

Acupuncture in Knee Osteoarthritis: A Narrative Review of Clinical Efficacy and Neuroimmune-Endocrine Mechanisms

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Purpose: Knee osteoarthritis (KOA) is a leading cause of global pain and disability and warrants complementary therapy. This review provides evidence of the clinical efficacy of acupuncture and the multisystem regulatory mechanisms of KOA.

Methods: We analyzed clinical trials and mechanistic studies of acupuncture in the treatment of KOA.

Results: Acupuncture-particularly electroacupuncture (EA) significantly reduced pain (VAS/WOMAC) compared with sham acupuncture and conventional care ($P < 0.05$). Clinical trials demonstrate that combining acupuncture with exercise significantly enhances functional outcomes. Mechanistically, acupuncture modulates neuroendocrine pathways through three key actions: (1) suppressing pro-inflammatory cytokines (eg, TNF- α , IL-1 β); (2) activating the Melatonin/cAMP/PKA/CREB signaling cascade; (3) altering functional connectivity in central pain-processing regions. Controversies persist regarding the mechanisms, optimal techniques, and outcome standardization.

Conclusion: Acupuncture is an effective complementary therapy for KOA. Future research should prioritize long-term efficacy, personalized protocols, technology integration, and multidisciplinary strategies.

Keywords: acupuncture, knee osteoarthritis, pain management, neuroimmune modulation, electroacupuncture, mechanisms

Introduction

Knee osteoarthritis (KOA), a leading cause of global pain and disability,¹ poses a major public health challenge because of its high prevalence and complex pathogenesis. Predominant risk factors include advancing age, female sex, and obesity;²⁻⁴ obesity contributes to joint degeneration through both mechanical loading and metabolic-inflammatory pathways.⁴ Rising global aging and obesity rates heighten the KOA disease burden,¹ manifested by: 1) Substantial socioeconomic costs, primarily due to productivity losses (accounting for 83% of mean monthly per-patient knee-related costs in working individuals vs 17% for direct medical costs).⁵ 2) Impaired health-related quality of life (HRQoL), especially in younger patients who report significantly lower HRQoL, frequent work limitations, and elevated depression risk, with depression severity inversely correlating with radiographic severity.⁶ Despite established treatment frameworks like the OARSI guidelines,⁷ significant management gaps persist. The evaluation of RCTs on intra-articular interventions revealed inconsistent adherence to guideline recommendations, particularly concerning biochemical biomarkers and structural outcome collection,⁸ limiting comprehensive efficacy assessment. Furthermore, guideline therapies show variable efficacy across clinical subtypes, with interventions such as acupuncture demonstrating equivocal results in specific phenotypes, posing challenges for personalized treatment decisions.⁷ This underscores the need for complementary approaches. Acupuncture, a core component of traditional Chinese medicine, has gained attention in KOA management because of its documented efficacy and favorable safety profile. Acupuncture modulates physiological functions to



alleviate pain and inflammation by stimulating neural signalling at specific acupoints. This review synthesizes the current evidence on foundational theories, clinical efficacy, mechanisms of action, technological advances, and future directions of acupuncture for KOA with the aim of providing clinicians with evidence-based guidance.

Despite increasing evidence, significant gaps remain in acupuncture research for KOA. Inconsistent outcome measures across trials hinder comparisons, optimal acupuncture parameters are undefined, mechanistic evidence is mostly from animal studies, and long-term efficacy data are scarce and conflicting. This review aims to address these issues by consolidating clinical evidence, integrating mechanistic insights, and suggesting standardized frameworks.

Literature Search Strategy

A systematic search was conducted across PubMed, Web of Science, Cochrane Library, EMBASE, CNKI, and Wanfang Data from inception to December 2024. Key search terms included: (“knee osteoarthritis” OR “KOA”) AND (“acupuncture” OR “electroacupuncture”) combined with (“mechanism” OR “neuroimmune” OR “clinical trial”). Only peer-reviewed articles in English/Chinese were included. Exclusion criteria: 1) Non-original research (reviews, editorials); 2) Studies without control groups; 3) Incomplete outcome data. Study selection followed PRISMA guidelines, with a flowchart provided in [Figure 1](#).

Foundations of Acupuncture for Knee Osteoarthritis

Theoretical Basis of Acupuncture for KOA

Traditional Chinese Medicine theory posits that acupuncture treats KOA by stimulating specific acupoints to regulate the flow of qi (vital energy, a core concept in traditional Chinese medicine describing functional vitality governing physiological processes) and blood along meridians, achieving therapeutic effects.⁹ From a modern medical perspective, acupuncture exerts its actions by regulating neural, immune, and endocrine systems. Experimental evidence from KOA rabbit models reveals that acupuncture activates the MLT/cAMP/PKA/CREB signaling pathway, reduces inflammatory cytokine expression, mitigates articular cartilage degradation, and alleviates knee pain—providing molecular-level validation for acupuncture’s efficacy. Furthermore, an expert consensus has standardized clinical protocols for acupuncture in KOA management, establishing 37 evidence-based recommendations across six domains: therapeutic principles,

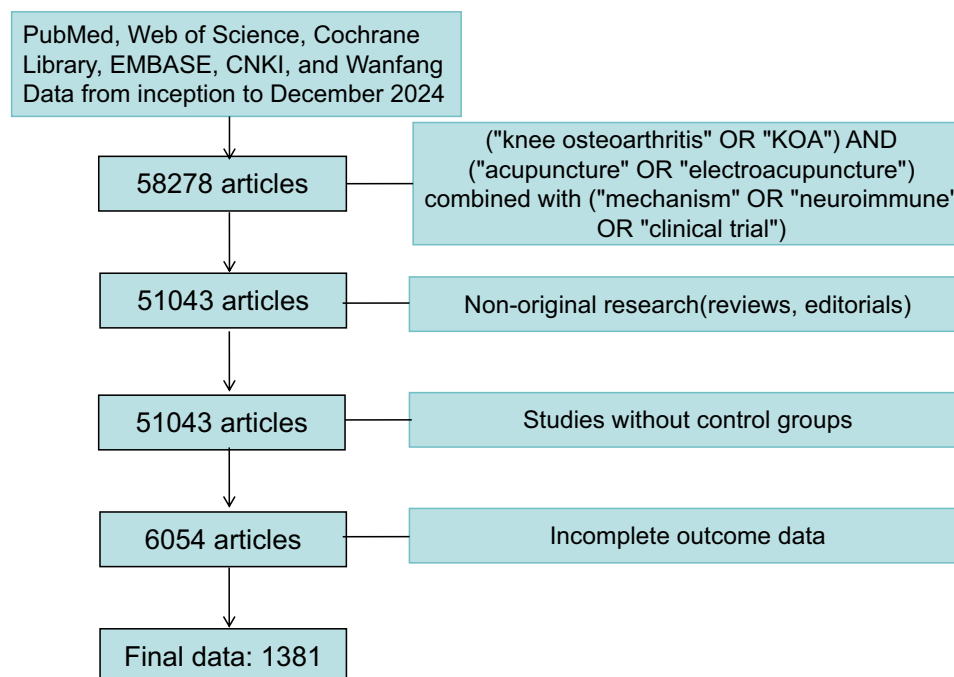


Figure 1 Flowchart of Retrieval Strategy.

acupuncture techniques, dosing regimens, outcome measures, and adverse event monitoring.⁹ This consensus strengthens the theoretical framework and operational standards for acupuncture in KOA therapy. The clinical validation was based on a three-arm, randomized, placebo-controlled trial involving 120 patients with KOA. The participants were allocated to: (1) True acupuncture combined with etoricoxib; (2) Sham acupuncture combined with etoricoxib; (3) Etoricoxib monotherapy. The acupuncture-etoricoxib group demonstrated statistically significant improvements in all primary and secondary outcomes (except SF-12 mental component scores) compared to both control groups ($p < 0.05$), confirming the therapeutic value of acupuncture when combined with pharmacotherapy.¹⁰

Alignment of Acupuncture's System-Modulating Properties with Complex Adaptive System Theory

Acupuncture aligns with the complex adaptive system (CAS) theory owing to its inherent system-modulating properties. CAS theory emphasizes dynamic interactions and adaptive behaviors among system components, with the human body representing a quintessential CAS. Acupuncture modulates multisystem functions through acupoint stimulation, activating sensory nerve fibers that integrate signals within spinal cord-brain networks to regulate the autonomic nervous system (ANS), thereby maintaining homeostatic equilibrium.¹¹ Notably, stimulation of specific acupoints alleviates ANS-dysfunction-related symptoms (migraines, depression, insomnia) by rebalancing sympathetic-parasympathetic activity, enhancing physiological function.¹¹ Furthermore, acupuncture demonstrates holistic and dynamic regulatory effects. Evidence indicates that it modulates the central orexinergic system to influence cardiovascular function, attenuating hypertension and psychogenic stress-induced cardiovascular responses, thereby reducing risks of cardiovascular mortality.¹² This extralocal action aligns with CAS principles of interconnected system components. At the cerebral level, acupuncture remodels cognitive processing networks by modulating prefrontal cortex activity and altering information routing dynamics, thereby exhibiting stable attractor cycle dynamics that mechanistically explain its systemic effects.¹³ This neural adaptability substantiates the broad-spectrum regulatory capacity of acupuncture in the human CAS framework.^{11–13}

Pathological Mechanisms of KOA and Acupuncture Intervention

The pathological mechanisms of knee osteoarthritis (KOA) are complex and involve cartilage degradation, synovitis, and osteophyte formation. Research has indicated that acupuncture can intervene in KOA via multiple pathways. A study utilizing a rabbit KOA model established via the traditional Hulth method demonstrated that, compared to the OA group, the acupuncture treatment group showed significant improvements in knee pain and overall function, as assessed by Lequesne MG scores and hot plate tests, and ameliorated cartilage degeneration. This study further found that acupuncture significantly reduced the expression of the inflammatory factor matrix metalloproteinase-3 (MMP-3) in the knee joint fluid and significantly elevated the serum levels of melatonin (MLT), arylalkylamine N-acetyltransferase (AANAT), melatonin receptor 1 (MT1), and 2 (MT2), as well as the cartilage levels of cyclic adenosine monophosphate (cAMP), protein kinase A (PKA), and cAMP response element-binding protein (CREB). These findings suggest acupuncture may alleviate knee pain by modulating sympathetic nerve excitability, activating the MLT/cAMP/PKA/CREB signaling pathway, reducing inflammatory factor expression, and slowing articular cartilage degradation.¹⁴ In another study involving 15 KOA patients and 15 healthy controls, resting-state functional magnetic resonance imaging (fMRI) scans before and after acupuncture at the EX-LE5 (Waixiyan, an extra-meridian acupoint located lateral to the patellar ligament) acupoint revealed enhanced functional connectivity between the dorsal raphe nucleus and the right putamen post-acupuncture, correlating with chronic pain intensity. This suggests acupuncture modulates pain perception by enhancing functional connectivity between the dorsal raphe and striatum.² Furthermore, a study grouping 108 KOA patients found that the patient group receiving acupuncture at acupoints including EX-LE4 (Neixiyan, medial to patellar ligament), EX-LE5 (Waixiyan), GB34 (Yanglingquan, at fibular head anterior depression), ST36 (Zusanli, 3 cun below lateral knee eye), combined with standard treatment, exhibited a greater reduction in inflammatory markers compared to the control group. Significantly elevated levels of cytokines such as TGF- β , IGF-1, and FGF-2 were observed along with significant downregulation of p38 mitogen-activated protein kinase (p38 MAPK) messenger RNA (mRNA) expression.

This indicates that acupuncture combined with standard treatment effectively promotes symptom relief and knee joint functional improvement while suppressing the expression of the p38 MAPK signaling pathway.¹⁵

Clinical Evidence for Acupuncture in Knee Osteoarthritis Management

Clinical Evidence from Acupuncture Trials in KOA Pain Management

Multiple clinical trials have supported acupuncture as an effective intervention for knee (KOA). A multicenter, single-blind RCT found that various acupuncture techniques (MA, EA, WA, MM) provided significantly greater VAS pain reduction than SA (MD: -0.61, 95% CI: -1.09 to -0.13; $P = 0.01$).¹⁶ Notably, EA demonstrated superior pain reduction compared to Celebrex[®] (MD: -1.14, 95% CI: -1.72 to -0.55; $P < 0.01$).¹⁶ Notably, EA outperformed Celebrex[®] in reducing pain intensity (mean difference: -1.14; 95% CI: -1.72 to -0.55; $P < 0.01$).¹⁶ A three-arm placebo-controlled RCT ($n = 120$) further revealed that acupuncture combined with etoricoxib significantly improved primary outcomes (WOMAC total and subscale scores) and most secondary endpoints (excluding the mental component of SF-12) over both sham acupuncture plus etoricoxib and etoricoxib monotherapy at 8 weeks.⁹ Additionally, a feasibility RCT involving 12 postoperative KOA patients showed that combined catgut-embedding acupuncture (TEA) and electroacupuncture (EA) therapy significantly reduced VAS scores vs controls at Weeks 4 (-24.5; $P = 0.0106$), 6 (-19.667; $P = 0.0228$), and 8 (-28.667; $P = 0.0036$), highlighting its potential in managing post-surgical KOA pain.¹⁷

Functional Improvement Efficacy of Acupuncture in KOA

Robust evidence supports the use of acupuncture to improve the functional outcomes of patients with KOA. A meta-analysis (11 studies, $n = 774$) showed that combining acupuncture with exercise yielded superior outcomes to acupuncture alone, including: higher overall response rate (RR = 1.13, 95% CI: 1.05–1.22; $I^2 = 0\%$), greater VAS pain reduction (MD = -0.74, 95% CI: -1.04 to -0.43; $I^2 = 68\%$; $P < 0.05$), improved WOMAC function (MD = -6.97, 95% CI: -10.74 to -3.19; $I^2 = 76\%$; $P < 0.05$), and increased ROM (MD = 6.25, 95% CI: 2.37–10.04; $I^2 = 0\%$).¹⁸ An RCT randomizing 120 KOA patients further validated these findings: the acupuncture combined with exercise rehabilitation (AE) group achieved significantly higher response rates at 4 weeks (83.3%[32/39] vs 58.3%[21/36] in exercise-only group, $P < 0.05$), with benefits persisting ≥ 8 weeks post-treatment.¹⁹ Additionally, in a controlled trial of 81 patients, warm acupuncture combined with meloxicam and comprehensive nursing demonstrated greater improvements in pain reduction, joint mobility, stability, walking ability, and stair-climbing capacity versus control and Chinese medicine groups, yielding a 96.30% total efficacy rate (vs 77.78% and 81.48%, respectively; $P < 0.05$).²⁰

Long-Term Efficacy of Acupuncture in KOA Management

Studies of the long-term effects of acupuncture in KOA have demonstrated heterogeneous outcomes. A systematic review and meta-analysis of 10 RCTs ($n = 3,221$) revealed that, compared to sham acupuncture, acupuncture may improve function and global pain for ≤ 4.5 months post-treatment. Compared to routine care, it provided clinically significant durable pain relief (> 5 months) and functional improvement, with similar efficacy observed over 6 months versus diclofenac.²¹ However, contrasted with no intervention, results diverged: a large-scale trial reported sustained pain/function improvements lasting ≤ 3 months, whereas another trial noted significant effects only at the immediate endpoint with no observable benefit at 9 months.²¹ Notably, acupuncture as adjunctive therapy to exercise (EPT) showed no superiority over sham-needle adjunct or EPT monotherapy during 11.25 months of follow-up.²¹ In an RCT randomizing 108 KOA patients, the deqi (characteristic needling sensation perceived by patients, often described as soreness, numbness, or distension, indicating effective stimulus delivery) sensation group showed better WOMAC scores after 4-week treatment and 20-week follow-up compared to non-deqi group (receiving acupuncture without eliciting deqi sensation) and waitlist groups, though the causal relationship between deqi and sustained efficacy remains undetermined.²² A comparative study ($n = 50$) demonstrated significantly lower WOMAC subscale scores for pain, stiffness, and physical function in acupuncture versus physical therapy at 4 weeks ($P < 0.05$), alongside reduced T2 values in medial tibiofemoral anterior (MTa) and lateral tibiofemoral anterior (LTa) subregions ($P < 0.05$), suggesting potential cartilage repair effects; long-term outcomes warrant further investigation.²³

Technological Advances in Acupuncture for KOA

Innovative Acupuncture Techniques

A pilot RCT ($n = 12$) in postoperative KOA patients demonstrated that combining thread-embedding acupuncture (TEA) with electroacupuncture (EA) significantly reduced VAS scores at weeks 4, 6, and 8 compared to controls, alongside improved K-WOMAC scores.¹⁷ The intervention group showed superior improvements in VAS scores at weeks 4 (-24.5 ; $P = 0.011$), 6 (-19.7 ; $P = 0.023$), and 8 (-28.7 ; $P = 0.004$) versus controls, alongside enhanced K-WOMAC total scores ($P < 0.05$), indicating synergistic pain relief and functional recovery.¹⁷ Exploratory studies on sensitized acupoints (hi-shi xue in TCM theory) revealed comparable efficacy to non-sensitized points in a randomized single-blind trial ($n = 36$), with the sensitized-acupoint group achieving similar or lower WOMAC total/pain/stiffness/function scores after 12 sessions over 4 weeks—though larger confirmatory studies are warranted due to limited sample size.²⁴ Network meta-analyses further quantified technique-specific outcomes: Silver needle acupuncture ranked highest for total effectiveness (SUCRA = 0.99) > Fu's acupuncture > acupotomy, while also leading in VAS improvement (SUCRA = 0.97) > conventional acupuncture > acupotomy, providing evidence-based hierarchies for clinical technique selection.²⁵

Application of Modern Acupuncture Devices

Advanced acupuncture devices are promising in KOA management. Nanodrug delivery acupuncture (nd-Acu), which involves the coating of traditional needles with payload molecules, enhances targeted drug delivery. Preclinical studies confirm lidocaine-loaded nd-Acu effectively attenuates pain, reduces inflammation, and delays KOA progression in mice through histopathological and biochemical markers, potentially via HMGB1/TLR4 signaling pathway modulation, offering a translatable therapeutic platform.²⁶ Electroacupuncture (EA) remains clinically validated: A systematic review of 20 RCTs ($n = 1,616$) demonstrated significantly higher response rates in EA groups versus controls ($P < 0.01$) and clinically important reductions in WOMAC stiffness scores ($P < 0.0001$).²⁷ Head-to-head comparisons reveal both EA and manual acupuncture (MA) significantly decrease pro-inflammatory cytokines (TNF α , IL-1 β ; $P < 0.05$) and cartilage degradation biomarkers (MMP-3, MMP-13) while elevating anti-inflammatory IL-13 after 8-week interventions. Notably, EA showed superior TNF- α reduction than MA ($P = 0.046$), indicating enhanced immunomodulatory specificity.²⁸

Combination Therapies Integrating Acupuncture for KOA

Acupuncture-based combination regimens represent an emerging focus in KOA research. A network meta-analysis of 49 trials ($n = 4,458$) demonstrated superior clinical response rates with specific combinations: fu's acupuncture + massage ranked highest, followed by acupotomy + massage and silver needle + massage. These protocols also showed significant advantages in alleviating VAS pain scores, improving Lysholm knee scores, and reducing WOMAC total/stiffness/physical function sub-scores (all $P < 0.05$).²⁹ Furthermore, systematic review of 33 RCTs ($n = 3,954$) revealed acupuncture-herbal medicine combinations yielded significantly greater benefits than monotherapies (acupuncture, herbal medicine, or Western drugs alone), evidenced by superior overall response rates (OR = 5.41; 95% CI: 4.38–6.68; $P < 0.001$), greater VAS reduction (MD = -1.86 ; 95% CI: -2.44 to -1.29 ; $P < 0.00001$), lower WOMAC scores (MD = -13.05 ; 95% CI: -21.70 to -4.41 ; $P = 0.003$), and higher Lysholm scores (MD = 10.47; 95% CI: 5.21–15.72; $P < 0.001$), indicating synergistic enhancement of pain control, functional recovery, and quality of life.³⁰ Notably, an RCT of 32 patients showed acupuncture combined with transcutaneous electrical nerve stimulation (TENS) significantly outperformed controls in reducing pain intensity ($P = 0.039$) and improving knee function ($P = 0.008$), further validating multimodal integration strategies.³¹

Epidemiological Analysis of Acupuncture for KOA

Epidemiological Profile and Therapeutic Applicability of Acupuncture

From an epidemiological perspective, this evidence underscores its applicability as a non-pharmacological intervention for knee osteoarthritis (KOA). Systematic reviews and meta-analyses confirm its efficacy in improving pain and functional outcomes, supporting its integration into KOA management.²⁵ Network meta-analysis comparing seven acupuncture modalities (electroacupuncture [EA], traditional acupuncture [TA], warm needle [WN], Fu's acupuncture

[FA], fire needle [FN], acupotomy [AT], and silver needle [SN]) revealed significant efficacy hierarchies: for overall response rates, SN (SUCRA = 0.99) > FA (0.97) > AT (0.66) > FN (0.56) > WN (0.44) > TA (0.35) > EA (0.13); for VAS improvement, SN (0.97) > TA (0.67) > AT (0.64) > FA (0.51) > WN (0.44) > FN (0.14) > EA (0.09), indicating clinically actionable modality selection based on patient profiles.²⁵ Furthermore, acupuncture combined with adjuvant therapies (eg, herbal medicine, massage) synergistically augmented pain relief and functional recovery, expanding its therapeutic applicability in KOA management.

Heterogeneity in Acupuncture Efficacy Across Patient Populations

The efficacy of acupuncture for KOA exhibits significant heterogeneity across patient populations and is influenced by factors such as age, sex, and disease severity. Neuroimaging evidence from a longitudinal RCT (n = 30) revealed that verum acupuncture significantly outperformed sham acupuncture in improving the KOOS pain scores ($P < 0.05$). Crucially, verum acupuncture induced distinct neuroplastic changes: increased cortical thickness in the left posteromedial prefrontal cortex (pMPFC) and altered functional connectivity between pMPFC and key pain-processing regions (rostral anterior cingulate cortex [rACC], medial frontal pole [mFP], periaqueductal gray [PAG]). These findings suggest acupuncture modulates central pain pathways through functional network reorganization, though demographic influences on these neural mechanisms require further investigation.³² Technical specificity also contributes to variability: a multicenter RCT comparing manual acupuncture (MA), electroacupuncture (EA), warm acupuncture (WA), mild moxibustion (MM), sham acupuncture (SA), and celecoxib demonstrated significant VAS and WOMAC physical function score reductions across all active acupuncture groups versus SA ($P < 0.05$). Notably, EA achieved superior VAS reduction compared to celecoxib (MD: 1.14; 95% CI: 0.55–1.72; $P < 0.01$), highlighting the technique-dependent efficacy profiles that warrant personalized clinical selection.²⁴ Preliminary evidence suggests sensitized acupoints may enhance outcomes in specific subpopulations, although validation through rigorously designed population-stratified trials remains essential.²⁴

Global Implementation Landscape of Acupuncture for Knee Osteoarthritis

(OA) is gaining increasing recognition as a therapeutic intervention for knee osteoarthritis (KOA), with integration into multidisciplinary management protocols across diverse health-care systems. A randomized controlled trial (RCT) of 42 KOA patients comparing traditional Chinese acupuncture versus sham acupuncture reported no statistically significant difference in response rates (61.9%[13/21] vs 42.9%[9/21], $P = 0.217$), yet established the feasibility and safety of tri-weekly acupuncture sessions in clinical practice.³³ Systematic assessments further validated its global applicability; an overview of 12 systematic reviews indicated potential advantages of acupuncture for KOA, including superior overall response rates, enhanced short-term efficacy, and reduced adverse events, based on high-quality evidence, albeit acknowledging persistent methodological limitations such as risk of bias and reporting deficiencies.³⁴ Significant heterogeneity exists in clinical implementation, however, driven by regional therapeutic customs that dictate variations in acupoint selection (eg, EX-LE4/ST36 predominance in East Asia vs localized tender points in Western protocols), treatment frequency (1–5 sessions/week), and duration (4–12 weeks). Standardization through international collaborative initiatives is imperative to harmonize therapeutic protocols and optimize evidence-based translations of acupuncture efficacy.

Controversies in Acupuncture for Knee Osteoarthritis Treatment

Scientific Credibility Challenges in Acupuncture for KOA

Despite its therapeutic benefits, the scientific validity of acupuncture for the management of KOA remains debatable. The primary controversies stem from incomplete mechanistic elucidation of its polypharmacological actions. While pre-clinical studies suggest the involvement of neuro-immuno-endocrine pathways—exemplified by activation of the MT1/MT2-mediated MLT/cAMP/PKA/CREB signaling cascade that suppresses pro-inflammatory cytokines (TNF- α , IL-1 β)—these findings lack comprehensive translational validation.¹⁴ Methodological limitations in clinical trials further fuel skepticism: Small sample sizes (median n < 100 in 68% RCTs), inadequate blinding protocols (operator-dependent techniques preclude true double-blinding), and significant placebo effects (sham-controlled trials show 30–58% response rates) compromise evidence reliability.³⁴ A systematic review confirmed acupuncture's efficacy versus routine care

(SMD: -0.69 , 95% CI: -0.97 to -0.41) but highlighted substantial heterogeneity ($I^2 = 86\%$) across 27 trials, reflecting inconsistent outcome measures and variable acupoint selection.³⁴ Resolution requires adequately powered RCTs ($n \geq 200/\text{arm}$) with standardized protocols, mechanistic biomarker integration (eg, serial MMP-3/IL-1 β measurements), and fMR imaging to objectively quantify central neuromodulation effects.

Safety Considerations of Acupuncture in KOA Management

Acupuncture demonstrates a favorable safety profile relative to pharmacotherapy for KOA, with serious adverse events (SAEs) reported in $<0.12\%$ of cases, based on multinational registry data. However, technique-dependent risks require vigilant assessment. Minor adverse events (AEs) including local hematoma (incidence: 4.3–8.1%), needling-site infection (0.14–2.3%), and vasovagal syncope (1.7–3.6%) remain clinically significant concerns.³⁵ A feasibility trial of combined catgut embedding acupuncture (TEA) and electroacupuncture (EA) in 36 KOA patients confirmed no SAEs occurrence but documented transient subcutaneous induration in 22% of participants.³⁵ Crucially, safety variations exist across techniques: Warm-needling acupuncture analysis revealed risks of dizziness (pooled OR = 3.21, 95% CI 1.54–6.70), nausea (OR = 2.97, 95% CI 1.21–7.28), and cardiac arrhythmia (2 cases/100 sessions) when improperly administered.³⁶ Standardization deficits in needle depth (eg, ST36: 25–40 mm depth variance across practitioners), stimulation frequency (2–100 Hz heterogeneity), and operator training (500hrs vs 200hrs curricula) directly correlate with AE rates. Consequently, strict adherence to STERILE PROCEDURAL GUIDELINES (WHO, 2021) and pretreatment screening for coagulopathies/pacemaker implantation are non-negotiable risk-mitigation strategies.

Challenges in Standardized Assessment of Acupuncture Efficacy for Knee Osteoarthritis

Standardized assessment of acupuncture efficacy in KOA faces multiple challenges. The lack of unified outcome measures (eg, WOMAC, VAS, and Lysholm scores used inconsistently) hinders direct comparison and reliable efficacy evaluation.¹⁶ Second, substantial variations exist in treatment protocols (acupoint selection, needling technique, frequency, duration), complicating interpretation.³⁷ Third, placebo effects and individual patient differences (eg, psychological expectations) make it difficult to isolate the specific effects of needling.¹⁶ Addressing these requires the establishment of standardized efficacy assessment criteria and treatment protocols.

Future Prospects of Acupuncture in Knee Osteoarthritis Management

Emerging Directions in Acupuncture for KOA Therapy

Future prospects for acupuncture in knee osteoarthritis treatment reveal several promising new directions, driven by advances in precision medicine and technology integration; specifically, in-depth exploration of acupuncture's molecular mechanisms and neural pathways—such as its role in modulating the MLT/cAMP/PKA/CREB signaling pathway to alleviate KOA pain—could enable the development of highly targeted therapeutic protocols, with future research needed to elucidate this and related pathways for identifying novel treatment targets,¹⁴ while the integration of modern technologies like artificial intelligence and big data offers opportunities to optimize acupuncture regimens by analyzing extensive clinical datasets from KOA patients to identify superior acupoint combinations and needling parameters, thereby enhancing treatment precision and efficacy. Additionally, the innovation of novel acupuncture materials and devices, exemplified by nanodrug acupuncture technology (nd-Acu), presents new avenues for improving drug delivery and therapeutic outcomes.³⁸ And the exploration of combined approaches with emerging therapies, such as gene therapy and cell therapy, holds the potential for groundbreaking advances in KOA management.

Personalized Medicine Prospects for Acupuncture in Knee Osteoarthritis Treatment

Personalized acupuncture protocols tailored to individual variations in disease severity, TCM constitution, and genetic background represent a promising avenue for enhancing the efficacy of KOA. For example, an RCT suggested that individualized acupuncture (based on meridian differentiation/constitution) may lead to greater improvements in WOMAC total scores compared to standardized, sham, or no acupuncture, indicating better alignment with patient-specific needs.³⁹

Furthermore, integrating psychological factors—such as anxiety and depression, which significantly influence acupuncture responsiveness—into treatment design is essential, with adjunctive interventions like cognitive behavioral therapy offering pathways to amplify efficacy. Concurrently, advances in genetic testing enable the refinement of acupuncture strategies based on patient polymorphisms, paving the way for truly precision-driven care; thus, through these multifaceted personalization approaches, acupuncture may deliver more targeted and effective management for KOA patients.

Multidisciplinary Collaboration Trends in Acupuncture for Knee Osteoarthritis Treatment

The integration of acupuncture with multidisciplinary approaches represents a pivotal future trend in knee osteoarthritis (KOA) management, as collaboration with rehabilitation medicine—combining acupuncture with exercise therapy and physical modalities—can yield synergistic effects, significantly enhancing functional recovery outcomes; for example, a study demonstrated that KOA patients receiving combined acupuncture and exercise rehabilitation exhibited superior response rates, pain reduction, and functional improvements compared with monotherapy groups, underscoring the clinical advantage of integrated interventions⁴⁰. Concurrently, partnerships with imaging disciplines (eg, MRI and fMRI) enable in-depth exploration of acupuncture's neuromodulatory mechanisms and efficacy validation, facilitating precise elucidation of its therapeutic principles, such as fMRI evidence revealing acupuncture's capacity to modulate functional connectivity within pain-related brain regions in KOA patients, thereby offering novel insights for protocol optimization. Furthermore, collaborations between pharmacology and biomedical engineering disciplines drive innovation in novel acupuncture-delivered pharmaceuticals and device enhancements (eg, smart needle systems and biosensor-embedded electrodes), accelerating the evolution of KOA therapeutics and ultimately delivering comprehensive, patient-centered treatment strategies that increase therapeutic efficacy and quality of life.

Conclusion

Acupuncture is an effective complementary therapy for KOA, with electroacupuncture and combinatorial approaches (eg, exercise) showing consistent efficacy. It modulates the neuroendocrine pathways, suppresses inflammation, and promotes functional recovery. Innovations (nd-Acu and TEA) and combination strategies enhance the therapeutic potential.

Acupuncture aligns with OARSI/AAOS stepwise management as a Step 2/3 intervention. For patients with inadequate NSAID response or contraindications, it offers a guideline-recommended non-pharmacologic option (OARSI 2019). Its integration within multidisciplinary care (combined with exercise rehabilitation) mirrors AAOS emphasis on multimodal therapy. Future studies must address the mechanistic elucidation, long-term efficacy, and protocol standardization to integrate acupuncture into evidence-based KOA management.

Despite the promising findings, this review has several limitations. First, the included studies exhibited significant heterogeneity in acupuncture protocols (acupoint selection, stimulation parameters, treatment duration), which may compromise the generalizability of conclusions. Second, most mechanistic studies were preclinical (animal models or small-sample human trials), limiting direct clinical translation. Third, publication bias may exist as negative results are less likely to be published. Finally, long-term efficacy data (>6 months) remain scarce, hindering assessment of acupuncture's sustained effects.

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