with the same type of exercise as the experimental group. Outcomes (O): The primary outcome measures comprised pain scores (eg, Visual Analog Scale, VAS), joint function scores (eg, Western Ontario and McMaster Universities Osteoarthritis Index [WOMAC], Lysholm scores), severity of knee joint function (Lequesne score), and overall clinical efficacy. All outcome measures must have been assessed using standardized and validated scales, with clearly reported follow-up data. Study Design (S): Only randomized controlled trials (RCTs) published in full in peer-reviewed journals were included to ensure scientific rigor in study design and reliability of results. The following studies were excluded: duplicate publications and data; non-randomized controlled studies, like case-control studies, cohort studies, cross-sectional studies, etc; studies with small sample sizes or insufficient data, such as those lacking outcome measures or not providing clear statistical methods; journal supplements, guidelines, letters, animal studies, and other articles that did not meet the clinical research criteria.

These eligibility criteria strictly followed the principles of evidence-based medicine, aiming to ensure the high quality of the included studies and the reliability of the results. The process intended to provide clear and scientific evidence regarding the efficacy of SNK combined with exercise for KOA.

Literature Screening

The search results were uploaded into EndNote X9.0, and the study selection was independently conducted by two authors, Yun Dong Xu and Jin Xu. First, duplicate publications were deleted. Next, the titles and abstracts of the remaining studies were checked to determine their potential eligibility. Third, full texts of potentially eligible studies were examined to finally determine whether they should be included. The results of the screening were cross-checked between the two authors, and in case of any discrepancies, a third researcher, Qianqian Yang, was consulted for discussion and final decision.

Data Extraction

Data extraction was independently implemented by Yun Dong Xu and Jin Xu leveraging a standardized data extraction checklist. In case of any dissents, a third researcher, Qianqian Yang, was consulted. The extracted data encompassed the first author, publication year, country, study design, mean age at onset, sample size, interventions, intervention duration, and outcome measures.

Quality Assessment

The quality of eligible studies was independently appraised by Yun Dong Xu and Jin Xu using the Cochrane Risk of Bias Tool 2.0 (ROB2) in accordance with the principles outlined in the Cochrane Handbook.²¹ The risk of bias assessment comprised the following aspects: selection bias (random sequence generation and allocation concealment); performance bias (blinding of participants and personnel); detection bias (blinding of outcome assessment); attrition bias (incomplete outcome data); and reporting bias (selective reporting). The risk of bias for each item was categorized as low, unclear, or high. Any disagreements were resolved by a third researcher, Qianqian Yang. The quality of evidence for key outcomes was evaluated using the GRADE framework (Grading of Recommendations Assessment, Development, and Evaluation), which considers factors such as risk of bias, inconsistency, imprecision, and publication bias.^{22,23} These criteria categorize the evidence as high, moderate, low, or very low quality. Certainty ratings were influenced by positive indicators like large effect sizes, study consistency, and evidence directness. The overall certainty for each outcome was

determined by the strength of the supporting evidence, using the minimal clinically important difference (MCID) as a reference when relevant.

Statistical Analysis

Meta-analysis was implemented utilizing Stata 18.0. For dichotomous data (treatment efficacy), relative risk (RR) and corresponding 95% confidence intervals (CIs) were used as effect measures; for continuous data (VAS, WOMAC, Lysholm score, and Lequesne index), mean difference (MD) with corresponding 95% CIs were used as effect measures. In trials with three or more arms, pairwise comparisons were conducted between groups. When one-way ANOVA indicated significant differences, subsequent comparisons used either the *t*-test or Mann–Whitney *U*-test, depending on data distribution. Bonferroni correction was applied to adjust p-values for multiple comparisons, and these adjusted values were used to assess the significance of differences between groups. Heterogeneity was quantified by the Q test and I^2 statistic. If the Q test p-value (Q p-value) ≤ 0.1 and $I^2 \geq 50\%$, a random-effects model was leveraged to pool the results; otherwise, a fixed-effects model was applied. Data were pooled using the Mantel-Haenszel method for the original effect measures. Subgroup analysis was executed to ascertain potential sources of heterogeneity across studies. Sensitivity analysis was conducted by removing one study at a time and recalculating the pooled estimates to investigate the influence of each RCT. Owing to the limited number of included studies (fewer than 10), no publication bias analysis was conducted.²⁴

Results

Search Results

5703 articles were identified from multiple databases, encompassing PubMed, Embase, Cochrane, Web of Science, CNKI, CBM, VIP, and Wanfang. In the initial screening phase, 1916 studies were excluded, including 1027 duplicates, 646 articles automatically flagged as irrelevant, and 243 articles excluded for other reasons. This left 2411 studies for title and abstract screening. After further screening, 1204 articles were excluded due to irrelevance, including 364 pathology and animal studies, 623 studies lacking effective interventions, and 235 studies not meeting clinical research standards. Ultimately, 1207 studies were included in the full-text review. A total of 1132 full-text articles were checked, and 54 studies were excluded for not meeting the inclusion criteria. The reasons for exclusion included: repeated publication of the same RCT with different outcomes or populations (65 studies), studies that did not report the outcome measures of interest (786 studies), non-peer-reviewed conference abstracts (32 studies), pathological studies without multivariate analysis (122 studies), and case-control studies that did not include relevant outcome measures (127 studies). Ultimately, ten studies were included in this analysis. The results are shown in [Figure 1](#).

Characteristics of Included Studies

Ten studies^{25–34} were included, with a total sample size of 778 participants, including 390 in the experimental group and 388 in the control group. The frequency of interventions ranged from three to six times per week, with an average of four times. Among the included studies, one used a combination of active training and passive manipulation in the exercise therapy of the control group, while two studies used passive manipulation combined with SNK in the experimental group.^{27,29} Seven studies used active training as the exercise therapy in the experimental group.^{25–29,33,34} Seven studies reported pain-related outcomes,^{22,23,25,28–31} five studies reported treatment efficacy,^{26,27,30,32,33} three studies reported WOMAC scores,^{27,33,34} three studies reported Lequesne scores for knee function,^{22,25,26} and four studies reported Lysholm scores.^{26,29,31,32} All included studies addressed outcomes related to pain and function. The results are summarized in [Tables 1](#) and [2](#).

Quality Assessment of Selected Studies

Among the ten included studies, six used a random number table to generate random sequences^{23,25,26,28,30,32}; one study used a random drawing method to generate the random sequence,²⁹ and 3 studies reported randomization but did not specify the exact method used.^{25,29,31} Consequently, the risk of selection bias in this study was graded as low due to the

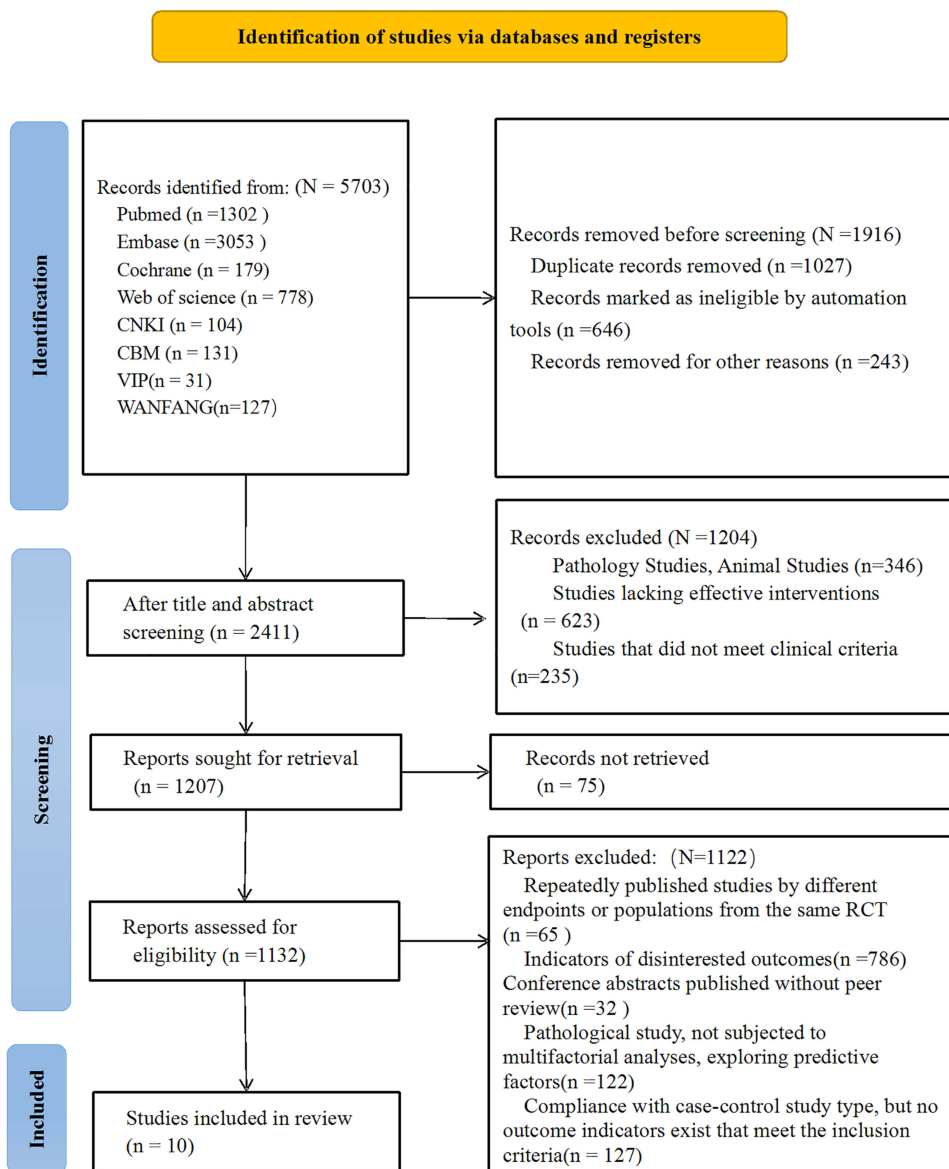


Figure 1 Search results.

generation of random sequences. Four studies^{26,30,31,33} used admission order or did not specify the randomization process, and these were assessed as some concerns. The results are shown in [Figure 2](#).

Outcome Measures

Treatment Efficacy

Five studies reported the treatment efficacy rate.^{26,27,30,32,33} Heterogeneity testing revealed no significant heterogeneity (Q p-value = 0.170, $I^2 = 37.70\%$), and thus a fixed-effect model was utilized for data pooling. The meta-analysis unraveled that SNK plus exercise was significantly superior to exercise alone in terms of treatment efficacy (RR = 1.30, 95% CI: [1.19, 1.42], $p = 0.170$), indicating that SNK plus exercise had an advantage in improving treatment outcomes ([Figure 3A](#)). According to the GRADE assessment, the evidence quality for clinical efficacy was rated as high ($\oplus\oplus\oplus\oplus$), indicating a high level of confidence in the effect estimates.

Table 1 Characteristics of Included Studies (n = 10)

Author (Country/Year)	Mean Age (Years) No (M/F)		Interventions/No		Duration/Day		Outcomes (Instrument)
	T	C	T	C	T	C	
Ma et al (China/2010) ³¹	60.2±6.8 9/18	61.3±8.6 13/17	SNK+isokinetic training(27)	Isokinetic training(30)	4w	20d	VAS(mm), Lysholm(score)
Wang and Lang (China/2015) ³²	58±8 16/21	57±10 19/19	SNK+ Maitland technique(37)	Maitland technique(38)	4w	4w	Curative effect(%), VAS(mm), Lysholm(score)
Zhang et al (China/2023) ²⁶	61.14±7.1 20/30	60.32±7.04 19/31	SNK + Exercise therapy(50)	Exercise therapy(50)	12w	12w	Curative effect(%), VAS(mm), Lysholm(score)
Ning et al (China/2013) ³⁰	57.76±5.23 23/40	58.28±4.54 32/45	SNK + manipulation(73)	Manipulation(77)	3w	3w	Curative effect(%), VAS(mm)
Wang et al (China/2004) ²⁹	38-68 8/12	40-70 9/11	SNK + movement exercise (20)	Movement exercise(20)	4w	4w	Lysholm(score)
Yue (China/2019) ²⁸	45-70 25/33	46-75 28/30	SNK+Rehabilitation therapy (58)	Rehabilitation therapy(58)	4w	4w	Lequesene(score)
Zhang et al (China/2020) ³⁴	55-84 6/24	51-79 7/23	SNK + Quadriceps Exercise Training(30)	Quadriceps Exercise Training(30)	3w	3w	Womac(score)
Li et al (China/2016) ³³	63.06±7.87 11/22	62.56±7.31 10/23	SNK+physicaland breathing exercises(33)	Physical&breathing exercises(33)	16w	16w	Curative effect(%), VAS(mm), Womac(score)
Wan et al (China/2013) ²⁵	42-70 11/19	42-70 10/20	SNK+Exercise Therapy(30)	Exercise Therapy(30)	4w	4w	VAS(mm), Lequesene(score)
Zhang (China/2019) ²⁷	60.03±8.81 13/19	60.38±9.05 14/18	SNK+Exercise therapy(32)	Exercise therapy(32)	8w	8w	Curative effect(%), VAS(mm), Lequesene(score), Womac(score)

Abbreviations: T, test group; C, control group; w, week, SNK, Small needle-knife.

Table 2 Characteristics of SNK and Exercise Characteristics

Included Studies	Interventions (SNK & Exercise Characteristics)		Frequency (Sessions/Week)		Duration		Adverse Effects
	T	C	T	C	T	C	
Ma et al ³¹	SNK + Isokinetic Training	Isokinetic Training	4/w	4/w	4w	20d	Not reported
Wang and Lang ³²	SNK + Maitland Technique	Maitland Technique	4/w	4/w	4w	4w	No adverse reactions
Zhang et al ²⁶	SNK + Exercise Therapy	Exercise Therapy	6/w	6/w	12w	12w	No adverse reactions
Ning et al ³⁰	SNK + Manipulation	Manipulation	4/w	4/w	3w	3w	No adverse reactions
Wang et al ²⁹	SNK + Movement Exercise	Movement Exercise	4/w	4/w	4w	4w	One case each for T
Yue ²⁸	SNK + Rehabilitation Therapy	Rehabilitation Therapy	3/w	3/w	4w	4w	No adverse reactions
Zhang et al ³⁴	SNK + Quadriceps Exercise Training	Quadriceps Exercise Training	4/w	4/w	3w	3w	No adverse reactions
Li et al ³³	SNK + Physical & Breathing Exercises	Physical & Breathing Exercises	3/w	3/w	16w	16w	No adverse reactions
Wan et al ²⁵	SNK + Exercise Therapy	Exercise Therapy	4/w	4/w	4w	4w	Not reported
Zhang ²⁷	SNK + Exercise Therapy	Exercise Therapy	4/w	4/w	8w	8w	One case each for T and C

Knee Pain Indicator (VAS)

Seven studies reported pain-related outcomes,^{25–27,30–33} all of which used the VAS (measured in cm) to measure pain severity. The follow-up periods included both eight weeks and over eight weeks to assess both short-term and long-term effects. To ensure data comparability and reliability, researchers clearly reported changes in VAS scores at each time point (Figure 3B).

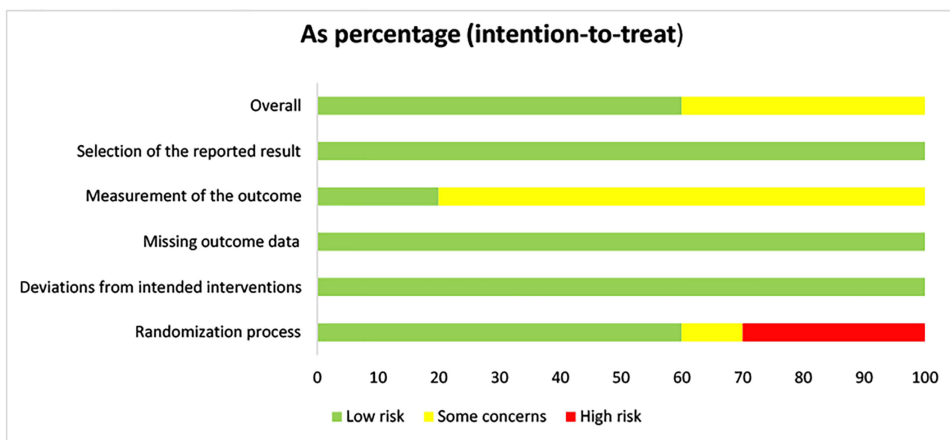
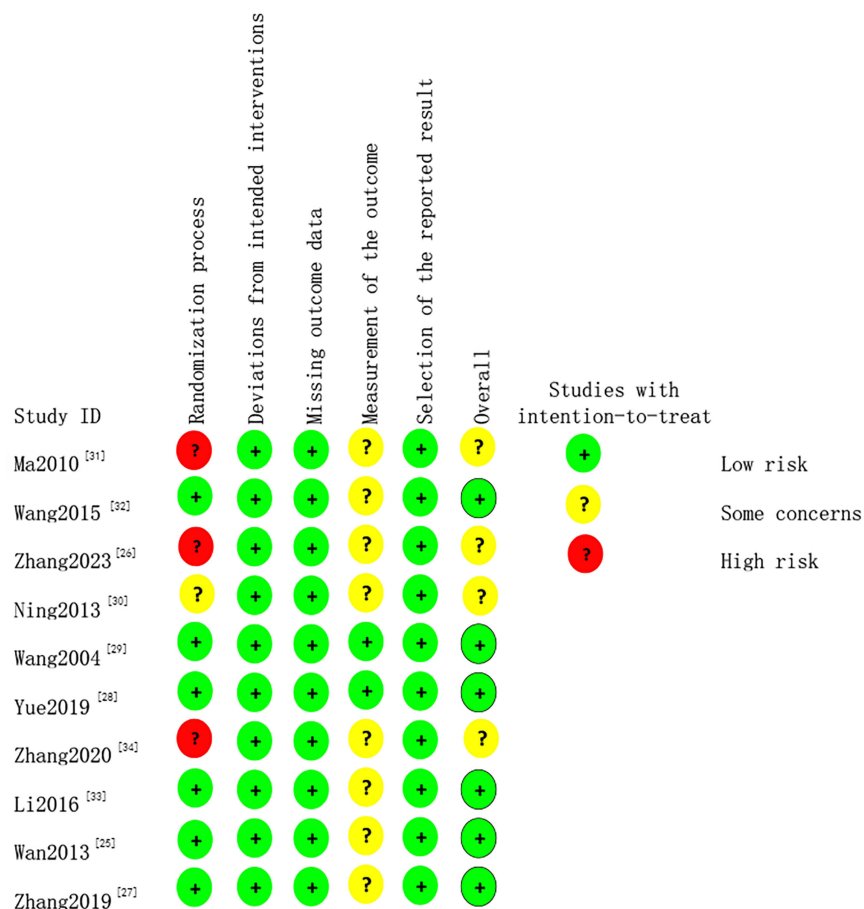


Figure 2 Quality Assessment of Selected Studies.

Meta-analysis unveiled that SNK plus exercise was significantly superior to exercise alone in relieving pain (MD = -1.64; 95% CI [-2.24, -1.05], $p < 0.001$). The heterogeneity test (Q p-value < 0.001 , $I^2 = 90.50\%$) unraveled significant heterogeneity among the studies. Therefore, a random-effects model was utilized for the meta-analysis, and a subgroup analysis was executed to further investigate the sources of heterogeneity. Subgroup analyses were performed based on exercise therapy type (active training vs passive rehabilitation), treatment frequency, and treatment duration (Table 3).

In the subgroup analysis by exercise type, statistically significant differences were noted between groups ($p < 0.001$). SNK combined with exercise significantly reduced VAS pain scores (MD = -1.64), indicating rapid knee pain relief, with the best results observed in short-term, high-frequency interventions integrating both active and passive exercises. The

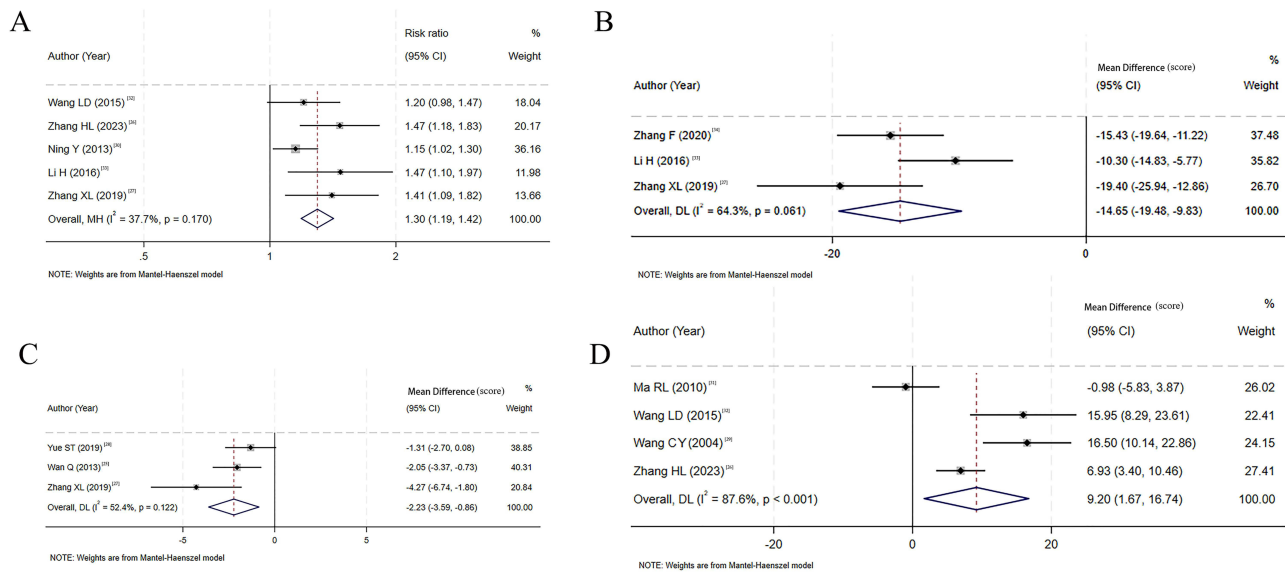


Figure 3 (A) forest map of efficiency; (B) forest map of Womac; (C) forest map of Lequesne; (D) forest map of Lysholm.

combination of SNK with active and passive exercise modalities (MD = -4.32, 95% CI: [-5.22, -3.42], $p < 0.001$) was significantly more effective in relieving pain than the control group. This combination method was more effective than either active exercise (MD = -1.11 95% CI [-1.47, -0.75], $p = 0.012$) or passive rehabilitation alone (MD = -1.61, 95% CI [-2.16, -1.06], $p = 0.521$). Additionally, the combination of SNK and passive rehabilitation also outperformed passive rehabilitation alone in reducing pain (MD = -1.61, 95% CI [-2.16, -1.06], $p = 0.521$). Similarly, in comparison to active exercise alone, the combination of SNK and active exercise was more efficacious (MD = -1.11, 95% CI [-1.47, -0.75], $p = 0.012$).

In the subgroup analysis by treatment duration, significant statistical differences were noted between the different duration groups ($P = 0.033$), with longer treatment durations generally associated with a more significant improvement of VAS. Short-term treatments (less than eight weeks) significantly improved pain (MD = -2.25, 95% CI: [-3.39, -1.11], $p < 0.001$), while long-term treatments (over eight weeks) demonstrated a more stable effect (MD = -0.97, 95% CI: [-1.28, -0.65], $p = 0.091$).

In the subgroup analysis by treatment frequency, there was a statistically significant difference between groups ($P = 0.010$). Weekly treatments demonstrated better efficacy (MD = -1.82, 95% CI: [-2.54, -1.10], $p < 0.001$),

Table 3 Characteristics of VAS Subgroup Analysis

Intervention Characteristics	Total Number of Cases	Heterogeneity		Meta-Analysis Results	Heterogeneity Between Groups
		I^2 (%)	P value	MD (cm) (95%CI)	
Treatment methods					p<0.001
Active exercise + passive rehab	57	0%	$P < 0.001$	-4.32 [-5.22, -3.42]	
Passive rehabilitation	215	0%	$P = 0.521$	-1.61 [-2.16, -1.06]	
Active exercise	285	72.80%	$P = 0.012$	-1.11 [-1.47, -0.75]	
Course of treatment					p=0.033
Less than 8 weeks	332	90.40%	$P < 0.001$	-2.25 [-3.39, -1.11]	
8 Weeks and Beyond	225	58.30%	$P = 0.091$	-0.97 [-1.28, -0.65]	
Treatment frequency					P=0.010
qw	408	90.40%	$P < 0.001$	-1.82 [-2.54, -1.10]	
biw	60	0%	$P < 0.001$	-0.80 [-1.09, -0.51]	

Abbreviations: qw, quaque week; biw, bid in the week.

while treatments every two weeks showed weaker effects (MD = -0.80, 95% CI: [-1.09, -0.51], p < 0.001). The GRADE assessment of the VAS score indicates high-quality evidence (⊕⊕⊕⊕), suggesting that the estimated pain relief effect is clinically reliable.

Severity of KOA

Three studies reported the WOMAC index (measured in points).^{27,33,34} Heterogeneity testing showed moderate heterogeneity (Q p-value = 0.061, I² = 64.30%). Consequently, a random-effects model was leveraged. The meta-analysis unraveled that SNK combined with exercise was significantly superior to exercise alone in improving the WOMAC index (MD = -14.65; 95% CI [-19.48, -9.83], p = 0.061), suggesting that SNK combined with exercise had an advantage in improving the WOMAC score (Figure 3C). The evidence quality for this outcome indicator is high (⊕⊕⊕⊕), supporting the stability of the functional improvement effect. Three studies reported the Lequesne index (measured in points) for knee function.^{25,27,28} Heterogeneity testing showed moderate heterogeneity (Q p-value = 0.122, I² = 52.40%). Accordingly, a random-effects model was applied. The meta-analysis results revealed that SNK plus exercise was notably more effective than exercise alone in improving the Lequesne score (MD = -2.23, 95% CI: [-3.59, -0.86], p = 0.122), indicating that SNK combined with exercise had an advantage in improving the Lequesne score (Figure 3D). The GRADE assessment indicates high-quality evidence (⊕⊕⊕⊕), demonstrating that the improvement in joint function scores is clinically significant.

Knee Function Indicators

Four studies reported the Lysholm score (measured in points).^{26,29,31,32} Heterogeneity testing showed moderate heterogeneity (Q p-value = 0.240, I² = 87.60%), and, therefore, a random-effects model was leveraged. The meta-analysis results indicated that SNK combined with exercise was significantly superior to exercise alone in improving the Lysholm score (MD = 9.20, 95% CI: [1.67, 16.74], p = 0.240), suggesting that SNK combined with exercise had an advantage in improving the Lysholm score (Figure 4). According to the GRADE criteria, the Lysholm score is supported by high-quality evidence (⊕⊕⊕⊕), indicating a high level of confidence in the estimated effect of knee function improvement.

Sensitivity Analysis

To assess the robustness of the meta-analysis results, a sensitivity analysis of five core outcome measures was conducted using the “one-by-one exclusion” method (Figure 4 A–E). The findings demonstrated high stability across all pooled

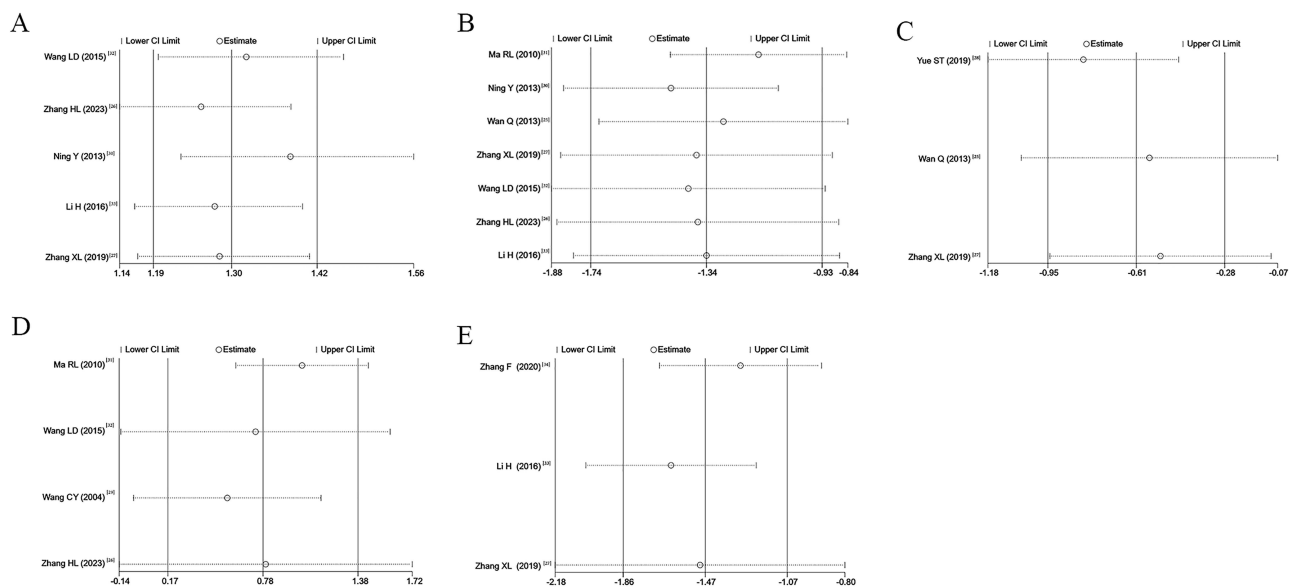


Figure 4 (A) sensitivity analysis of efficiency; (B) sensitivity analysis of VAS; (C) sensitivity analysis of Lequesne; (D) sensitivity analysis of Lysholm; (E) sensitivity analysis of Womac.

effect sizes. In the efficacy analysis (Figure 4A), removing any single study resulted in a relative risk (RR = 1.30) fluctuation range of 1.27–1.33, with the confidence interval CI[1.14,1.56] consistently within the effectiveness range and never crossing the null line (RR = 1).

Regarding VAS scores (Figure 4B), the combined mean difference ranged from MD = -1.64 (95% CI: -2.24 to -1.05) to -1.60 (95% CI: -2.20 to -1.00) following the exclusion of the Wang LD (2015) study confirming the statistical significance of pain relief was not affected by individual studies. Regarding functional outcomes, the pooled effect sizes of the Lequesne score (Figure 4C) and Lysholm score (Figure 4D) showed only minor fluctuations (0.14–0.78 points) after excluding studies such as Zhang XL (2019). Similarly, WOMAC scores (Figure 4E) remained stable at -14.65 (95% CI[-19.48,-9.83]) even after removing Zhang HL (2023). Baujat plot analysis indicated that all studies contributed less than 15% to overall heterogeneity, with standardized residuals consistently below 2.0, suggesting no significant outliers. Collectively, these sensitivity analyses confirm the consistent efficacy of SNK combined with exercise therapy across various clinical settings and patient subgroups, providing strong methodological support for its clinical translation.

Publication Bias Analysis

Although the sensitivity analysis demonstrated the robustness of the results, potential publication bias still needs to be considered. Since the number of studies for each outcome indicator is fewer than ten, this study did not conduct a publication bias assessment.²⁴

Quality and Certainty of the Evidence

All outcome indicators received high-level evidence support from the GRADE system, indicating that the efficacy of acupuncture knife therapy combined with exercise therapy in treating knee osteoarthritis has been well-validated (Supplementary Appendix 3). This rating was grounded in the substantial effect sizes observed for each outcome and the consistency of findings across studies, with no downgrading factors such as bias, inconsistency, or imprecision identified. All treatment effects surpassed the Minimal Clinically Important Difference (MCID), reinforcing the high quality of evidence. Nonetheless, recognizing potential limitations related to randomization bias, small sample sizes, and the limited number of included studies, we performed sensitivity analyses to verify the robustness of the results. Despite the small sample sizes, pooled effect estimates showed no significant variability. Additionally, publication bias was evaluated, and no substantial evidence of bias was detected. Therefore, the high certainty designation remains well-supported by the magnitude and consistency of the treatment effects. This strong evidence offers a solid scientific foundation for the clinical promotion and broader application of acupuncture knife therapy combined with exercise therapy, further enhancing its prospects in treating knee osteoarthritis patients.

Discussion

This is the first study to ascertain the efficacy of SNK combined with exercise in patients with KOA using systematic review and meta-analysis methods. This analysis included ten independent studies involving 788 patients to systematically ascertain the effectiveness of SNK plus exercise in treating KOA. The results indicated that this combined therapy significantly outperformed exercise alone in relieving pain and enhancing joint function.

Improving Clinical Efficacy

The therapeutic effect of SNK combined with exercise is 30% higher than exercise alone, indicating that this combined approach can significantly improve the treatment success rate in clinical practice. It is particularly suitable for moderate to severe patients requiring rapid symptom relief. Our findings are consistent with Ning et al³⁰ that SNK combination therapy is more effective in treating knee osteoarthritis (KOA), reducing recovery time in patients. This effect arises from the SNK, which alleviates soft tissue adhesions around the knee joint, restores elasticity and flexibility, and reduces the restriction of joint movement caused by soft tissue, thereby providing an ideal rehabilitation foundation for subsequent exercise therapy.³⁵ Additionally, SNK reduces local inflammatory responses and decreases the release of inflammatory mediators such as IL-1 and TNF- α , improving the local microenvironment and promoting joint function recovery.³⁶ Exercise therapy, in turn, enhances the strength and stability of knee joint muscles, further consolidating the therapeutic

effect. Exercise systematically enhances the strength of the muscles surrounding the knee joint, improving joint stability.³⁷ This process helps distribute the joint load, reduce cartilage wear, improve the range of motion, and thereby enhance overall therapeutic outcomes.³⁸

Simultaneously, SNK facilitates the release of opioid peptides near the nerve via localized, minimally invasive incisions, alleviating pain by activating opioid receptors.³⁹ Additionally, SNK may diminish pain perception by modulating peripheral nerve conduction and reducing the transmission of nociceptive signals.⁴⁰ Its analgesic effect is further amplified by descending central inhibition, wherein the central nervous system modulates spinal cord pain signaling to enhance relief.³⁹

The synergistic effect of SNK and exercise not only significantly improves treatment efficacy in the short term but also achieves sustained therapeutic effects through long-term muscle strengthening and inflammation management.⁴ This finding strongly supports the combined use of SNK and exercise in clinical practice, especially for patients who do not respond well to exercise alone.

Alleviating Knee Pain

SNK combined with exercise demonstrated significant advantages in relieving knee pain over exercise alone, this suggests that the SNK combination therapy can significantly alleviate patients' pain symptoms, making it the preferred choice for those whose primary symptom is severe pain. The mechanism behind this effect is likely related to the ability of SNK to rapidly relieve nerve compression around the knee joint, reduce neurogenic hyperalgesia, and provide pain relief.⁴¹ It has been shown that SNK relieves pressure on the nerves around the knee joint, reduces excessive nerve stimulation, and inhibits pain transmission.³⁸ It also reduces the inflammatory responses in peripheral nerves, quickly alleviating pain.⁴² This local neural modulation not only improves the patient's mobility but also facilitates the execution of exercise therapy. The significant reduction in pain provides a better foundation for the patient's rehabilitation, further enhancing the overall treatment outcomes.⁴³

Exercise therapy promotes the secretion of synovial fluid, increasing joint lubrication, and can relieve pain in the long term.¹⁷ Additionally, strengthening exercises for the quadriceps and hamstrings further improve the biomechanical state of the knee joint, effectively distributing stress, reducing the pressure on articular cartilage, and achieving sustained effects for relieving pain.⁴ Research has shown that the biomechanical state of the knee joint in KOA patients improves with the strengthening of muscle strength, thereby further reducing joint inflammation.⁴⁴

Further subgroup analysis revealed that SNK combined with active training was more effective than passive rehabilitation. This may be because, after SNK relieves soft tissue adhesions and reduces nerve compression, active training better activates the surrounding knee muscles, enhancing joint stability and weight-bearing capacity, resulting in longer-lasting pain relief. In contrast, passive rehabilitation, which relies on external forces, has limited efficacy in promoting the recovery of muscles.

Moreover, treatment frequency also affected the results. The bi-weekly treatment exhibited better outcomes than the weekly treatment. This suggests that more frequent treatments are more effective in alleviating pain. High-frequency SNK combined with exercise therapy can more effectively improve local soft tissue tension and blood circulation, while simultaneously enhancing muscle strength and promoting joint function recovery. At the same time, short-term treatment (less than 8 weeks) was most effective for alleviating pain, making it suitable for patients in the acute flare-up phase to rapidly relieve symptoms. Long-term treatment (more than 8 weeks), on the other hand, helps consolidate the therapeutic effect. Clinicians can use an intensive treatment plan to quickly alleviate pain symptoms in the early and acute phases of KOA, while for chronic or recurrent patients, long-term treatment helps consolidate and maintain the effects for pain relief.⁴⁵

Reducing Severity of KOA

SNK combined with exercise therapy significantly improved symptoms of KOA. Our findings demonstrate that SNK combined with exercise therapy significantly reduces the severity of KOA compared with exercise alone. This combination therapy relieves pain and joint stiffness, and improves daily activity ability in patients with KOA, offering substantial benefits, particularly for patients in the middle to late stages of the condition. These results are consistent

with previous studies, such as Kamal et al⁷ and Zhang et al,²⁶ who have reported that combining SNK-based interventions with rehabilitation exercises significantly relieves symptoms in KOA patients. The observed reduction in disease severity is biologically plausible because the pathogenesis of KOA is highly dependent on chronic inflammatory responses within the joint, mediated by inflammatory factors such as interleukin-1 (IL-1) and tumor necrosis factor (TNF- α),⁴⁶ which are major contributors to pain. SNK targets damaged tissue through precise incisions, leading to a reduction in inflammatory factor release and downregulation of pro-inflammatory mediators, which helps mitigate neurogenic hypersensitivity within the nervous system. Concurrently, it enhances analgesia through multiple biological mechanisms, including stimulation of opioid peptide release, modulation of peripheral nerve conduction, and activation of descending central inhibitory pathways, collectively contributing to its therapeutic pain-relieving effect. Exercise therapy improves systemic blood circulation, promotes the metabolism and clearance of inflammatory mediators, further alleviates both intra- and extra-articular inflammation, and delays the progression of joint degeneration.⁴⁷ These results further support the role of SNK in alleviating pathological changes in soft tissue. When combined with exercise therapy to strengthen muscle strength and range of motion, it fundamentally improves functional limitations in KOA patients. Additionally, the significant improvement in the Lequesne index further corroborates the effectiveness of SNK combined with exercise therapy in reducing the severity of KOA, particularly in moderate to severe cases. This reflects its ability to improve basic functional activities such as walking and standing, potentially reducing the risk of falls and enhancing patients' ability to live independently.

Improving Knee Joint Function

SNK combined with exercise therapy significantly improved knee joint function. Our findings demonstrate that SNK combined with exercise therapy significantly improves knee joint function. The combined treatment markedly improved knee stability, range of motion, and functional performance, leading to improvements in daily activities and quality of life. These findings align with previous studies. For instance, Fransen et al³⁸ have found that exercise therapies, particularly those targeting joint function, provide lasting relief for KOA. Bennell et al³⁷ have reported that strengthening exercises, when combined with soft tissue therapies like SNK, results in significant functional improvements. These functional gains are clinically important because the knee joint, as one of the body's primary weight-bearing joints, relies on intact cartilage tissue, a stable ligament system, and strong muscle groups for its function.⁴⁸ In KOA patients, degenerative changes in the articular cartilage lead to reduced knee joint function, followed by activity limitations and muscle weakness.³⁷ SNK works by releasing soft tissue adhesions, restoring elasticity and flexibility, thus improving joint range of motion. By reducing local inflammation, improving soft tissue tension, and alleviating knee joint pressure, it promotes the repair of the knee joint's anatomical structure.⁴³ Exercise therapy strengthens the muscles surrounding the knee joint, distributes joint load, and reduces further cartilage damage. Overall, these results indicate that SNK combined with exercise not only alleviates symptoms but also significantly enhances patients' daily functional performance, thereby reducing the risk of disability.⁴⁹

In summary, SNK combined with exercise can not only relieve pain but also enhance function through a "release-rebuild" synergistic mechanism. SNK provides rapid pain relief through multiple mechanisms, including the release of soft tissue adhesions, reduction of local inflammation, alleviation of nerve compression, and enhancement of endogenous analgesic pathways such as opioid peptide release, peripheral nerve modulation, and descending central inhibition. Exercise therapy strengthens the muscles surrounding the knee joint, improving joint stability and biomechanics, further consolidating the therapeutic effect. Subgroup analysis further clarified how to optimize treatment plans, such as prioritizing active training, increasing treatment frequency, and using short-term high-density therapy in the early stages to rapidly alleviate symptoms, while extending treatment duration based on the patient's condition to maintain long-term efficacy.

SNK combined with exercise, as a safe, effective, and economical non-pharmacological treatment option, provides an effective alternative for KOA patients who cannot tolerate the side effects of medications or the risks of surgery. It is especially suitable for patients with early to moderate-stage KOA and those in the acute flare-up phase who require rapid pain relief. Compared to surgery and long-term medication therapy, this approach works rapidly, is easy to administer,

and can be used in various medical settings. In future clinical applications, standardizing SNK plus exercise protocols and developing individualized treatment plans are expected to maximize the therapeutic effects for KOA.

Narrative Interpretation of Exercise Types in KOA Treatment

This subsection provides a narrative interpretation of different exercise therapies used in combination with small needle-knife (SNK) treatment for knee osteoarthritis (KOA), drawing on subgroup meta-analyses and the characteristics of the exercise interventions in the included trials. Most studies utilized strength training to enhance muscle stability around the knee, thereby improving joint stability and alleviating pain.⁵⁰ In contrast, fewer studies employed endurance or aerobic training, which primarily improved overall joint function and stamina but had a weaker effect on pain relief.

Strength training (anaerobic exercise) appeared to be particularly effective in enhancing joint stability and reducing pain. Conversely, endurance training (aerobic exercise) mainly improved joint mobility and physical fitness, with less direct impact on pain reduction. Although endurance training helped enhance joint flexibility, it seemed less effective than strength training in pain relief and functional recovery.

When combined with SNK therapy, active exercises like strength training tended to yield better outcomes, especially in short-term pain relief and joint function improvement. Passive rehabilitation combined with SNK showed some benefits but appeared less effective in pain and function improvement. For patients with severe pain, integrating strength training with SNK may be more effective, while endurance training with SNK could be preferable for those with milder symptoms.

Implications for Practice

This meta-analysis provides evidence-informed support for the use of small needle-knife (SNK) combined with exercise therapy as a non-pharmacological option in the management of knee osteoarthritis (KOA).⁵¹ Overall, the combined therapy increased the clinical efficacy rate by approximately 30% compared with exercise alone and led to consistent improvements in pain, function and global severity indices. These findings suggest that SNK plus exercise may be particularly relevant for patients with moderate-to-severe symptoms or an insufficient response to exercise-based rehabilitation alone.

From a clinical perspective, a stratified approach according to pain intensity, disease stage and functional goals may be useful. In patients with more severe pain or acute symptom flares, more intensive short-term courses of SNK combined with active rehabilitation exercises appear to facilitate rapid pain relief and functional gains. In contrast, in patients with milder or recovery-phase symptoms, less frequent SNK sessions alongside ongoing active exercise may help maintain benefits while reducing treatment burden. Across the included studies, passive rehabilitation alone showed limited effectiveness and seemed to be more beneficial when combined with SNK or active training.

The observed improvements in WOMAC, Lequesne and Lysholm scores indicate that SNK plus exercise may help address both pain and activity-related limitations, supporting its use as an adjunct to conventional rehabilitation programs in early and more advanced KOA. At the same time, clinicians should recognize that patients with marked structural damage (eg advanced meniscal tears or severe subchondral changes) may still require surgical or other interventional procedures, with SNK and exercise serving as complementary rather than stand-alone treatments. In practice, treatment decisions should be guided by careful clinical and imaging assessment, local expertise and patient preferences, rather than by a rigid, one-size-fits-all protocol.

Limitations

This study strongly supports the significant efficacy of small needle-knife (SNK) therapy combined with exercise therapy in treating knee osteoarthritis (KOA), despite some inevitable heterogeneity. This variation likely stems from clinical and patient differences, such as practitioner expertise, treatment complexity, and intervention duration. Subgroup analyses clarified some heterogeneity sources, while multiple sensitivity tests confirmed the stability of effect sizes. However, longer-term follow-up is essential to enhance future research. Patient-specific factors—such as disease duration, age, and joint degeneration severity—can influence outcomes, particularly in advanced cases. Moreover, inconsistent exercise therapy dosages, including frequency and duration, may impact treatment consistency. Thus, future studies should

prioritize standardizing and optimizing exercise regimens, enabling more precise evaluations and delivering clinically relevant dosage guidelines.

The effectiveness of small needle-knife (SNK) therapy is closely tied to practitioner experience, as technical variations can significantly influence outcomes. SNK demands precise anatomical knowledge and careful dosage control, underscoring the need for regional training programs based on standardized clinical guidelines to enhance practitioner proficiency. Despite its proven efficacy in treating knee osteoarthritis (KOA), SNK's invasive nature carries inherent risks, including subcutaneous hematomas, infections, and neurovascular injuries. To minimize these complications, preoperative coagulation assessments, strict aseptic protocols, and continuous monitoring of vital signs are essential. Postoperative care should emphasize infection prevention and the use of compression bandages. SNK is contraindicated in patients with coagulation disorders, severe systemic diseases, or psychiatric conditions.⁵²

All clinical trials included in this study were conducted in China, which may limit the generalizability of the findings to other populations. As a traditional Chinese medicine technique, the adoption of small needle-knife (SNK) therapy in other regions depends on local medical practices and cultural acceptance. Nonetheless, the core therapeutic mechanisms of SNK combined with exercises such as soft tissue release and inflammation modulation—are broadly applicable and hold potential for wider use. To confirm global efficacy and support broader clinical integration, future studies should prioritize international multicenter trials and the development of standardized treatment protocols.

Looking ahead, future research should address these limitations by clarifying the long-term effectiveness, safety profile, and optimal SNK-plus-exercise protocols in diverse KOA populations, thereby better defining the role of this combined approach in evidence-based KOA management.

Conclusion

This meta-analysis provides a comprehensive evaluation of the clinical efficacy of combining small needle-knife (SNK) therapy with exercise for treating knee osteoarthritis (KOA). SNK–exercise therapy showed significant advantages in pain reduction, joint function, and quality of life compared with monotherapy, supporting its broader consideration in clinical practice. Future randomized controlled trials with larger and more diverse cohorts, standardized SNK and exercise protocols, and longer follow-up are needed to confirm and extend these findings. Such studies will also help clarify the mechanisms underlying the combined intervention and guide the refinement of mechanism-based integrative treatment strategies for KOA. Establishing standardized SNK–exercise protocols across centers, while allowing appropriate individualized adaptations, may further optimize therapeutic outcomes.

Abbreviations

KOA, Knee Osteoarthritis; SNK, Small Needle-Knife; RCTs, Randomized Controlled Trials; ROB2, Risk of Bias 2 (Tool); VAS, Visual Analog Scale; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index; MD, Mean Difference; RR, Relative Risk; CI, Confidence Interval; OARSI, Osteoarthritis Research Society International; NSAIDs, Nonsteroidal Anti-Inflammatory Drugs; TCM, Traditional Chinese Medicine; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; PROSPERO, International Prospective Register of Systematic Reviews; CNKI, China National Knowledge Infrastructure; CBM, China Biomedical Literature; PICOS, Participants, Interventions, Comparators, Outcomes, Study Design; GRADE, Grading of Recommendations Assessment, Development and Evaluation; MCID, Minimal Clinically Important Difference.

Data Sharing Statement

Data sharing is not applicable to this article as no datasets were generated or analysed during the current study.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare that they have no competing interests in this work.

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