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Review Article

Curative Effect of Electroacupuncture and Manual Acupuncture for Knee Osteoarthritis: A Meta-Analysis

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Abstract

Background: We aimed to examine how electroacupuncture and manual acupuncture affect treatment results, pain levels, and joint function in individuals with knee osteoarthritis.

Methods: Research was carried out in various databases including PubMed, Medline, Embase, CENTRAL, and CNKI. Following the "Cochrane manual", the risk of bias of included RCTs was assessed. A funnel plot was utilized to evaluate any potential bias in the publications. The impact size was indicated by the average discrepancy along with its 95% confidence interval.

Results: The EA group showed a higher effectiveness rate ($P = 0.001$) and a lower WOMAC pain score ($P < 0.00001$) compared to the control group. The EA group had a lower WOMAC pain score compared to the SA/exercise group and the group that received manual acupuncture. The WOMAC pain score was significantly lower in the EA group compared to the manual acupuncture group under intense electroacupuncture stimulation ($P < 0.0001$). The WOMAC pain score was significantly lower in the EA group compared to the manual acupuncture group when weak current acupuncture was applied ($P = 0.0001$). However, no significant difference in WOMAC function score between EA and control group.

Conclusion: Comparison to manual acupuncture, placebo acupuncture, and exercise training, electroacupuncture enhanced the effectiveness of treating KOA and decreased the WOMAC pain score in patients with KOA. The level of pain relief achieved may be linked to the strength of the current stimulation. However, electroacupuncture had no significant effect on WOMAC function score.

Keywords: Knee osteoarthritis; Electroacupuncture; Pain; Function

Introduction

Knee osteoarthritis (KOA) is a common long-term joint condition characterized by degenerative cartilage of the knee joint and secondary bone hyperplasia (1). Its incidence is on the rise (2). Symptoms of KOA encompass knee pain, stiffness, and dysfunction (3, 4). The onset of KOA is insidious, leading patients to seek medical help only in the disease's advanced stages (5). Afflicted individuals endure persistent, intense pain and restricted joint mobility (6, 7), putting them at a heightened risk of disability (8). Additionally, KOA imposes significant psychological and financial strains on patients (9).

As of now, there are no definitive cures for KOA in clinical practice (10,11). Given the substantial risks, there's a growing emphasis on limiting the use of NSAIDs and opioids. In advanced cases, knee joint replacement remains the primary intervention (10). Acupuncture, a cornerstone of Traditional Chinese Medicine (TCM), has proven effective in alleviating KOA-associated pain, with manageable side effects (12,13). Therefore, acupuncture has become one of the treatment options for KOA (12,13). The underlying mechanism of acupuncture and moxibustion involves biology and dynamics, which may be related to the increase of blood circulation caused by external stimulation and the acceleration of clearing inflammatory media (14).

The effectiveness of acupuncture in treating KOA is controversial, particularly around the possibility that electroacupuncture (EA) and hand-acupuncture (MA) techniques may lead to different outcomes.The specific debate is whether electroacupuncture is superior to hand acupuncture in terms of analgesic effect, therapeutic effect and functional recovery.Studies have pointed out that electroacupuncture (EA) and manual acupuncture (MA) are both safe and feasible interventions for the treatment of KOA, but the advantages of both have not been determined (15).However, there are also studies that do not support acupuncture to relieve pain symptoms in patients with KOA.There is a lack of guidance on how to choose an appropriate acupuncture technique. High-quality randomized controlled trials directly comparing electroacupuncture, manual acupuncture, and placebo acupuncture for KOA are scant.Drawing definitive conclusions from isolated studies is challenging.

Hence, we embarked on a meta-analysis to delve into the effects of electroacupuncture and manual acupuncture on pain, joint function and joint stiffness in patients with KOA.

Methods

Literature Retrieve

Research was carried out in various databases including PubMed, Medline, Embase, CENTRAL, and CNKI. The keywords were (electroacupuncture OR acupuncture OR acupuncture therapy OR sham acupuncture OR manual acupuncture OR needle OR needles) AND (knee osteoarthritis OR KOA OR OA) OR (physical therapy modalities OR Physical therapy). There were no limitations on the language and publication date of the literature. The search concluded from 1950 to 2024 year.

Literature screening

Criteria for literature selection included : (1 Patients diagnosed with knee osteoarthritis; (2 Studies with both experimental and control groups; (3 The experimental group received electroacupuncture and the control group received manual acupuncture, placebo acupuncture, or no acupuncture and moxibustion; (4 Outcomes measured included treatment effectiveness, the functional score of Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), and pain score; (5 Studies were randomized controlled trials.

Literature exclusion criteria included: (1 Duplicative reports and individual case reports; (2 subjects received surgical or drug treatment; (3 Studies lacked a control group; (4 The baseline data of the experimental group and the control group were poorly balanced or no baseline data were compared; (5 The required data could not be obtained, and authors could not be contacted.

Data extraction

The data from the chosen studies was extracted by two researchers separately, recording details such as the author, title, publication date, type of study, amount of experimental and control groups, treatment success rate, WOMAC function, pain, and stiffness scores. Attempts were made to retrieve missing data from the literature by reaching out to the author. Following the completion of data extraction, 2 researchers conducted a cross-verification process. For differences of opinion, two researchers reached a consensus after consulting a third party.

Document quality evaluation

The quality of the studies was assessed by Luo and Jing. The bias risk assessment was conducted for the randomized controlled trials included using the Cochrane manual's bias risk assessment tool for randomized trials' (18). The assessment covered five areas: bias in randomization, bias in intervention adherence, bias in missing outcome data, bias in outcome measurement, and bias in reporting results selectively. For details of the assessment, refer to RoB2. Research was classified into three categories: low risk of bias, some concerns, and high risk of bias. If the bias risk assessment results in all areas are "low risk", then the overall risk of bias is "low risk"; If the bias risk assessment result of some fields is "some concerns" and there is no "high risk" field, then the overall bias risk is "some concerns"; As long as one domain bias risk assessment result is "high risk", then the overall bias risk is "high risk".

Evaluation of diversity and examination of bias in publications

The heterogeneity test utilized the Chi-square test. If the I^2 value after adjusting for freedom exceeded 50% or the *P*-value was less than 0.1, it was concluded that there was heterogeneity in the published studies, leading to the use of a random effects model. The reasons for variability were investigated through subgroup analysis and sensitivity analysis. The intensity of electroacupuncture stimulation and the acupuncture method used in the control group were the factors affecting the curative effect, and we carried out subgroup analysis accordingly. Sensitivity analysis was performed by excluding low-quality studies and analyzing the same data using different statistical models. The combined effect size was re-estimated and compared with the results of the previous meta-analysis. If there was no significant change in the result, the sensitivity was low and the result was more robust and reliable. On the contrary, if the difference was large or even the opposite conclusion is obtained, it indicated that the sensitivity was high and the robustness of the results was low. The interpretation of the results and conclusions should be very careful, indicating that there were important and potential bias factors related to the effect of the intervention measures, and the source of controversy needed to be further clarified. In subgroup analysis and sensitivity analysis, if heterogeneity disappears, we assumed that heterogeneity was due to the variables controlled in subgroup analysis and sensitivity analysis. In cases where the cause of variation cannot be identified, it may be necessary to present the findings from the literature separately without combining them. If the degree of freedom was adjusted to $I^2 \leq 50\%$ and $P \geq 0.1$, indicating no heterogeneity in the literature, the fixed effect model was applied (19). Publication bias was assessed using a Funnel plot and Egger test. We observed whether the funnel diagram is symmetrical. If the scatter is symmetrical, there is no publication bias, and if the scatter is biased to one side, there is publication bias.

Statistical methods

The study utilized statistical data analysis with the Cochrane software, RevMan 5.3. We conducted meta-analyses for each outcome measure separately. Sensitivity analysis was used to assess the robustness of the results while looking for sources of heterogeneity. The mean difference (MD) between the risk ratio (RR) and its 95% confidence interval (CI) was utilized to characterize the magnitude of the effect. A two-tailed *P* value less than 0.05 signified statistical significance.

Ethical approval

As this study involved the summary and analysis of other studies, it did not involve medical ethics approval or patient-informed consent.

Results

Characteristics of included literature

A grand total of 2863 articles were obtained from the databases. Based on our screening criteria, 2849 of these were excluded, leaving 14 articles for inclusion in the study. These encompassed a total of 1,474 KOA patients, with 738 in the acupuncture group and 736 in the control group. The literature screening process is detailed in Fig. 1, while Table 1 presents the basic information of the selected articles and an assessment of bias risk.

Table 1: Characteristics of included literature and risk assessment of bias

Author and year	*Study type*	*No. of patients*		*Risk of basis*
		EA	Control	
Chen 2013 (20)	RCT	104 Age:60.4 (11.7) Female:57	109 Age:60.5 (11.1) Female:53	high risk
Chen 2020 (21)	RCT	28 Age:45.9 (4.0) Female: 13	28 Age:45.4 (2.3) Female: 11	high risk
Duanmu 2023 (22)	RCT	40 Age:59.8 (3.1) Female: 19	40 Age:59.2 (3.7) Female: 18	high risk
Gao 2012 (23)	RCT	34 Age:41.4 (2.2) Female: 13	35 Age:42.2 (1.9) Female: 15	high risk
Hu 2023 (24)	RCT	30 Age:50.4 (1.8) Female: 10	30 Age:51.2 (2.7) Female: 13	high risk
Ji 2011 (25)	RCT	35 Age:62.9 (5.1) Female: 16	35 Age:63.4 (4.9) Female: 13	some concerns
Jubb 2008 (26)	RCT	34 Age:64.1 (1.6) Female: 29	34 Age:66.1 (1.9) Female: 26	low risk
Li 2018 (27)	RCT	54 Age:65.5 (4.1) Female: 24	46 Age:65.7 (3.8) Female: 22	some concerns
Tu 2021 (28)	RCT	151 Age:58.2 (2.3) Female: 72	145 Age:58.9 (3.4) Female: 70	high risk
Wang 2020 (29)	RCT	25 Age:60.8 (6.1) Female: 12	28 Age:61.1 (5.3) Female: 10	some concerns
Yin 2017 (30)	RCT	60 Age:62.2 (3.1) Female: 23	60 Age:63.7 (3.0) Female: 28	some concerns
Yin 2019 (31)	RCT	42 Age:64.8 (6.4) Female: 17	41 Age:64.7 (5.2) Female: 19	some concerns
Zhang 2017 (32)	RCT	37 Age:55.8 (3.2) Female: 14	36 Age:56.4 (4.2) Female: 17	high risk
Zhang 2020 (33)	RCT	64 Age:52.4 (4.0) Female: 30	69 Age:52.8 (5.1) Female: 32	high risk

Note: RCT means randomized control trails

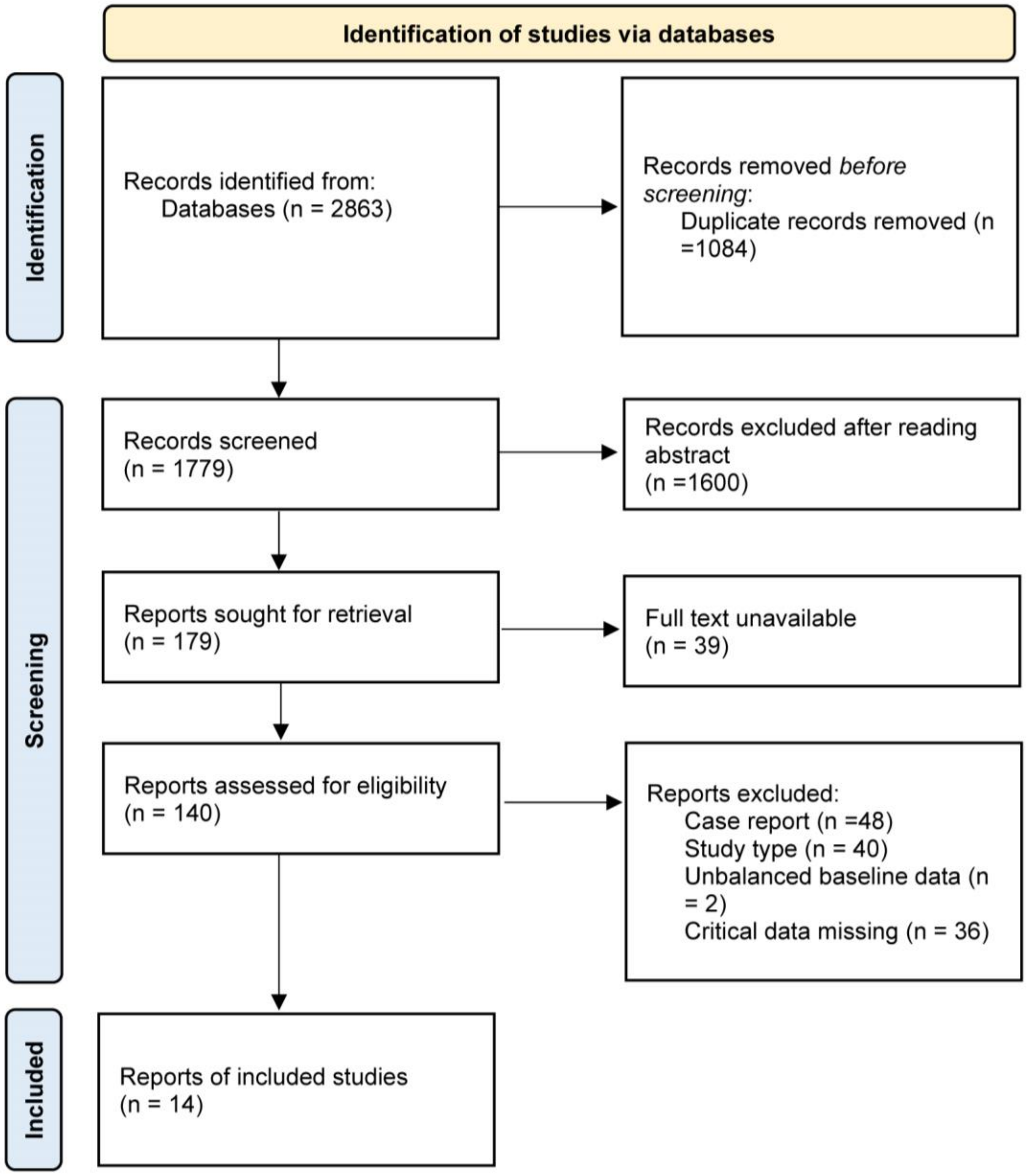

Fig. 1: Flow chart of literature screening

Comparison of effective rate of EA group and control group

A total of 8 studies (21, 25-29, 31, 32) comparing the effective rate of EA group and the control group were included in our meta-analysis. The heterogeneity test indicated a lack of diversity within the 8 studies ($Chi^2 = 4.61$, $P = 0.71$, $I^2 = 0\%$). Consequently, we utilized a fixed-effect model for combining the data. The EA group demonstrated a higher effective rate compared to the control group, with a relative risk of 1.17 (95% CI (1.06, 1.28), Z = 3.24, $P = 0.001$), as shown in Fig. 2. Both the funnel plot and the Egger test showed symmetrical distribution of data points, indicating absence of publication bias, as shown in Fig. S1 (Not published).

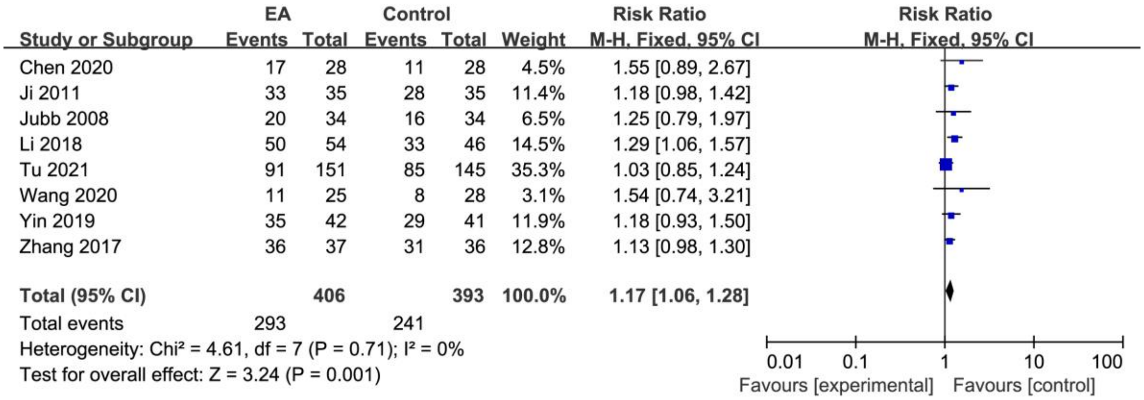

Fig. 2: Forest plot of comparison of treatment effective rate of EA group and control group

Evaluating the WOMAC pain scores in the EA group compared to the control group

Our meta-analysis included 12 studies (20-24, 26, 28-33) that compared WOMAC pain scores between the EA group and the control group. Heterogeneity test showed that there was heterogeneity among 12 studies (Chi^2=47.26, *P*<0.00001, I^2=77%). The random effect model is used to merge. The EA group had a lower WOMAC pain score compared to the control group (MD = -2.27, 95% CI (-3.06, -1.47), Z = 5.61, *P* < 0.00001), as shown in Fig. 3.

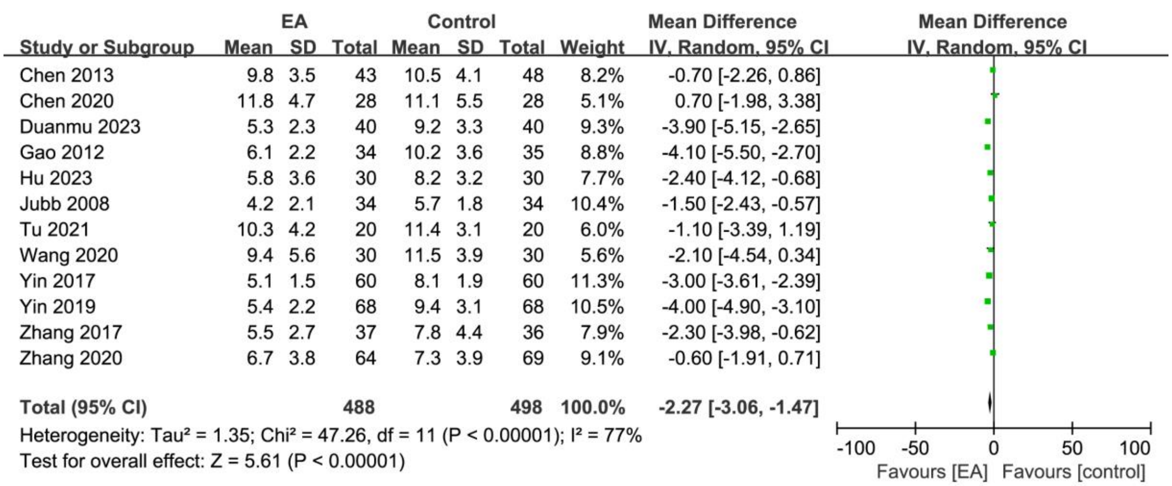

Fig. 3: Forest plot of comparison of WOMAC pain score between EA group and control group

In order to investigate the differences, we performed a subgroup analysis focusing on the intervention methods used in the control group, dividing them into groups receiving placebo acupuncture/exercise and manual acupuncture. A total of 6 studies (22-24, 30-32) compared the WOMAC pain scores of EA group and placebo acupuncture/ exercise group. The six studies showed no variation (Chi^2=7.75, *P*=0.17, I^2=35%), leading to the utilization of the fixed effect model for their combination. The WOMAC pain score was significantly lower in the EA group compared to the SA/exercise group, with a mean difference of -3.33 (95% CI (-3.75, -2.92), Z = 15.64, *P* < 0.00001). A total of 6 studies (20, 21, 26, 28, 29, 33) compared the WOMAC pain score between EA group and manual acupuncture group. The six studies showed no variation

(Chi^2=3.89, P=0.56, I^2=0%), leading to the utilization of the fixed effect model for their combination. The WOMAC pain score was significantly lower in the EA group compared to the manual acupuncture group (MD = -1.07, 95% CI (-1.69, -0.46), Z-score = 3.42, P-value = 0.0006).

The conclusion of subgroup analysis is consistent with that of overall analysis, as shown in Fig. 4. Both the funnel plot and the Egger's regression test revealed a symmetrical distribution of scattered points, indicating no evidence of publication bias, as shown in Fig. S2. The WOMAC pain score was significantly reduced in the EA group compared to the manual acupuncture group when subjected to intense electroacupuncture stimulation (MD = -3.94, 95% CI (-4.70, -3.18), Z = 10.17, P< 0.0001). The WOMAC pain score was reduced in the EA group compared to the manual acupuncture group when weak current acupuncture was applied (MD = -2.35, 95% CI (-3.55, -1.15), Z = 3.83, P = 0.0001) (Fig. S3).

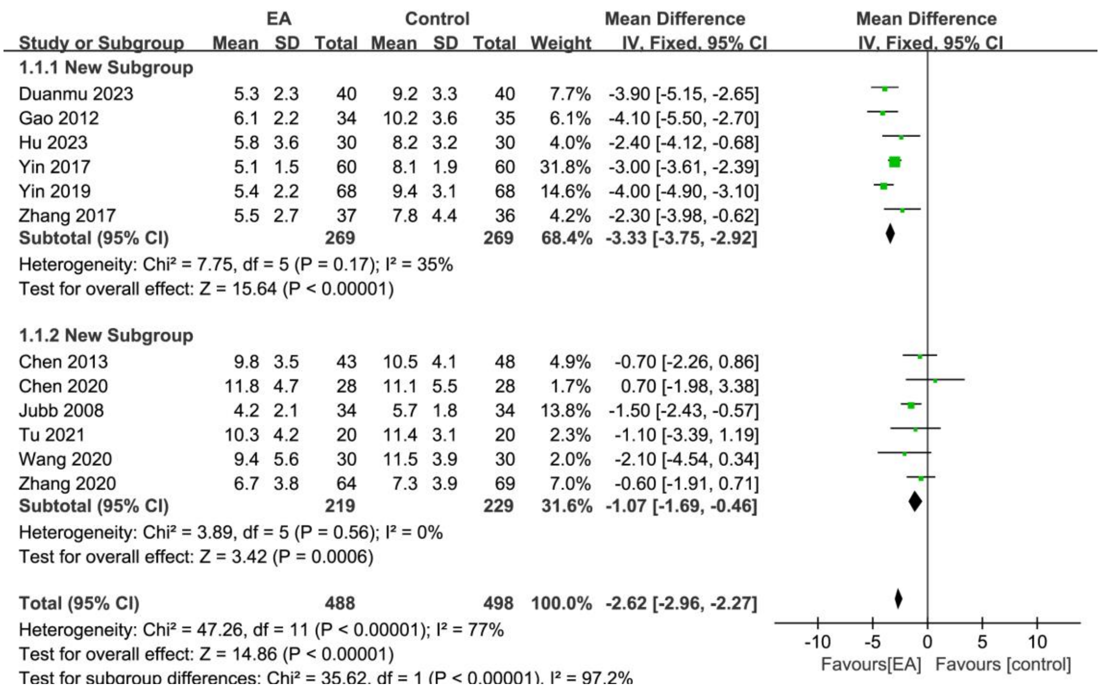

Fig. 4: Forest plot of subgroup analysis of WOMAC pain score between EA group and control group

Evaluating the WOMAC function score differences between the EA group and the control group

Our meta-analysis included 10 studies (20-24, 28-31, 33) that compared the WOMAC function score between the EA group and the control group. The heterogeneity test indicated that the 10 studies did not exhibit any heterogeneity (Chi^2 = 8.64, P = 0.47, I^2 = 0%). Merging was conducted using the fixed effect model. Figure 5 displayed that the EA group and the control group had similar WOMAC function scores with no notable distinction (MD = -1.14, 95% CI (-2.54, 0.26), Z = 1.59, P = 0.11), as shown in Fig.5.

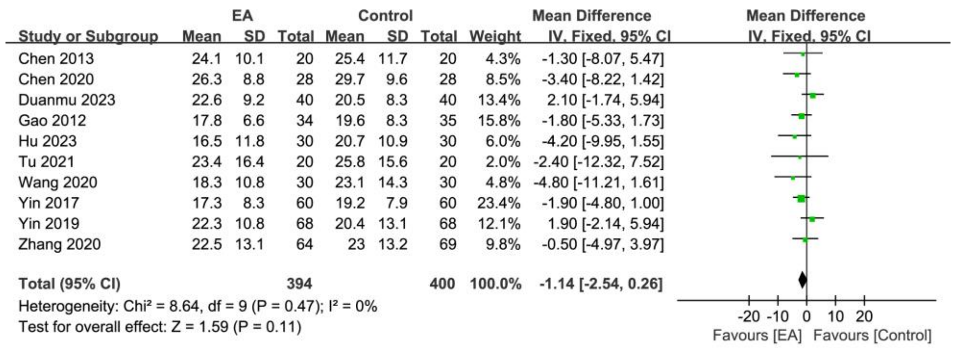

Fig. 5: Forest plot of comparison of WOMAC function score between EA group and control group

To gain more understanding, we performed a subgroup analysis focusing on the intervention strategies used by the control group. As a result, the participants were divided into two subgroups: one receiving placebo acupuncture/exercise and the other receiving manual acupuncture.

Five studies (20, 21, 28, 29, 33) examined the WOMAC function score differences between the EA group and the placebo acupuncture/exercise group. The five studies showed no variation (Chi^2=6.09, P=0.19, I^2=34%), leading to the decision to combine them using the fixed-effect model. Compared with placebo acupuncture/exercise group, EA group has no significant difference in WOMAC function (MD =-0.66, 95% CI (-2.33, 1.01), Z = 0.78, P = 0.44).

In the same way, 5 studies (22-24, 30, 31) also examined the WOMAC function scores in both the EA group and the manual acupuncture group. The five studies showed no variation (Chi^2=1.49, P=0.83, I^2=0%), leading to the utilization of the fixed effect model for their combination. The WOMAC function score did not show a significant difference between the EA group and manual acupuncture group, with a mean difference of -2.28 (95% CI (-4.87, 0.31), Z = 1.73, P = 0.08). The subgroup analysis results align with the overall analysis findings, as shown in Fig. 6. In conclusion, the funnel plot and Egger's test indicated that the data points were distributed symmetrically within the confidence interval. There was no significant publication bias, as shown in Fig. S4.

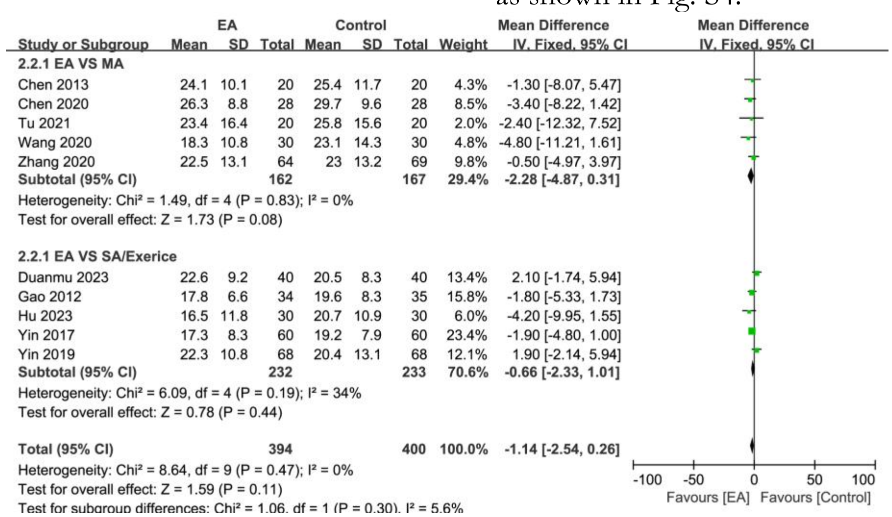

Fig. 6: Forest plot of subgroup analysis of comparison of WOMAC function score between EA group and control group

Discussion

Our meta-analysis found that electroacupuncture stimulation can improve the treatment efficiency of KOA. Electroacupuncture is more effective than manual acupuncture, placebo acupuncture, and exercise training in improving the treatment outcomes for KOA patients by reducing the WOMAC pain score, although it does not have a significant impact on the WOMAC function score. There was no significant difference in functional scores between electroacupuncture stimulation and manual acupuncture, exercise and placebo groups. Electroacupuncture stimulation can only reduce pain in KOA patients and cannot improve joint function. We believe that the use of electroacupuncture stimulation in the treatment of KOA patients should be more targeted, only to reduce the pain of patients, and should not overstate the impact of electroacupuncture stimulation on joint function, thereby delaying the treatment of patients in terms of function.

Electroacupuncture is in the process of manual acupuncture. Acupuncture is retained in the body, applied to the needle handle completely or selectively, and pulsed current is used to play the dual roles of acupuncture and pulsed electrotherapy. Some studies have expounded the potential mechanism of electroacupuncture in the treatment of KOA, mainly in anti-inflammatory, anti-oxidation, regulation of inflammatory related factors and signal pathways, regulation of related gene expression, central and peripheral analgesic systems and biomechanical properties (34-37). Compared with placebo acupuncture/exercise training, electroacupuncture can greatly reduce the pain score of patients, and the score drops by 3.37 points. Compared with manual acupuncture, electroacupuncture decreased the pain score by 1.14 points. The former's score is one-third of the latter's. This shows that compared with electroacupuncture, manual acupuncture and placebo acupuncture/exercise training, the pain relief of patients changes step by step.

In terms of signal pathway, some studies have pointed out that electroacupuncture can regulate the signal pathway related to TLR4 and inhibit synovitis (34). It can regulate Wnt/β-catenin signaling pathway and inhibit the secretion of inflammatory factors, thus slowing down the degradation of cartilage matrix and the apoptosis of chondrocytes (35). It can regulate MAPK signaling pathway and reduce spinal cord sensitization (36). In terms of inflammatory factors, electroacupuncture can reduce the production of prostaglandin E2, tumor necrosis factor, calcitonin gene-related peptide, interleukin and substance *P* (34-36). These inflammatory factors are all related to pain. In biomechanics, Fu Shengxing et al (37) conducted a set of experiments to analyze the alterations in joint load, temporal and spatial parameters, and arthritis index of lower extremities in patients with knee osteoarthritis before and after receiving electroacupuncture therapy. The findings indicated that electroacupuncture treatment was successful in enhancing the joint load capacity of knee osteoarthritis patients while ascending stairs and decreasing the dynamic cumulative load. Electroacupuncture can enhance the speed at which KOA patients ascend and descend, decrease the variability of certain spatiotemporal parameters, boost stability and coordination while walking up and down stairs, and enhance patients' climbing abilities. Xu Haifei et al (38) studied the changes of biomechanical characteristics of electroacupuncture treatment of KOA patients going up and down stairs through finite element simulation, and the results proved that electroacupuncture treatment could transfer influence and improve stress absorption ability. The compressive stress of articular cartilage can be effectively improved, so as to restore the force balance in the joint, delay the degeneration of articular cartilage and promote the repair of articular cartilage.

The curative effect of electroacupuncture on KOA is controversial. According to our analysis, it may be related to the following aspects: First, it may be related to the lack of standardized schemes for acupuncture treatment. Varied frequencies and durations of acupuncture sessions can greatly influence the outcomes of acupuncture therapy. The use of electroacupuncture instrument involves the waveform, frequency, intensity, treatment time, frequency (interval time) and course of treatment of pulsed electricity. Lv et al (39) studied the effects of electroacupuncture with different current intensities on chronic pain of KOA patients. The results showed that strong electroacupuncture (> 2 mA) was superior to weak electroacupuncture (< 0.5 mA) in alleviating pain intensity and inhibiting chronic pain. Unfortunately, based on the literature we included, it is impossible to directly compare the effect of current intensity on pain in KOA patients. However, we found that the pain score decreased by 3.94 points under strong electroacupuncture stimulation and by 2.35 points under weak electroacupuncture stimulation. The pain amplitude of KOA patients stimulated by strong electroacupuncture is greater than that stimulated by weak current syndrome. Dense-dense wave, continuous wave and intermittent wave electroacupuncture can improve the clinical symptoms of KOA. Dense-dense wave electroacupuncture has the best overall effect, and its mechanism may be related to increasing the content of transforming growth factor -β1 in particular fluid, thus promoting the repair of articular cartilage (40). There was no notable distinction in efficacy between electroacupuncture sessions lasting 15 minutes and those lasting 30 minutes, suggesting that the therapeutic benefits were similar regardless of duration (41). Secondly, it may be related to the classification and staging of diseases. In many clinical reports, KOA classification and staging are not stratified. Early KOA and late KOA, KOA caused by different causes may have different sensitivity to treatment. Thirdly, the evaluation standard of curative effect mostly adopts clinical symptom score, which is subjective, and only a few reports adopt more objective pathological and imaging standards. Additionally, the unique nature of acupuncture makes it challenging for doctors to use a blind method. Furthermore, there is a shortage of extensive research involving large sample sizes and multiple centers. Some studies have failed to account for the impact of various factors such as acupuncture techniques, acupoint selection, and physician expertise on the effectiveness of electroacupuncture (20, 28, 29, 33). Because KOA's condition is lingering and difficult to heal, the follow-up time of most clinical studies is too short to fully reflect the long-term curative effect of electroacupuncture. The intervention duration of different treatment schemes may be related to the curative effect. Strengthening MA requires more than 8 weeks of intervention to benefit patients (28).

The result of a previous meta-analysis (42) is similar to ours. This research validated that electroacupuncture can enhance the effectiveness of treatment for knee osteoarthritis, particularly in reducing stiffness, while its impact on pain and functionality is comparable to that of pain-relieving medications. We have confirmed that electroacupuncture is better than acupuncture and placebo acupuncture in relieving pain in KOA patients, and it may be related to the current intensity. We did not include the comparison of analgesic drugs.

This study had certain constraints. First, the number of included papers was small, and there is the possibility of missing studies, which may affect the credibility of our results. Therefore, it is necessary to further expand the number of literatures to obtain more robust conclusions. Secondly, in the literature included in this paper, only one study is considered as low bias risk, and 8 studies are considered as high bias wind direction. The accuracy and reliability of the research results may be affected and reduce the credibility of the results. On the basis of expanding the number of documents, more strict control of the included documents can make up for this defect. At the same time, high-quality double-blind randomized trials are needed to verify the research conclusions. Thirdly, there are few observation indexes in this study. This may lead to our conclusions being one-sided. Electroacupuncture stimulation may have a broader effect on patients, such as reducing swelling and extending walking distance. In future randomized controlled clinical trials, more observational indicators need to be set up to evaluate the efficacy of acupuncture stimulation more comprehensively. Fourthly, the lack of stratification in research subjects and treatment plans makes it challenging to derive specific, clinically valuable conclusions. In future clinical trials, patients need to be stratified to make the conclusions more targeted.

Conclusion

Electroacupuncture may enhance the effectiveness of treating KOA and decreasing the WOMAC pain score in KOA patients when compared to manual acupuncture, placebo acupuncture, and exercise training. The level of pain relief could be influenced by the strength of the current stimulation. However, electroacupuncture has no significant effect on WOMAC function score. The use of electroacupuncture stimulation in the treatment of KOA patients should be more targeted, only to reduce the pain of patients, and should not overstate the impact of electroacupuncture stimulation on joint function, thereby delaying the treatment of patients in terms of function. Of course, when using electroacupuncture to treat KOA, factors such as treatment time, current strength, and patient selection criteria need to be considered.Further clinical trials are needed to develop adjuvant treatment regimens. We recommend larger randomized controlled trials with longer follow-up, stratifying patients according to disease severity or etiology, and investigating the best parameters for electroacupuncture therapy.

Journalism Ethics considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

Acknowledgements

Not applicable.

Conflict of Interest

The authors declare that there is no conflict of interests.

Data availability statement

The data used to support the findings of this study are included within the article. Supplementary materials not published here, may be requested by respected readers from the corresponding author.

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