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*Original Article*

# Effect of warm reinforcing acupuncture combined with whole-body vibration training on knee joint function and inflammatory factors in stroke patients with knee osteoarthritis

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**Abstract:** Objective: To investigate the clinical efficacy of warm reinforcing acupuncture (WRA) combined with whole-body vibration training (WBVT) on knee joint function and inflammatory factors in patients with stroke complicated by knee osteoarthritis (KOA). Methods: A retrospective study was conducted on 207 patients with stroke complicated by KOA admitted to our hospital between March 2023 and March 2025. A total of 93 patients received WRA combined with WBVT and routine treatment (observation group); the remaining 114 patients received only routine treatment (control group). Baseline characteristics, clinical efficacy, Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) scores, Lysholm Knee Scoring Scale (LKSS) scores, Visual Analog Scale (VAS) pain scores, Barthel Index (BI) scores, and serum inflammatory factor levels (C-reactive protein [CRP], tumor necrosis factor-α [TNF-α], and interleukin-6 [IL-6]) were compared between the two groups. Results: After treatment, the observation group showed significantly greater improvement than the control group in WOMAC score (pain, stiffness, daily living function), LKSS score, VAS score, and BI score (all $P<0.001$). The observation group also had lower serum CRP, TNF-α, and IL-6 levels (all $P<0.001$). The total effective rate in the observation group was 92.47%, while it was 80.40% in the control group ($x^2=5.89$, $P=0.015$). Conclusion: The combination of WRA and WBVT can significantly improve knee joint function, relieve pain, improve self-care ability, and inhibit inflammatory responses in stroke patients with KOA. This combined treatment offers a new approach for the rehabilitation of stroke patients with KOA.

**Keywords:** Stroke, knee osteoarthritis, warm reinforcing acupuncture, whole-body vibration training

## Introduction

Stroke is one of the most debilitating neurological diseases in the world and it is major a public health challenge [1] . According to a recent report, the number of stroke cases in China has risen by 86.0% since 1990, resulting in a huge medical care burden [2]. A considerable number of stroke cases have motor dysfunction, and stroke is one of the leading causes of disability and death [3]. The heterogeneity of abnormal motor control in the knee joint is particularly evident, affecting gait stability and potentially contributing to the development and/or progression of knee osteoarthritis (KOA) due to abnormal mechanical loads [4]. KOA typically affects articular cartilage, leading to swelling and discomfort in the knee joint [5]. When KOA occurs concurrently with stroke, a vicious cycle of "disability-pain-reduction in activity" is formed, further hindering patients' mobility and reducing their quality of life [6]. Rehabilitation interventions for stroke patients with KOA are usually limited to single-modality motor training or pain relief. However, the effectiveness of treatment is often compromised due to the persistence of the inflammatory microenvironment and the slow recovery of neuromuscular con-

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trol. This necessitates the rapid exploration of synergistic intervention methods.

As part of traditional Chinese medicine, acupuncture has a long history of clinical practice and unique advantages in treating joint pain and dysfunction [7, 8]. Warm reinforcing acupuncture (WRA) is a unique acupuncture technique used in clinical practice, characterized by its specific needle insertion, manipulation, and withdrawal techniques, which can achieve the effects of promoting blood circulation, removing blood stasis, reducing swelling, and relieving pain [9]. Previous studies have shown that WRA improves joint function by improving local tissue blood flow and promoting the absorption of inflammatory factors [10, 11]. However, acupuncture alone may have limited effectiveness in treating central motor control deficits after stroke [12]. Neuroscientists recognize whole body vibration training (WBVT) as an increasingly popular neuromuscular activation method, which is said to induce reorganization of spinal reflex pathways and plasticity changes in the cortical motor areas [13]. Previous studies have confirmed that WBVT can enhance muscle tone, balance, and joint stability in stroke patients [13, 14]. However, the role of WBVT in influencing the local inflammatory microenvironment remains unclear. Moreover, excessive vibration may exacerbate joint stress, inhibiting potential synergistic value when used in combination with anti-inflammatory and analgesic treatments. Given this, this study speculates upon the combination of WRA and WBVT.

This study hypothesizes that combining WRA with WBVT may produce a dual effect of "peripheral anti-inflammatory and central plasticity promotion". Warm acupuncture can improve the local microenvironment, creating better tissue conditions for whole-body vibration training. In addition, the mechanical stress generated by whole-body vibration training will promote the biomechanical transmission of acupuncture effects, which may produce a synergistic effect. However, such combined applications are relatively rare in the research stage. The innovation of this study lies in the novel combination of WRA and WBVT, aiming to achieve a dual effect of "peripheral anti-inflammatory and central plasticity promotion". We hypothesize that this combined approach can synergistically regulate the local inflammatory microenvironment through WRA, while simultaneously promoting central nervous system reorganization and motor control through WBVT, thereby constructing a multi-target intervention system that addresses both peripheral joint lesions and central motor deficits. The findings of this study will offer new clinical insights for the rehabilitation treatment of stroke patients with KOA and provide theoretical support for the optimization of integrated traditional Chinese and Western medicine rehabilitation models.

## Materials and methods

### *Research participants*

This retrospective study included stroke patients with KOA treated at the First Teaching Hospital of Tianjin University of Traditional Chinese Medicine between March 2023 and March 2025. Patients meeting the inclusion and exclusion criteria were screened through the electronic medical record system, resulting in a final inclusion of 207 patients. Based on their different treatment regimens during hospitalization, patients were divided into an observation group (93 cases) and a control group (114 cases). All patients received routine treatment; the observation group received additional treatment including WRA combined with WBVT. This study has been approved by the Ethics Committee of the First Teaching Hospital of Tianjin University of Traditional Chinese Medicine.

### *Inclusion and exclusion criteria*

Inclusion criteria: (A) Meeting the diagnostic criteria for stroke and a clear lesion imaged by cranial CT or MRI [15]; (B) Diagnosed with KOA symptoms by imaging examination; (C) Able to cooperate with WRA combined with WBVT treatment and received at least one complete course of treatment during hospitalization; (D) Completed all examinations and had complete data during hospitalization.

Exclusion criteria: (A) Combined with severe dysfunction of important organs such as heart, liver, and kidney; (B) With contraindications to WRA (such as skin infection, bleeding tendency, etc.) or WBVT (such as severe hypertension,

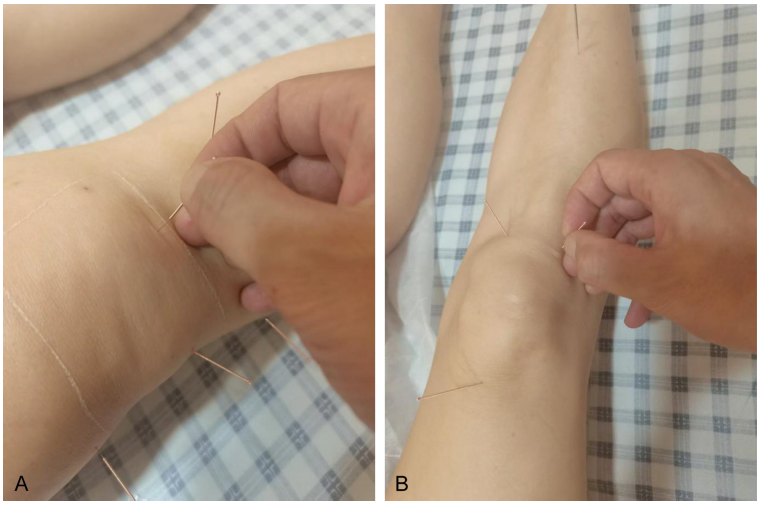

**Figure 1.** Anterior view of the lower limb showing common acupuncture points for knee osteoarthritis. A. It includes key acupoints such as Dubi and Yanglingquan; B. It includes key acupoints such as the Inner Knee eye point and the Yinlingquan point.

arrhythmia, prosthesis implantation, etc.); (C) Combined with other joint diseases such as rheumatoid arthritis and gouty arthritis; (D) Combined with malignant tumors, hematological diseases.

*WRA and WBVT treatment*

The WRA treatment was administered based on traditional Chinese medicine theory and specifically targets acupoints related to KOA (as illustrated in **Figure 1**). The technique involved a specific acupuncture methods to generate a warming sensation, believed to promote blood circulation and reduce inflammation. To ensure standardization, the acupuncture parameters were defined as follows: needles (0.25 mm × 40 mm) were inserted to a depth of 20-30 mm to achieve the desired sensation (De Qi). This was followed by a specific warming and tonifying technique, including rotating the needle forward 3-5 times, followed by 3-5 repetitions of forceful insertion and gentle lifting. This cycle was repeated until the patient reported a local warming sensation. Needles were retained for 25 minutes each time, three times a week for four weeks.

The WBVT protocol was designed to complement the WRA treatment by enhancing neuromuscular activation and improving lower limb function. Patients received WBVT training three times a week for 4 weeks. Each training session lasted 20 minutes, consisting of a 5-minute warm-up period at a low vibration frequency (15 Hz) and amplitude (2 mm), followed by three sets of 5-minute vibration training sessions (frequency of 30-40 Hz and amplitude of 4-6 m), with a 1-minute rest between sets. Patients were instructed to stand on the vibration platform with their feet shoulder-width apart and knees slightly bent to ensure proper posture and balance. The training intensity was adjusted according to the patient's tolerance and progress to promote muscle activation, improve joint stability, and enhance overall physical function.

*Data collection*

Basic information about the patients, such as age, gender, body mass index (BMI), disease duration, medical history (hypertension, diabetes), and affected side, were collected. Knee function was assessed using the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) questionnaire and the Lysholm knee scoring scale (LKSS). The WOMAC scale is a tool that allows patients to assess the extent to which knee and hip osteoarthritis interferes with their lifestyle by answering questions [16]. It includes three subscales: pain, stiffness, and activities of daily living (ADL), with a total score of 120. A higher score indicates a more severe condition. The LKSS is a patient self-assessment scale that assesses the patient's knee condition and function from the patient's perspective [17]. The score range is 0-100, with a higher score indicating better knee function and milder symptoms. Pain intensity was assessed using the Visual Analogue Scale (VAS), a simple subjective continuous scale used to measure pain intensity [18]. It typically consists of a 10-centimeter straight line with "no pain" marked at one end and "most intense pain" at the other. Patients indicate their current pain level by marking the line; a higher score indicates more intense pain. The Barthel Index (BI) was used to quantify ADL, a commonly used tool for assessing ADL in patients with disabilities or chronic diseases

**Table 1.** Comparison of baseline characteristics

| Variables | Total (n=207) | Observation group (n=93) | Control group (n=114) | Statistic | *P* |
|---|---|---|---|---|---|
| Age (year) | 71.95±7.09 | 71.54±7.35 | 72.29±6.88 | t=-0.76 | 0.449 |
| BMI (kg/m$^2$) | 21.59±0.87 | 21.53±0.86 | 21.64±0.88 | t=-0.91 | 0.364 |
| Disease course (year) | 4.34±0.34 | 4.37±0.36 | 4.31±0.32 | t=1.07 | 0.286 |
| Gender (%) | | | | $X^2$=0.18 | 0.668 |
| Male | 79 (38.16) | 34 (36.56) | 45 (39.47) | | |
| Female | 128 (61.84) | 59 (63.44) | 69 (60.53) | | |
| Hypertension (%) | | | | $X^2$=0.45 | 0.503 |
| No | 132 (63.77) | 57 (61.29) | 75 (65.79) | | |
| Yes | 75 (36.23) | 36 (38.71) | 39 (34.21) | | |
| Diabetes (%) | | | | $X^2$=0.25 | 0.616 |
| No | 170 (82.13) | 75 (80.65) | 95 (83.33) | | |
| Yes | 37 (17.87) | 18 (19.35) | 19 (16.67) | | |
| Affected side (%) | | | | $X^2$=0.07 | 0.795 |
| Left | 107 (51.69) | 49 (52.69) | 58 (50.88) | | |
| Right | 100 (48.31) | 44 (47.31) | 56 (49.12) | | |

Abbreviation: BMI, body mass index.

[19]. It includes 10 basic ADL-related items, with a total score of 0-100; a higher score indicates better functional independence. The concentrations of inflammatory factors (C-reactive protein (CRP), tumor necrosis factor-α (TNF-α), and interleukin-6 (IL-6)) were detected using enzyme-linked immunosorbent assay (ELISA). All information was obtained from the patient's medical records and laboratory test results during hospitalization.

*Criteria for clinical efficacy evaluation*

At the end of 4 weeks of treatment, a comprehensive evaluation was conducted based on symptom improvement and functional recovery, classifying clinical efficacy into three levels: (A) Markedly Effective: Significant relief of knee pain and stiffness, significant improvement in ADL, and a WOMAC total score reduction rate ≥70%; (B) Effective: Some relief of knee pain and stiffness, some improvement in ADL, and a WOMAC total score reduction rate ≥30% but <70%; (C) Ineffective: No significant relief of clinical symptoms, no significant improvement in function, and a WOMAC total score reduction rate <30%. The total effective rate was the proportion of the sum of "markedly effective" and "effective" cases to the total number of cases in the group.

*Statistical analysis*

Statistical analysis was performed using SPSS 26.0 software. Quantitative data were presented as mean ± standard deviation (SD), and categorical data were expressed as frequency (%). For comparisons of baseline characteristics between the two groups, independent samples t-tests were used for quantitative data, and chi-square tests were used for categorical data. Paired t-tests were used for within-group comparisons of the primary outcome measures, and independent samples t-tests were used for between-group comparisons. Univariate and multivariate logistic regression analyses were used to explore the association between treatment methods and efficacy. P<0.05 was considered statistically significant.

## Results

*Comparison of baseline characteristics between the two groups*

Baseline characteristics between the two groups showed no significant differences in age, body mass index (BMI), disease duration, gender, hypertension, diabetes mellitus and affected side distribution (all P>0.05), indicating comparability (**Table 1**).

*Comparison of clinical efficacy between the two groups*

The total effective rate in the control group was 80.40% (92/114), while the total effective rate in the observation group was 92.47% (86/93) (**Table 2**). The difference between the two groups was statistically significant

**Table 2.** Comparison of clinical efficacy between the two groups

| Grouping | n | Marked effect | Improvement | Ineffective | Total effective |
|---|---|---|---|---|---|
| Observation group | 93 | 49 (52.69) | 37 (39.78) | 7 (7.52) | 86 (92.47) |
| Control group | 114 | 53 (46.49) | 39 (34.21) | 22 (19.30) | 92 (80.40) |
| $x^2$ value | | | | | 5.89 |
| *P* value | | | | | 0.015 |

**Table 3.** Independent influence of treatment methods on the effective rate

| Variables | Univariate Logistic | | | Multivariate Logistic* | | |
|---|---|---|---|---|---|---|
| | β | *P* | OR (95% CI) | β | *P* | OR (95% CI) |
| Control group | | | 1.00 (Reference) | | | 1.00 (Reference) |
| Observation group | 1.08 | 0.019 | 2.94 (1.19-7.23) | 1.12 | 0.016 | 3.06 (1.23-7.59) |

*Multivariate analysis was conducted to adjust for confounding factors: age, gender, and BMI. Abbreviation: OR, odds ratio; CI, confidence interval.

**Table 4.** Comparison of WOMAC scores between the two groups

| Grouping | n | Pain | | Stiffness | | Daily life | | Total score | |
|---|---|---|---|---|---|---|---|---|---|
| | | Before treatment | After treatment | Before treatment | After treatment | Before treatment | After treatment | Before treatment | After treatment |
| Observation group | 93 | 15.78±2.46 | 3.16±0.50* | 6.58±1.32 | 1.12±0.32* | 58.27±6.16 | 18.62±2.47* | 80.63±7.15 | 22.90±2.68* |
| Control group | 114 | 15.93±2.52 | 4.25±0.62* | 6.44±1.52 | 1.83±0.66* | 57.83±6.09 | 25.27±3.53* | 80.20±6.50 | 31.36±3.70* |
| t value | | -0.42 | -14.08 | 0.71 | -10.11 | 0.51 | -15.88 | 0.46 | -19.04 |
| *P* value | | 0.678 | <.001 | 0.480 | <.001 | 0.611 | <.001 | 0.649 | <.001 |

*Compared with before treatment, P<0.001. Paired sample t-test was used. Abbreviation: WOMAC, Western Ontario and McMaster Universities.

($\chi^2$=5.89, P=0.015), indicating that the combined treatment regimen had a significant advantage in improving the clinical symptoms of KOA patients.

*Independent influence of treatment methods on efficacy*

Logistic regression analysis was performed with treatment effect as the dependent variable (1: total effective; 0: ineffective) and treatment method as the independent variable. The results showed that the combined treatment of WRA and WBVT was significantly associated with better treatment outcomes (OR=2.94, 95% CI: 1.19-7.23, P=0.019) (**Table 3**). This association remained after adjusting for confounding factors (age, gender, BMI), indicating that the combined treatment approach had an independent effect on treatment efficacy.

*Comparison of WOMAC scores between the two groups*

Before treatment, there were no statistically significant differences in the total WOMAC score and scores of each dimension (pain, stiffness, ADL) between the two groups (all P>0.05) (**Table 4**). After treatment, the total WOMAC score and scores of each dimension in both groups decreased significantly (P<0.001). The observation group showed greater improvement in pain, stiffness, ADL, and total score than the control group (all P<0.001), suggesting that the combined treatment regimen was significantly effective in relieving knee pain, improving stiffness symptoms, and enhancing ADL.

*Comparison of LKSS scores between the two groups*

Before treatment, there was no statistically significant difference in the LKSS scores between the two groups (P>0.05). After treatment, the LKSS scores in both groups significantly improved (P<0.001), with the observation group showing greater improvement than the control group (P<0.001), indicating that combined treatment effectively improved knee joint function (**Figure 2**).

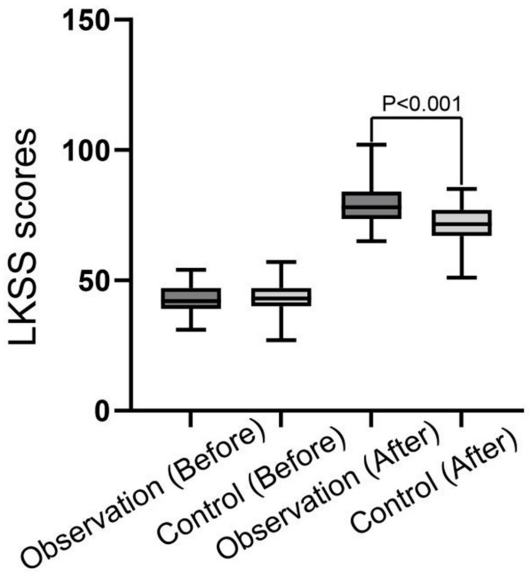


**Figure 2.** Comparison of LKSS scores between the two groups. Abbreviation: LKSS, Lysholm knee scoring scale.

*Comparison of pain scores between the two groups*

Before treatment, there was no statistically significant difference in VAS scores between the two groups (P>0.05) (**Table 5**). After treatment, VAS scores in both groups significantly decreased (P<0.001), with the observation group showing a greater decrease than the control group (P<0.001), indicating that combined treatment was effective in relieving pain.

*Comparison of BI scores between the two groups*

Before treatment, there was no statistically significant difference in BI scores between the two groups (P>0.05) (**Table 5**). After treatment, the BI scores of both groups significantly improved (P<0.001), and the improvement in the BI score of the observation group was significantly greater than that of the control group (P<0.001), indicating that the combined treatment had a significant effect on improving patients' self-care ability.

*Comparison of serum inflammatory factor levels between the two groups*

Before treatment, there were no statistically significant differences in CRP, TNF-α and IL-6 levels between the two groups (all P>0.05) (**Figure 3**). After treatment, the CRP, TNF-α and IL-6 levels in both groups significantly decreased (all P<0.001), and the decrease in the observation group was greater than that in the control group (all P<0.001), suggesting that the combined treatment can effectively inhibit the expression of serum inflammatory factors and reduce the inflammatory response.

## Discussion

Patients with stroke complicated by KOA often face the dual challenges of impaired motor function and persistent inflammatory microenvironment, and the clinical efficacy of existing single rehabilitation methods is limited [20]. This study innovatively applied the combination of WRA and WBVT in the rehabilitation treatment of patients with stroke complicated by KOA. The results showed that the observation group was significantly better than the control group in improving knee joint function, relieving pain, inhibiting inflammatory response and improving ADL. The results of this study not only provide a new clinical approach for the rehabilitation treatment of patients with stroke complicated by KOA, but also provide a theoretical basis for optimizing the integrated traditional Chinese and Western medicine rehabilitation model. First, the results confirmed that the treatment plan of WRA combined with WBVT significantly improved knee joint function. The decrease in the WOMAC score indicated that the patient's knee pain, stiffness, and ADL have been significantly improved; while the increase in the LKSS score further confirmed the efficacy of this combined therapy in improving the overall function of the patient's knee joint. At present, there are relatively few research reports on WRA, but existing studies have confirmed that WRA has a therapeutic effect on KOA. Chang et al. found through a randomized controlled study that warm acupuncture can significantly improve the WOMAC index in patients with KOA [21]. In addition, Sun et al. also reported that warm acupuncture has a definite curative effect on knee joint function in patients with KOA [22]. In related studies, in addition to WRA, other acupuncture therapies also showed significant clinical effects, which further confirmed the important value of acupuncture in the treatment of KOA. Its mechanism of action may be related to WRA improving the local microenvironment of the knee joint by regulating local blood circulation and pro-

**Table 5.** Comparison of VAS and BI scores between the two groups

| Grouping | n | VSA | | BI Index | |
|---|---|---|---|---|---|
| | | Before treatment | After treatment | Before treatment | After treatment |
| Observation group | 93 | 7.15±0.83 | 2.67±0.47* | 18.34±3.62 | 29.16±6.13* |
| Control group | 114 | 7.08±0.77 | 3.54±0.50* | 18.81±3.77 | 24.09±5.62* |
| t value | | 0.64 | -12.85 | -0.90 | 6.20 |
| *P* value | | 0.521 | <.001 | 0.372 | <.001 |

*Compared with before treatment, P<0.001. Paired sample t-test was used. Abbreviation: VAS, Visual Analogue Scale; BI, Barthel Index.

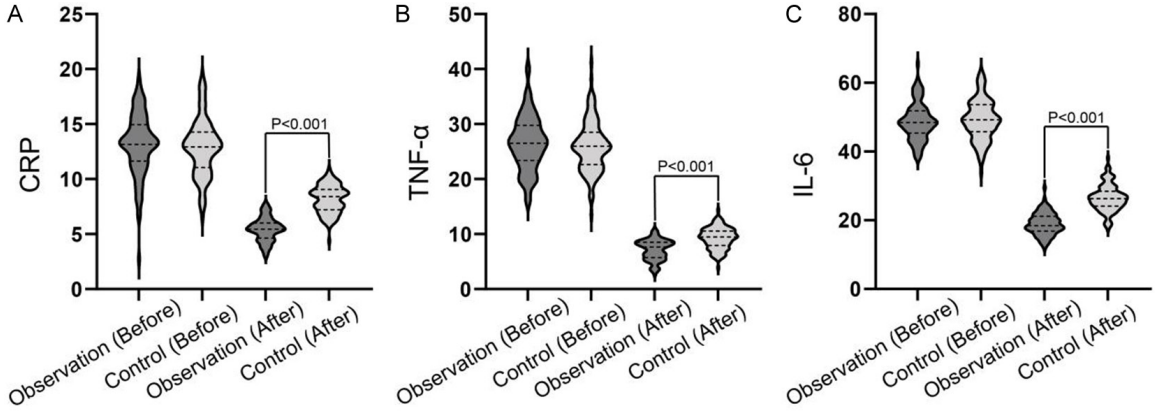


**Figure 3.** Comparison of serum inflammatory factors between the two groups. A. CRP; B. TNF-α; C. IL-6. Abbreviation: CRP, C-reactive protein; TNF-α, tumor necrosis factor-alpha; IL-6, interleukin-6.

moting the absorption of inflammatory factors [23]. The specific principle of this mechanism of action has been verified in some animal models. Kong et al. found through observation of a rat model of cerebral hemorrhage that acupuncture may intervene in the inflammatory response by regulating the expression of microRNA-23a-3p (miR-23a-3p) [24]. Studies by Wang et al. have shown that acupuncture can significantly inhibit the expression of inflammatory factors in the hippocampus and plasma of rats, and have confirmed that it can reduce the inflammatory response through the Mir-93-mediated TLR4/MyD88/NF-κB signaling pathway [25]. This study speculates that WRA may reduce the local inflammatory response and improve the synovial microenvironment and blood perfusion by modulating pathways such as miR-23a-3p and TLR4/MyD88/NF-κB, thereby creating favorable tissue conditions for the implementation of subsequent WBVT. WBVT can stimulate proprioceptive afferents through mechanical vibration, promote the remodeling of spinal reflex pathways and plasticity changes in the motor cortex [26]. This central neural remodeling can synergistically improve the control ability of muscles around the knee joint and joint stability [27]. It can be seen that the anti-inflammatory and microcirculation-improving effects of WRA may enhance the neuromuscular system's responsiveness to the mechanical stimulation of WBVT. Previous studies have shown that WBVT has a significant effect on improving the somatic motor function and knee extensor strength of patients with KOA [28]. In this study, the treatment plan of WRA combined with WBVT may be able to improve the knee joint function of patients more effectively by achieving the synergistic effect of "peripheral anti-inflammatory - central plasticity promotion". In clinical application, this combined therapy is expected to provide a more comprehensive rehabilitation intervention plan for patients with stroke and KOA, especially in improving knee joint dysfunction.

The combined treatment also showed significant effects in pain management and self-care ability improvement. Pain relief may be related to the analgesic effect of WRA and the improve-

ment of muscle strength and balance ability by WBVT [29, 30]. Moreover, the improvement in self-care ability may stem from the improvement of knee joint function and the improvement of the patient's overall physical fitness. Future studies can further explore the efficacy of this combined regimen in patients with different types of stroke complicated with KOA. Regarding the regulation of serum inflammatory factor levels, CRP, TNF-α, and IL-6 levels in the observation group were significantly reduced after treatment, and the reduction was greater than that in the control group. This suggests that WRA combined with WBVT can effectively inhibit the expression of serum inflammatory factors and reduce the inflammatory response. Inflammation plays an important role in the pathogenesis of KOA, and the inflammatory microenvironment after stroke may further aggravate joint damage [31, 32]. By inhibiting the expression of inflammatory factors, the combined treatment may help break the vicious cycle of "functional impairment-pain-reduced activity" and thus promote patient rehabilitation. In clinical application, this combined regimen can serve as an effective anti-inflammatory approach, and when combined with other rehabilitation therapies, it can provide a more comprehensive treatment strategy for stroke patients with KOA.

This study has some limitations. First, as a retrospective study, it may be subject to selection and information bias. Although inclusion and exclusion criteria were established to maximize patient homogeneity, the non-randomized controlled design prevented the exclusion of confounding factors. Second, the small sample size and short observation period may limit the assessment of long-term efficacy and potential side effects. Furthermore, the detailed analysis of patients' neurological function recovery was not conducted, thus the contribution of the combined treatment to post-stroke neurological function recovery could not be clearly defined. Future research could employ prospective randomized controlled trials with larger sample sizes and longitudinal study designs. The follow-up period could be extended, and neurological function assessment indicators could be included. This would help to more comprehensively evaluate the efficacy and safety of WRA combined with WBVT. Nevertheless, the results of this study indicate that this combined treatment has the potential for operational standardization and expansion in clinical translation. Through clinical training and promotion, standardized procedures for WRA (e.g., needle depth, rotation angle, and retention time) can be achieved, while the modular design of the whole-body vibration training equipment (e.g., adjustable vibration frequency and amplitude) can adapt to patients with different functional states. For ischemic stroke patients, rapidly delivering oxygen-rich blood to the brain can prevent the death of brain cells that are typically very sensitive to hypoxia. Simultaneously, monitoring serum inflammatory factors can be used to predict efficacy. Furthermore, based on the significant reduction in inflammatory markers and marked functional improvement observed in this study, we can preliminarily stratify the patient population most likely to benefit from this combined treatment. Patients with elevated baseline levels of serum inflammatory factors (e.g., CRP>5 mg/L or IL-6>5 pg/mL) may be the ideal target subgroup, as the anti-inflammatory effects of warm acupuncture may be particularly beneficial for them. Meanwhile, stroke survivors with moderate knee joint dysfunction (e.g., baseline WOMAC score between 40 and 80 or LKSS score between 40 and 60) and relatively preserved cognitive function, who are able to adhere to the WBVT protocol might achieve the most significant functional improvement. This combined treatment appears to address the core pathophysiological issue of "inflammation-functional impairment-pain" in this comorbidity population. Future prospective studies with pre-specified subgroup analyses are necessary to validate these preliminary observations and refine patient selection criteria, ultimately paving the way for personalized rehabilitation programs.

## Conclusion

This retrospective analysis explored the clinical efficacy of WRA combined with WBVT in stroke patients with KOA. The study revealed that the combined treatment significantly improved knee joint function, reduced pain, enhanced self-care ability, and inhibited the expression of serum inflammatory factors. The results provide a more effective rehabilitation solution for

the clinical challenge of post-stroke knee osteoarthritis. This program has dual effects of peripheral anti-inflammatory and central nervous system function regulation, and its operation has the potential for standardization. Standardized operation and modular design of equipment hold promise for clinical application, improving patients' quality of life and reducing disease burden.

## Disclosure of conflict of interest

None.

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