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# Combined effect of therapeutic ultrasound and exercise on pain and swelling in people with knee osteoarthritis: a systematic review

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# Combined effect of therapeutic ultrasound and exercise on pain and swelling in people with knee osteoarthritis: a systematic review


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# Abstract


## Background

Knee osteoarthritis (KOA) is a chronic musculoskeletal disorder associated with pain, swelling, functional limitation, and reduced quality of life. Therapeutic ultrasound and exercise are frequently prescribed conservative interventions; however, evidence regarding their combined effectiveness remains unclear.

## Objective

To systematically evaluate the combined effects of therapeutic ultrasound and any form of exercise on pain and swelling in individuals with knee osteoarthritis.

## Methods

A systematic search of Web of Science, CINAHL, PubMed, AMED, and MEDLINE was conducted for studies published between 2004 and 2024. Randomized controlled trials involving adults aged ≥40 years with knee osteoarthritis were included. Methodological quality was assessed using the Joanna Briggs Institute (JBI) critical appraisal tools. The review was conducted in accordance with PRISMA 2020 guidelines and registered with PROSPERO (CRD42024579383).

## Results

Six studies met the inclusion criteria. Overall, 75% of included studies were rated as moderate to high methodological quality. Evidence consistently supported improvements in pain and functional performance following combined therapeutic ultrasound and exercise interventions. Evidence for reduction in joint swelling was limited, with only one study reporting a significant effect.

## Conclusion

Combined therapeutic ultrasound and exercise interventions appear effective for reducing pain and improving function in individuals with knee osteoarthritis. Evidence supporting effects on swelling is limited. High-quality randomized trials with longer follow-up are required to confirm long-term benefits.

**Keywords:** Therapeutic ultrasound; Exercise; Pain; Swelling; Knee osteoarthritis; Systematic review

### 1. Introduction

Knee osteoarthritis (OA) is one of the most prevalent musculoskeletal disorders worldwide and is characterized by pain, joint swelling, discomfort, stiffness, functional limitations, marked muscle atrophy, and, in severe cases, disability and incapacity (Allen et al., 2019). These conditions exert substantial adverse effects on functional performance and quality of life, are often associated with anxiety and depression, and significantly burden individual health by increasing healthcare utilization and placing added strain on family members (Jia et al., 2022).

Knee OA is a chronic condition affecting a large proportion of the global population, with profound physical, psychological, and economic consequences. A systematic review conducted over two decades ago estimated that more than 368 million people worldwide live with knee osteoarthritis, highlighting its considerable social and economic impact (Hunter et al., 2019; Cui et al., 2020). Globally, the prevalence of knee OA among individuals aged 40 years and older is approximately 22.9% (Cui et al., 2020).

Furthermore, knee OA is projected to become the fourth leading cause of disability among women and the eighth among men worldwide (Jia et al., 2022).

The main objectives of osteoarthritis management are pain relief, reduction of cartilage degeneration, enhancement of functional capacity, and limitation of disability (Huang et al., 2005). Management strategies encompass both pharmacological and non-pharmacological interventions (Cetin et al., 2008; Ulus et al., 2012). Due to age-related comorbidities and the high prevalence of polypharmacy, individuals with osteoarthritis often prefer non-pharmacological and non-surgical treatment options (Zeng et al., 2021a; Ulus et al., 2012).

Non-pharmacological interventions for knee osteoarthritis include physiotherapy modalities, lifestyle modification, exercise therapy, transcutaneous electrical nerve stimulation (TENS), short-wave diathermy, therapeutic ultrasound, superficial heat application, and patient education ( Somashekar et al., 2015; Kitano et al., 2024). Therapeutic ultrasound is a physiotherapy modality that delivers deep heat to tissues, thereby improving joint range of motion, enhancing tissue repair, reducing pain, and decreasing edema (Samaan et al., 2022; Liu et al., 2022). In this modality, electrical energy is converted into sound waves, which then generate thermal energy as they pass through biological tissues (Durmus et al., 2010). Therapeutic ultrasound may be administered in continuous or pulsed modes for the management of painful musculoskeletal conditions (Király et al., 2022). While pulsed ultrasound produces primarily non-thermal effects that aid in inflammation reduction, continuous ultrasound generates thermal effects; both approaches are commonly employed in clinical practice (Yetisir & Öztürk, 2024).

In the literature, these therapeutic interventions are often applied either individually or in combination (Alfredo et al., 2020). Both exercise and ultrasound therapy have been shown to relieve pain, reduce inflammation, and facilitate tissue healing (Ulus et al., 2012). Exercise programs frequently incorporate patient education and home-based activities, whereas ultrasound therapy has generally demonstrated greater effectiveness in pain reduction than in improving disability outcomes (Cetin et al., 2008). Physical activity can address many factors contributing to disability (de Sire et al., 2021). Although exercise interventions including aerobic and strengthening exercises are widely investigated in the management of knee osteoarthritis, findings across studies have been inconsistent (Macías-Hernández et al., 2022).

Therapeutic exercise helps individuals with osteoarthritis (OA) prevent the accelerated joint degeneration associated with inactivity, without worsening joint deformities that may further increase degeneration and pain (Zhou et al., 2018). Evidence suggests that the effects of exercise are comparable to those of moderate analgesics and non-steroidal anti-inflammatory drugs (Wallis et al., 2013; Tucker et al., 2011; Fransen et al., 2015). Despite these benefits, most people with knee OA remain inactive or do not engage in sufficient physical activity (Farr et al., 2008; Wallis et al., 2013), and only a small proportion achieve the recommended level of at least 150 minutes of moderate-intensity exercise per week (Chang et al., 2020).

Based on findings from clinical trials, current clinical guidelines for knee OA strongly recommend both strengthening and aerobic exercises (Golightly et al., 2012; Fransen et al., 2015; Kolasinski et al., 2020). Aerobic exercise has been shown to enhance immune function, reduce pain, prevent muscle wasting, promote the repair of damaged cartilage, and improve fat metabolism (Zeng et al., 2021a). Likewise, strengthening exercises are associated with pain reduction (Hall et al., 2018), improved psychological well-being (Singh et al., 1997), and maintenance of cartilage integrity (Van Den Hoogen et al., 1998).

Consequently, exercise is widely regarded as a fundamental component of knee OA management (Raposo et al., 2021).

Although numerous studies have examined the individual effects of therapeutic ultrasound and exercise in the management of knee osteoarthritis, there is limited evidence from systematic reviews evaluating their combined effects on pain and swelling. Therefore, the present review aimed to assess the effects of therapeutic ultrasound combined with any form of exercise on pain and swelling in individuals with knee osteoarthritis.

# 2. Methods

## 2.1 Study design and registration

This systematic review was conducted in accordance with the **PRISMA 2020** guidelines [Page et al., 2021] and registered with PROSPERO (CRD42024579383). A comprehensive search strategy was developed in consultation with a research librarian (UB).

## 2.2 Eligibility criteria

Studies were eligible if they:

- Included adults aged ≥40 years with knee osteoarthritis
- Employed therapeutic ultrasound (continuous or pulsed) combined with any form of exercise
- Reported pain, swelling, function, or stiffness outcomes
- Used randomized controlled

Studies involving inflammatory arthritis, prior knee surgery, or intra-articular corticosteroid injections, non RCTs and those with no full English text, were excluded.

## 2.3 Information sources and search strategy

Five databases (Web of Science, CINAHL, PubMed, AMED, MEDLINE) were searched from August to October 2024. The full search strategy is provided in **Appendix 1**.

## 2.4 Study selection

Two reviewers (SM, LU) independently screened titles, abstracts, and full texts using Rayyan software. Disagreements were resolved by a third reviewer (UB).

**Results**

## 2.5 Quality appraisal

This was appraise by SM and AUG, the quality of the RCTs nine papers was assessed using the JBI checklist for RCTs. Answers to the quality appraisal items were defined as yes and no. A score of one was given to the answer yes, and a score of zero was given to the other answers and the overall appraisal is weather to include or exclude base on the available answer. Based on previous systematic reviews, studies with a JBI score higher than 70% were classified as having a high quality, those with a score between 50% and 70% as having a medium quality, and those with a score less than 50% as having a low quality. Only moderate and high-quality studies were included in the review(Kundu et al., 2024) as shown in table 2a below

### 2.6 Data extraction and synthesis

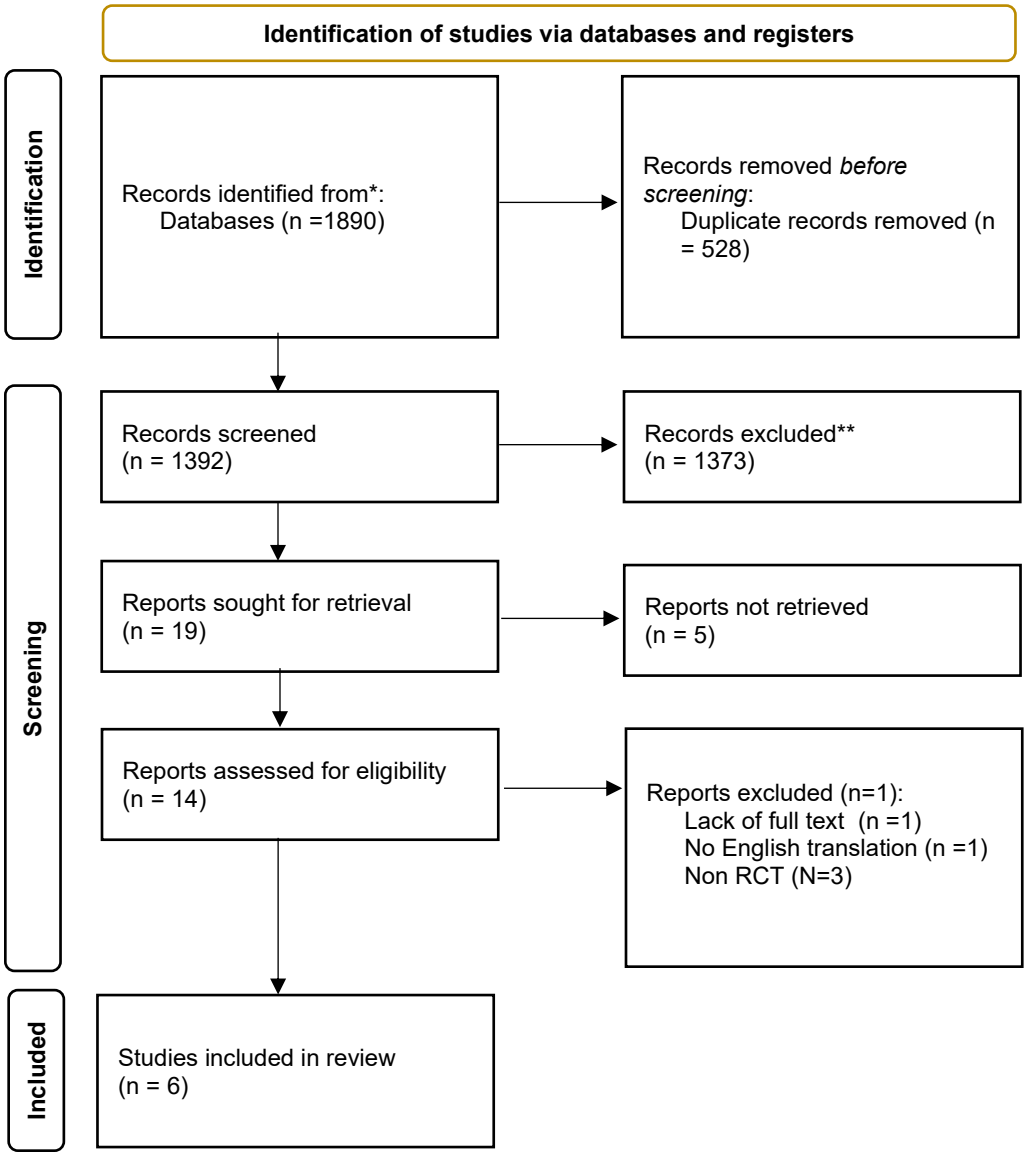
SM and UB used an Excel file that had already been created to extract the data. The following data was taken from every study that qualified: Author (year), study title, research goal or goals, study design, nation of the study's genesis, Features of Participants (Population; N; Average Age (SD); M/F Distribution), Parameters of the intervention: group receiving treatment, Parameters of the intervention: group under control, outcome or outcomes evaluated, outcome measures applied for each outcome, Assessment time points, such as baseline, post-intervention, and follow-up The quantity and causes of dropouts at various times, if any, The main findings' specifics include the magnitude of the effect, p-values, within-between group differences, and the author(s)' conclusion.

## 3. Results

### 3.1 Search and screening outcome

A total of 1,890 records were identified through searches of five electronic databases. The study selection process, conducted in accordance with the **PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines**, is illustrated in **Figure 1**.

SM and LU independently performed the initial screening of titles and abstracts using **Rayyan** software. A total (n=1890) **of articles** were assessed for eligibility and duplicates were removed using the software (n=528). Then title screening phase where the discrepancy was resolved **UB**. 1392 underwent titles and abstract screening by **SM** and **LU**, 1373 were excluded and UB resolved discrepancies in abstract screening. This process led to the identification of 19 **articles** that met the criteria for title and abstract screening. However, 5 studies could not be retrieved. 14 **full-text articles** were retrieved and uploaded for further full-text screening. The full-text screening was conducted by **SM** and **LU**. Following this screening, 6 **articles** met the inclusion criteria and were included in the final analysis, 3 were excluded due their design quasi-experiment, and 3 were excluded due to lack of full text and no English translation.




### 3.3.2 Control parameters

The six studies incorporated control conditions (Bennell et al., 2005; Cetin et al., 2008; Huang et al., 2005; Kitano et al., 2023; Samaan et al., 2022; Ulus et al., 2012). Control interventions varied and included placebo treatment, isokinetic exercise, absence of strengthening exercise, sham low-intensity pulsed ultrasound combined with therapeutic exercise, exercise therapy alone, continuous ultrasound, and sham ultrasound.

## 3.5 Quality appraisal of included studies

Overall, 75% of the included studies were rated as moderate methodological quality ( Bennell et al., 2005; Cetin et al., 2008; Huang et al., 2005; Kitano et al., 2024; Samaan et al., 2022; ; Ulus et al., 2012), as summarized in **Table 2a**.

# Table 2a Methodological quality appraisal of included randomized controlled trials (RCTs) using the JBI Critical Appraisal Checklist

| Study | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | Q11 | Q12 | Q13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bennell et al. (2005) | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Cetin et al. (2008) | ✓ | ✗ | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Huang et al. (2005) | ✓ | ✓ | ✓ | ✓ | ✗ | ✗ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Kitano et al. (2024) | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Samaan et al. (2022) | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Ulus et al. (2012) | ✓ | ✓ | ✓ | ✓ | ✗ | ✗ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

**Notes:** ✓ = Yes; ✗ = No.
**Abbreviation:** JBI, Joanna Briggs Institute.

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### JBI Critical Appraisal Questions for RCTs

Q1 Randomization method appropriate
Q2 Allocation concealment
Q3 Baseline comparability
Q4 Participant blinding
Q5 Personnel blinding
Q6 Outcome assessor blinding
Q7 Identical treatment apart from intervention
Q8 Adequate follow-up
Q9 Intention-to-treat analysis
Q10 Consistent outcome measurement
Q11 Reliable outcome measurement
Q12 Appropriate statistical analysis
Q13 Appropriate trial design and analysis

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# 3.6 Main study findings

Six studies evaluating the combined effects of therapeutic ultrasound and exercise interventions in individuals with knee osteoarthritis were included. The studies were conducted across Asia,

Europe, Australia, South America, and Africa and assessed outcomes related to pain, physical function, and range of motion (ROM), disability, swelling, and quality of life using validated outcome measures.

Huang et al. (2005) from Taiwan evaluated ROM and disability using a goniometer, the Lequesne index (Lequesne et al., 1987), and VAS at baseline. N=One hundred twenty subjects with bilateral knee OA (Altman grade II). Treatment Group=Subjects were randomized sequentially into 1 of 4 groups. Group I received isokinetic muscular strengthening exercises, group II received isokinetic exercise and continuous US, group III received isokinetic exercise and pulsed US treatment. All groups received 20 minutes of hot packs and 5 minutes of passive ROMexercise on an electric stationary bike (20 cycles/min) of bothknees before undergoing muscle strengthening exercises. Control group: group IV was the control group.and the 30 in group IV served as controls and received neither strengthening exercises nor US treatments. Points of assessment: before, after, and follow up and 8weeks. The $p < 0.05$ for all the groups. The authors reported that pulsed ultrasound combined with isokinetic strengthening exercises was effective in managing periarticular soft tissue pain in patients with knee osteoarthritis.

Bennell et al. (2005) in Australia assessed pain, function, and disability using VAS, WOMAC, and the SF-36 (Ware and Sherbourne, 1992). N= 140 community volunteers with knee osteoarthritis participated and 119 completed the trial. Treatment group: Following baseline assessment, participants were randomly assigned to physiotherapy or placebo treatment while control received placebo, points of assessment: baseline, 12weeks, 24weeks, the p-value >0.05. The physiotherapy programme evaluated did not demonstrate greater effectiveness than regular therapist contact in reducing pain or disability.

Cetin et al. (2008), from Turkey, measured pain and disability using VAS and the Lequesne index across five randomized groups. N= One hundred women from the local community (mean age, 59.82 9.05 yrs) with clinical and radiologic diagnoses of knee OA, treatment groups : One hundred patients with bilateral knee osteoarthritis were randomized into five groups of 20 patients each: group 1 received short wave diathermy hot packs and isokinetic exercise; group 2 received transcutaneous electrical nerve stimulation hot packs and isokinetic exercise; group 3 received ultrasound hot packs and isokinetic exercise; group 4 received hot packs and isokinetic exercise; control group: Group 5 served as controls and received only isokinetic exercise. Point of assessment: Patients were evaluated at baseline and at the end of the treatment sessions by the physician, who was blinded with regard to the type of treatment the patients would receive. All patients received treatment three times weekly for 8wks. The p-value >0.05 The study reported significant improvements, particularly when physical agents were used prior to exercise therapy.

Kitano et al. (2023), conducted in Japan, evaluated pain, ROM, infrapatellar fat pad (IFP) thickness, and functional capacity using VAS, goniometry, and WOMAC at baseline and post-intervention. N= 26, Baseline demographic and clinical characteristics Variable LIPUS + Therapeutic exercise ,2Sham LIPUS + Therapeutic exercise, mean age of the two groups are Age (years) 63.5 ± 8.6, 56.5 ± 7.5 respectively. Treatment group; the study included 26 patients with knee OA, who were randomized into the LIPUS group (patients underwent LIPUS+therapeutic exercise) and the control group: the therapeutic exercise group (patients underwent sham LIPUS+therapeutic exercise, point of assessment. All patients received treatment

two times weekly, 5weeks. The p-value >0.05. This was the only study to report that low-intensity pulsed ultrasound combined with therapeutic exercise was safe and effective in reducing IFP swelling, relieving pain, and improving function.

Samaan et al. (2022) from Egypt assessed pain, ROM, and functional capacity using VAS, goniometry, and WOMAC before and after treatment. , N= 60, There were 60 participants with grades II and III KOA based on the radiological findings in Kellgren and Lawrence grading scale. Participants were allocated randomly into three groups, study group I (HILT+ET), study group II (LIPUS+ET), and control (ET) group Participants in the three groups received active range of motion (ROM) exercises, muscle strengthening, and flexibility exercises. Treatment was administered 5 times/wk for two successive weeks. All outcomes were measured pre- and post-treatment. The p-value >0.05. Conclusion, the finding of our study affirms the application of HILT combined with ET for patients with KOA and is safe and well tolerated and effective in pain relief and the improvement of knee joint ROM, position sense and hence function. The HILT combined with ET was more effective than LIPUS combined with ET and exercises.

Ulus et al. (2012), conducted in Turkey, assessed pain, functional ability, and disability using VAS, WOMAC, and the Lequesne index before and after treatment. While ultrasound was found to be safe, no additional benefit was observed when it was added to conventional physical therapy, suggesting the need for larger studies with longer follow-up periods. N= 40, Forty-two inpatients with bilateral knee OA were randomized by an independent researcher not involved in the data assessment, to receive either therapeutic continuous US (group 1) or sham US (group 2). All outcomes were measured pre- and post-treatment. The p-value >0.05.

To classify osteoarthritis, the Kellengren-Lawrence scale was used in most (80%) of the studies, and 60% of the studies were rated 2-3 and 20% were rated 2-4.

# 4.0 Discussion

This systematic review examined the combined effects of therapeutic ultrasound (US) and exercise on pain and swelling in individuals with knee osteoarthritis (OA). Existing evidence indicates that therapeutic exercise alone is effective in alleviating knee OA related pain (Rewald et al., 2020). However, whether the addition of US confers incremental benefits beyond exercise remains uncertain (Liu et al, 2022: Zhou et al, 2018).

Evidence supporting the combined effects of US and exercise on joint swelling is limited (Samaan et al., 2022). Most included studies reported no significant reduction in swelling, with only one study (Kitano et al., 2023) demonstrating that low-intensity pulsed ultrasound (LIPUS) combined with therapeutic exercise was safe and effective in reducing infrapatellar fat pad swelling, relieving pain, and improving function in patients with knee OA (Zhou et al,2018).

Findings related to pain reduction were consistent across studies. Several physical modalities including pulsed electromagnetic energy, therapeutic ultrasound, exercise therapy, and thermotherapy were effective in reducing pain; however, no single modality consistently demonstrated superiority (Samaan et al., 2022). Prolonged continuous US combined with exercise

was shown to improve pain, mobility, and functional activity (Alfredo et al., 2020), whereas a structured physiotherapy program did not outperform routine therapist contact in reducing pain or disability (Bennell et al., 2005). Other studies reported enhanced exercise performance and pain reduction when physical agents were applied before strengthening exercises (Cetin et al., 2008). Pulsed US has also been shown to augment the effects of strengthening exercises for periarticular soft-tissue pain (Huang et al., 2005). Notably, Kitano et al. (2023) was the only study to report a significant reduction in swelling with LIPUS combined with exercise. Comparatively, high-intensity laser therapy combined with exercise demonstrated greater improvements in pain, proprioception, and functional outcomes than LIPUS with exercise (Samaan et al., 2022). Other findings suggest that US combined with retro-walking improved pain, knee range of motion, and WOMAC scores more effectively than TENS with retro-walking (Somashekar et al., 2015), while combined physical therapy and exercise produced better outcomes than exercise alone in bilateral knee OA (Terzi & Altin, 2017). Conversely, Ulus et al. (2012) reported that adding US to conventional physiotherapy did not provide additional benefit, reinforcing the need for larger and longer-term trials.

Collectively, these findings indicate that while therapeutic exercise reliably reduces pain in knee OA, the additional contribution of US particularly for swelling reduction remains inconclusive (Ulus et al, 2012). Some studies report modest benefits in pain, function, or range of motion, but no intervention consistently outperforms others (Liu et al, 2022: Ulus et al, 2012: Zhou et al, 2018).

Knee OA is characterized by progressive pain, stiffness, edema, and functional limitation, particularly following prolonged inactivity (Somashekar et al., 2015). Given the cardiovascular and gastrointestinal risks associated with long-term oral pharmacological therapy (Kitano et al., 2023), non-pharmacological interventions such as US which is generally well tolerated, especially in older adults remain clinically relevant (Alfredo et al., 2020). Therapeutic ultrasound typically operates at frequencies of 1–3 MHz, targeting soft tissues at depths of 2–5 cm (Rewald et al., 2020). Its non-thermal effects (e.g., cavitation and acoustic streaming) may influence cellular permeability and tissue metabolism (Rewald et al., 2020), while thermal effects contribute to localized tissue heating (Macías-Hernández et al., 2022).

Several limitations should be acknowledged. Only English-language studies with accessible full texts were included, potentially excluding relevant evidence. The small number of eligible studies and limited availability of high-quality randomized controlled trials further constrained the strength of conclusions. Challenges related to blinding, short intervention durations, and lack of long-term follow-up were common, despite OA being a chronic condition.

Methodological heterogeneity including variability in treatment protocols, therapist expertise, intervention dosage, and participant characteristics may have introduced bias and limited generalizability. Additionally, small sample sizes, particularly in Kitano et al. (2023), increased the risk of systematic error. Nevertheless, these studies still provide valuable clinical insights.

Future research should focus on large-scale, well-designed randomized trials with standardized intervention protocols and extended follow-up periods to clarify both short- and long-term effects of combining therapeutic ultrasound with exercise in individuals with knee osteoarthritis.

## 5. Conclusions

This review demonstrates that combining therapeutic ultrasound with exercise improves pain and functional performance in individuals with knee osteoarthritis. Evidence for reduction in swelling remains limited. Future high-quality trials with standardized protocols and long-term follow-up are warranted.

# Declarations

### Ethics approval and consent to participate

Not applicable.

### Consent for publication

Not applicable.

### Availability of data and materials

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

### Competing interests

The authors declare no competing interests.


### Funding

No external funding was received.


### Authors' contributions

All authors contributed to study conception, methodology, data extraction, analysis, drafting, and critical revision of the manuscript. All authors approved the final version.


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## APPENDICES

# Appendix 1

## Search Strategy

The search strategy was developed using the **PICO framework** to identify relevant studies.

**Population (P):** People with knee osteoarthritis
**Intervention (I):** Therapeutic ultrasound
**Comparator (C):** Therapeutic exercises
**Outcomes (O):** Pain and swelling

## Search Terms

### Population (Knee Osteoarthritis)

- "Knee osteoarthritis"
- "KOA"
- "Knee OA"
- "Osteoarthritis"

### Intervention (Therapeutic Ultrasound)

- "Ultrasound"
- "Therapeutic ultrasound"
- "US"
- "Therapeutic US"
- "1 Hz ultrasound"
- "3 Hz ultrasound"
- "Low-intensity ultrasound"
- "High-intensity ultrasound"
- "Pulsed ultrasound"
- "Continuous ultrasound"

### Comparator (Therapeutic Exercises)

- "Therapeutic exercise"
- "Exercises"
- "Physical exercise"
- "Exercise training"
- "Strengthening exercise"
- "Aerobic exercise"
- "Walking"
- "Jogging"
- "Squatting"
- "Bicycle ergometer"
- "Cycling"

- "Treadmill"
- "Overground walking"
- "Steppers"

**Primary Outcomes**

- "Pain"
- "Algesia"
- "Pain intensity"
- "Pain rating"
- "Swelling"
- "Oedema"
- "Edema"
- "Arthritic pain"
- "Arthritic swelling"

**Secondary Outcomes**

- Functional capacity
- Quality of life
- Joint stiffness

## Notes

- Search terms were combined using Boolean operators (**AND / OR**) as appropriate.
- The strategy was adapted to suit individual database requirements

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