Effect of resistance rotational correction manipulation for the knee joint on joint force line and joint temperature in patients with knee osteoarthritis: a randomized controlled trial

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Abstract

Introduction: Knee osteoarthritis (KOA) is a common chronic degenerative disease in middle-aged and elderly people, characterized by joint pain, functional impairment, and abnormal joint alignment. Knee joint resistance rotation therapy, a traditional Chinese medicine massage technique, has been reported to have clinical benefits, but research on its effects and mechanisms in regulating joint alignment and knee temperature is limited. The aim of the study was to observe the effects of knee joint resistance rotation therapy compared with conventional massage on pain, function, joint alignment, and joint temperature in patients with KOA, and to explore its clinical effects and possible mechanisms of action.

Material and methods: A single-blind, randomized controlled trial was conducted, including 40 patients with knee osteoarthritis (KOA) who visited the outpatient department of the Affiliated Hospital of Shandong University of Traditional Chinese Medicine from October 2020 to July 2021. They were randomly divided into a treatment group (resisted knee rotation) and a control group (routine massage), with 20 patients in each group. Both groups received treatment twice a week for a total of 3 weeks. Pain intensity was assessed using the Visual Analogue Scale (VAS) before and after treatment, joint function was assessed using the Knee Injury and Osteoarthritis Outcome Score (KOOS), joint alignment was assessed by measuring the angle between the tibial articular surface and the long axis of the femur using X-ray, and temperature changes in different areas of the knee joint were detected using infrared thermography.

Results: Ultimately, 34 patients (19 in the treatment group and 15 in the control group) completed the study (6 dropped out, dropout rate 15%). After treatment, VAS scores in both groups were significantly lower than before treatment (treatment group: 5.21 ±1.72 vs. 1.26 ±1.10, $p < 0.001$; control group: 5.20 ±1.61 vs. 1.73 ±1.03, $p < 0.001$), but the difference between the groups was not statistically significant (MD = –0.47, 95% CI: –1.22 to 0.28, $p = 0.212$). Both groups showed significant improvements in KOOS scores across dimensions such as pain, symptoms, and activities of daily living

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compared to pre-treatment levels ($p < 0.05$). Furthermore, the treatment group had lower reported scores than the control group for pain (8.63 ±3.70 vs. 11.80 ±3.12, MD = –3.17, 95% CI: –6.02 to –0.32, $p = 0.012$), activities of daily living (10.53 ±5.58 vs. 15.00 ±6.20, MD = –7.47, 95% CI: –12.56 to –0.38, $p = 0.034$), and total score (48.21 ±15.96 vs. 60.33 ±8.68, MD = –12.12, 95% CI: –22.01 to –2.23, $p = 0.012$). After treatment, the angle between the tibial articular surface and the long axis of the femur increased significantly from baseline in the treatment group compared to before treatment (98.10 ±2.56 vs. 99.78 ±2.45, $p = 0.046$), while there was no statistically significant difference in the control group ($p > 0.05$). After treatment, the temperature in multiple areas of the anterior and posterior knee joint was significantly lower in the treatment group compared to before treatment ($p < 0.05$), while there was no statistically significant difference in temperature in the control group ($p > 0.05$).

Conclusions: Knee joint resistance rotation therapy may improve pain, joint function, joint alignment, and knee temperature in patients with knee arthritis (KOA). Although some KOOS outcomes favored this therapy over conventional massage, the between-group difference in VAS scores was not statistically significant.

Key words: fascia, helical force line, joint force line, knee osteoarthritis, knee temperature, resistance rotational correction manipulation for the knee joint, Tuina.

Introduction

Knee osteoarthritis (KOA) is a common musculoskeletal disease, which is one of the important causes of limb dysfunction and even disability [1]. According to epidemiological studies, approximately 3.8% of the global population suffers from knee osteoarthritis [2], while the prevalence increases significantly in people over 60 years of age, with approximately 9.6% of men and 18% of women having symptomatic osteoarthritis [3]. KOA can be divided into primary and secondary types. Primary KOA is mainly related to factors such as age, genetics, and obesity, while secondary KOA is usually associated with identifiable causes, such as joint injury, congenital malformation, or metabolic diseases [4, 5]. The main clinical manifestations of this disease are joint pain, swelling, deformity, stiffness, and functional impairment [6, 7]. The impact on patients' quality of life includes not only joint pain and functional impairment, but also sleep disorders and depression [3, 8–10].

Treatment of KOA emphasizes comprehensive management, with non-pharmacological therapies playing a crucial role. Manual therapy, as a non-pharmacological approach, may help relieve pain and improve function. Resisted knee rotation is a technique developed by the author and used in clinical practice to treat KOA. Its advantages include ease of application, and preliminary observations have suggested that it may quickly alter knee joint alignment, relieve pain, and reduce limitations in range of motion. However, high-quality research on the specific effects and potential mechanisms of this technique is still lacking.

This study aimed to evaluate the clinical efficacy of resisted knee rotation in patients with KOA through a randomized controlled trial, and to preliminarily explore its possible mechanisms of action. The Visual Analogue Scale (VAS) and Knee Injury and Osteoarthritis Outcome Scale (KOOS) were used as outcome measures. We hypothesized that patients receiving resisted knee rotation would show greater improvements in VAS and KOOS scores than the control group receiving conventional massage therapy. Secondary outcome measures included knee alignment, assessed by X-ray measurements of the tibiofemoral angle, and local surface temperature distribution (measured by infrared thermography). We further hypothesized that resisted knee rotation may produce therapeutic effects through biomechanical pathways (such as changes in joint alignment) and/or physiological pathways (such as changes in local blood circulation and metabolism).

Material and methods

Research design

This study was a prospective, single-blind, randomized controlled trial conducted at the outpatient department of the Affiliated Hospital of Shandong University of Traditional Chinese Medicine from October 2020 to July 2021. The study protocol was approved by the Medical Ethics Committee of the Affiliated Hospital of Shandong University of Traditional Chinese Medicine (approval number: (2020) Lun Shen No. (031)-KY), and all participants provided written informed consent.

Research subjects

Recruitment procedures: 1) Recruitment location: Outpatient Department of Tuina (Chinese massage) at the Affiliated Hospital of Shandong University of Traditional Chinese Medicine. 2) Recruitment Period: October 2020 to July 2021. 3) Recruitment methods: Screening of outpatients, in-hospital posters, and recruitment through online community platforms (such as WeChat official accounts and WeChat Moments). 4) Recruitment

Process: Eligible participants provided written informed consent, completed baseline assessments, and were then randomly assigned to their respective treatment groups.

Inclusion criteria: 1) Meeting the diagnostic criteria for knee osteoarthritis (KOA) in the Guidelines for Diagnosis and Treatment of Osteoarthritis revised by the Chinese Rheumatology Branch in 2010 [11]; 2) age 40–75 years; 3) voluntarily joining this trial and signing informed consent.

Exclusion criteria: 1) History of knee trauma and surgery; 2) knee tumors, tuberculosis, osteomyelitis, or other relevant infections; 3) psoriasis, syphilitic neuropathy, ochronosis, metabolic bone disease and acute trauma; 4) severe liver and kidney dysfunction, severe cardiovascular disease, diabetes and mental illness; 5) anterior or posterior cruciate ligament injury, collateral ligament injury, meniscal tear, or fracture.

Withdrawal and termination criteria: 1) Poor compliance that compromised the evaluation of efficacy; 2) unforeseen reasons, such as serious adverse events, or specific physiological changes (such as pregnancy) that prevented continuation of the trial; 3) use of other relevant treatments during the trial, which affected the efficacy rating; 4) voluntary withdrawal from the trial; 5) failure to attend scheduled follow-up visits.

Forty patients with KOA who met the inclusion criteria were recruited and randomly assigned in a 1 : 1 ratio to the treatment group (n = 20) and the control group (n = 20). One patient in the treatment group withdrew because a business trip prevented attendance at scheduled follow-up visits, leaving 19 patients to complete the study. In the control group, 5 patients withdrew because they were unable to attend follow-up visits regularly, leaving 15 patients to complete the study. A total of 34 patients (19 in the treatment group and 15 in the control group) were ultimately included in the analysis (6 withdrawals, overall attrition rate 15%). All analyses followed the intention-to-treat (ITT) principle. The participant flow is shown in Figure 1.

Sample size calculation

The sample size was calculated using a two-sample t-test with PASS 26.0 software. The significance level was set at α = 0.05 (one-sided test, based on the prespecified hypothesis that resisted knee rotation improves pain and joint function in patients with KOA), with 80% power. The estimated effect sizes for the primary outcome measures (VAS score and KOOS score) were: a difference of 1.0 point in VAS score between groups and a difference of 3.0 points in KOOS pain score between groups. The final required total sample size was 34 patients, with 17 patients in each group. Considering a potential dropout rate of 10%, the planned sample size was increased to 40 patients, who were randomly assigned to the treatment group and the control group in a 1 : 1 ratio.

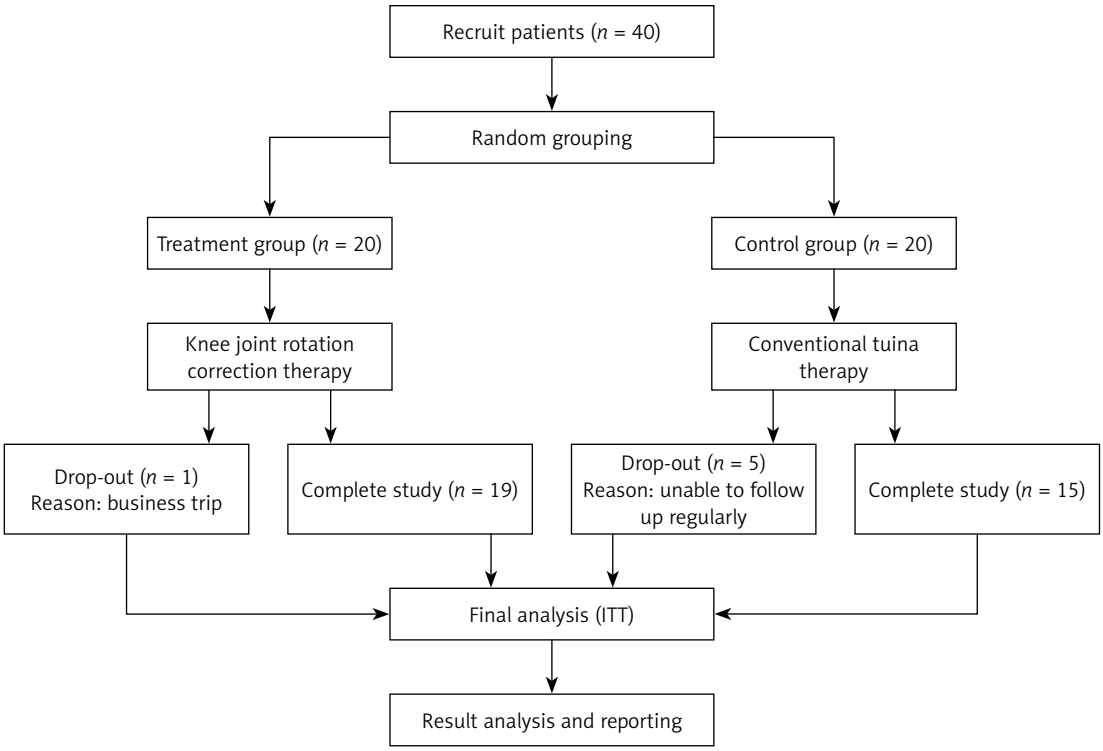

Figure 1. Subject flowchart

Randomization and blinding

Randomization was performed using computer-generated random numbers (Excel RAND function) and a four-block permutation randomization method, randomly assigning subjects to two groups in a 1 : 1 ratio. Random sequence generation and allocation concealment were performed by an independent statistician using a sealed envelope method.

Implementation of blinding

Blinding of participants and treatment operators: Complete blinding was not feasible because of the substantial differences between the two interventions. Outcome assessors and statistical analysts were blinded to group allocation.

Measures to maintain blinding: a) Outcome assessors only knew the subject's identification number and were unaware of the grouping information; they avoided discussing treatment-related content with subjects during the assessment process; b) Identification numbers were used instead of group information during statistical analysis, and the group allocation code was not revealed until the analysis was complete.

Therapeutic method

Study group: treatment using knee joint resistance rotation technique

The procedure was as follows:

1) Measurement of internal and external knee eye position: The highest point of the tibial tuberosity was designated and marked as Point O. Points A and B were located 3 cm to either side in the horizontal direction. Vertical lines were then drawn from Points A and B, and their intersections with the tibial plateau were designated Points C and D, respectively. Points C and D were marked, and the height difference between them was recorded. The angle between the line connecting Points C and D and the horizontal line was measured, and the triangle formed by Points O, A, and B was also assessed.
2) Application of the knee joint resistance rotation technique: Both thumbs were placed on either side of the tibial tuberosity, while the other four fingers of each hand encircled and stabilized the popliteal fossa from behind the knee. Both hands simultaneously applied a twisting force in the same direction, from the higher of Points C and D towards the lower point. The patient was instructed to apply an opposing force in the opposite direction. The clinician and patient worked together to achieve an isometric contraction involving the knee joint. The opposing force was set at the maximum force the patient could exert in the opposite direction. Each resistance was maintained for 15 s. During the procedure, the palms were kept relatively fixed against the skin without friction, while allowing the skin and subcutaneous tissue to slide relative to the underlying structures. The technique was repeated three times.
3) Repeat measurement: The heights of Points C and D, representing the medial and lateral knee reference points, were measured again.

Treatment was performed twice a week for 3 weeks.

Control group

Conventional Tuina was used for treatment, with the stated aims of relaxing the meridians and collaterals, promoting blood circulation, removing blood stasis, releasing adhesions, and lubricating the joints. The procedures followed the treatment methods for knee osteoarthritis described in the textbook Tuina, published by People's Medical Publishing House as part of the 13th Five-Year Plan.

1) Muscle-relaxing techniques: Rolling and kneading techniques were applied to the muscles around the knee joint (quadriceps, hamstrings, medial and lateral collateral ligaments) for 5 min;
2) Acupressure: Acupressure was applied to the inner and outer knee eyes, Yanglingquan, and Zusanli acupoints for 30 s each;
3) Joint mobilization: Passive knee flexion and extension movements were performed 10 times, with the intensity adjusted to the patient's tolerance.

Treatment was administered twice a week for 3 weeks.

Observational indicators

Primary outcome scale

VAS scores: used to assess pain intensity (0 points for no pain, 10 points for severe pain). Assessments were conducted before treatment, 1 week after treatment, 2 weeks after treatment, and 3 weeks after treatment began.

KOOS (Knee Injury and Osteoarthritis Outcome Score): The KOOS comprises five subscales: pain, symptoms, activities of daily living, motor and recreational functions, and knee-related quality of life, with 42 items in total. In this study, a reverse-scoring method was used, meaning that higher scores indicate more severe symptoms or problems. This differs from the standard KOOS scoring system, in which scores range from 0 (extreme problems) to 100 (no problems). This scoring approach should be clearly defined, and subsequent studies will use the standard scoring method (0 points = extreme problems; 100 points

= no problems). Assessments were conducted before treatment and on the day after the treatment course ended.

Secondary outcome indicators

X-ray examination: Because the manual therapy was performed with the knee flexed in a non-weight-bearing position, in which the difference between the medial and lateral knee reference points was considered more pronounced, and because the knee flexion angle could be visually assessed, the following imaging protocol was adopted. Patients lay supine with their knees flexed to 15° and their toes pointing forward, with the toes, ankles, knees, and hips aligned. Anteroposterior X-ray images of the knee were obtained, and the angle between the tibial articular surface and the long axis of the femur was measured. Examinations were performed before treatment and on the day after treatment ended.

Infrared thermography: All infrared thermographic measurements were performed in a temperature-controlled chamber maintained at 24 ±1°C and 40–60% humidity to minimize the influence of ambient temperature and humidity on the results. Before testing, patients sat quietly in the chamber for 15 min to allow their skin temperature to stabilize. The equipment was calibrated by professional engineers before the study, including temperature, distance, and image calibration. Images were obtained from a standard distance of 2.5–2.6 m, with patients in a standard posture with their fingers together and palms facing forward at ear level. Two infrared images (anterior and posterior views) were obtained to determine the average temperature (AAT) of the knee surface projection area. The upper and lower boundaries of the overall knee region of interest were defined as 8 cm above and below the popliteal crease, respectively; the medial and lateral boundaries were defined by the medial-most and lateral-most vertical lines of the knee. The region was further divided into four areas: inferomedial, inferolateral, superolateral, and superomedial. Mean temperatures were calculated for each of these four areas and the overall region. Examinations were performed before treatment and on the day after treatment ended.

Measurement reliability assessment: Secondary outcome measures were assessed in 10 patients by two independent physicians, with a two-week interval between measurements. The intraclass correlation coefficient (ICC) was used to assess measurement reliability. The results showed high intra-rater reliability (two measurements by the same physician: ICC = 0.92, 95% CI: 0.85–0.96) and good inter-rater reliability (measurements by two physicians: ICC = 0.89, 95% CI: 0.81–0.94).

Bias control

Selection bias: Random number tables were used allocate patients to the two groups. Strict inclusion/exclusion criteria were followed during recruitment to standardize participant selection.

Execution bias: All treatment operators were massage therapists with over 5 years of clinical experience, and treatment was performed strictly according to standardized procedures to minimize variation in treatment delivery.

Measurement bias: Blinding was implemented for outcome assessors and statistical analysts to minimize bias during outcome assessment and data analysis. X-ray measurements and infrared thermography were performed using standardized procedures, and measurement reliability was assessed.

Loss-to-follow-up bias: Dropout patients were followed up by telephone to understand the reasons for dropout. Intention-to-treat (ITT) principles were used for statistical analysis to reduce the impact of loss-to-follow-up bias on the results.

Statistical analysis

SPSS 26.0 statistical software was used for data analysis. Normally distributed continuous data were expressed as means ± standard deviations (SDs). Between-group comparisons were performed using independent-samples *t*-tests when the assumption of equal variances was met, and Welch's *t*-test otherwise. Paired sample *t* test was used for intra-group comparison. Count data were expressed by frequency, and χ^2 test was used for comparison between groups. $P < 0.05$ was considered to be statistically significant. Prism 9 was used to generate figures.

Grubbs' test ($\alpha = 0.05$) was used to identify univariate outliers. When a potential outlier was identified, the data were first checked for measurement or data-entry errors, and any errors were corrected. For genuine extreme values, sensitivity analyses using robust statistical methods (e.g., medians and interquartile ranges) were performed to assess the stability of the results.

Results

Comparison of general data between the two groups

In the control group, 5 patients withdrew because they were unable to attend regular hospital visits, and in the study group, 1 patient withdrew because of a business trip. Finally, a total of 34 patients were included in the analysis. There were no significant differences in lesion site, sex, course of disease, age, height and weight between the two groups ($p > 0.05$) (Table I).

Comparison of VAS scores before and after treatment between the two groups

Before treatment, there was no statistical significance in VAS scores between the two groups ($p > 0.05$), indicating comparability. After treatment, VAS scores decreased significantly in both groups compared with baseline (treatment group: 5.21 ±1.72 vs. 1.26 ±1.10, $p < 0.001$; control group: 5.20 ±1.61 vs. 1.73 ±1.03, $p < 0.001$). There was no significant difference in VAS scores between Study group and Control group (MD = –0.47, 95% CI: –1.22–0.28, $p = 0.212$, $p > 0.05$) (Table II).

The mean baseline VAS score was similar in the two groups. After the first treatment session, the reduction in VAS score was greater in the study group, but the between-group difference was not statistically significant ($p = 0.068$). No statistically significant between-group differences were observed at the other treatment time points (Figure 2).

Comparison of KOOS scores before and after treatment between the two groups

Before treatment, there was no statistical significance in KOOS scores between the two groups ($p > 0.05$), indicating comparability. After treatment, KOOS scores for pain, symptoms, activities of daily living, sport and recreational function, quality of life, and the total score decreased in both groups ($p < 0.05$). Between-group differences were statistically significant for pain (8.63 ±3.70 vs. 11.80 ±3.12, MD = –3.17, 95% CI: –6.02 to –0.32, $p = 0.012$, Cohen's $d = –0.92$), activities of daily living (10.53 ±5.58 vs. 15.00 ±6.20, MD = –7.47, 95% CI: –12.56 to –0.38, $p = 0.034$, Cohen's $d = –0.77$), and the total score (48.21 ±15.96

Table I. Comparison of general data between the two groups

Group	Case	Lesion site [Case (%)]		Lesion site [Case (%)]		Course of disease [years]	Age [years]	Height [cm]	Weight [kg]
		Left knee	Right knee	Male	Female				
Study	19	9 (47.37)	10 (52.63)	9 (47.37)	10 (52.63)	4.31 ±0.59	60.11 ±10.12	169.35 ±9.03	72.10 ±10.11
Control	15	6 (40.00)	9 (60.00)	3 (20.00)	12 (80.00)	4.23 ±0.66	59.93 ±9.96	165.95 ±6.90	67.95 ±9.98
χ^2/t value		0.185		2.749		0.372	0.051	1.205	1.195
P-value		0.667		0.097		0.355	0.958	0.236	0.241

Table II. Comparison of VAS scores before and after treatment between the two groups (mean ± SDs, score)

Time	Study ($n = 19$)	Control ($n = 15$)	*t* value	*P*-value
Before T	5.21 ±1.72	5.20 ±1.61	0.017	0.986
1st week after T	2.42 ±1.50	3.47 ±1.73	–1.894	0.067
2nd week after T	1.89 ±1.10	2.40 ±1.45	–1.167	0.251
3rd week after T	1.26 ±1.10	1.73 ±1.03	1.271	0.212
F value	30.247	15.714	–	–
P-value	< 0.001	< 0.001	–	–

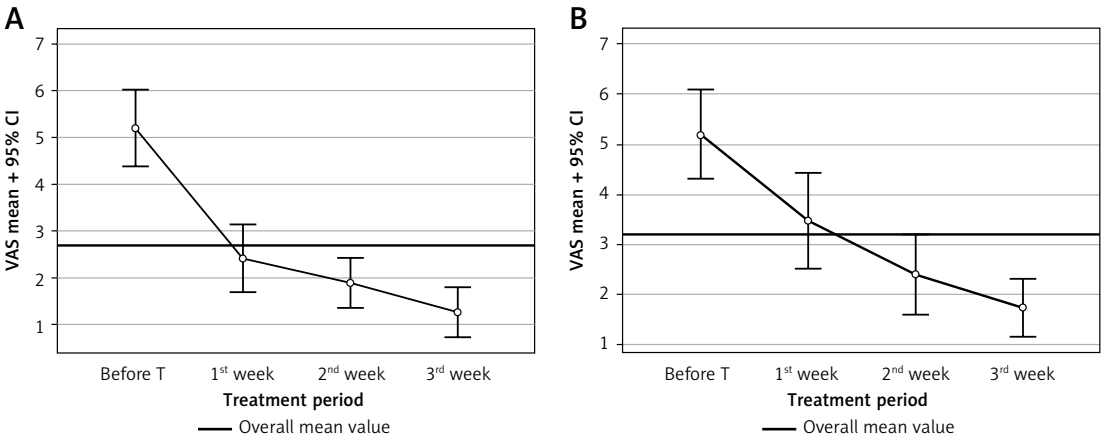

Figure 2. Mean VAS scores of different treatment periods: **A** – VAS scores in study group, **B** – VAS scores in control group

vs. 60.33 ±8.68, MD = –12.12, 95% CI: –22.01 to –2.23, p = 0.012, Cohen's d = –0.92). Scores were lower in the treatment group than in the control group for these outcomes. No statistically significant between-group differences were observed for sport and recreational function or quality of life (p > 0.05) (Table III).

Comparison of imaging angles and changes in angles between the two groups before and after treatment

At baseline, there was no statistically significant difference in imaging angles between the two groups (p > 0.05). After treatment, the imaging angle (the angle between the tibial articular surface and the long axis of the femur) increased significantly in the study group (98.10 ±2.56° vs. 99.78 ±2.45°, p = 0.046), whereas no statistically significant within-group difference was observed in the control group (p > 0.05). There was no statistically significant difference in imaging angles between the two groups after treatment (p > 0.05). However, the change in imaging angle was significantly greater in the treatment group than in the control group (1.68 ±0.84° vs. –0.19 ±1.26°, MD = 1.87°, 95% CI: 1.16–2.58°, p < 0.001, Cohen's d = 1.79) (Table IV).

Comparison of knee temperature before and after treatment between the two groups

At baseline, there was no statistically significant difference in anterior knee temperature between the two groups (p > 0.05). After treatment, anterior knee temperature decreased significantly from baseline in the study group (p < 0.05), whereas no statistically significant within-group difference was observed in the control group (p > 0.05). There was no statistically significant difference in anterior knee temperature between the groups after treatment (p > 0.05). To assess the stability of the results, a sensitivity analysis was conducted according to the prespecified statistical protocol. After exclusion of the outlier, anterior knee temperature was significantly lower in the treatment group than in the control group (p < 0.05). This finding should be interpreted cautiously, as the outlier may reflect genuine individual variation (Table V, Figure 3). At baseline, there was no statistically significant difference in posterior knee

Table III. Comparison of KOOS scores before and after treatment between the two groups (mean ± SD, score)

KOOS subscale	Time	Study (n = 19)	Control (n = 15)	t value	P-value
Pain	Before treatment	17.63 ±2.39	15.89 ±3.65	1.675	0.103
	After treatment	8.63 ±3.70	11.80 ±3.12	2.653	0.012
	t value	8.906	3.298		
	P-value	< 0.001	0.002		
Symptoms	Before treatment	17.53 ±2.67	15.20 ±4.31	1.936	0.061
	After treatment	12.11 ±2.89	11.67 ±3.44	0.405	0.687
	t value	6.004	2.479		
	P-value	< 0.001	0.019		
Activities of daily living	Before Treatment	23.00 ±9.92	21.67 ±8.41	0.414	0.681
	After Treatment	10.53 ±5.58	15.00 ±6.20	2.208	0.034
	t value	4.775	2.472		
	P-value	< 0.001	0.019		
Sport and recreational function	Before treatment	11.74 ±2.13	11.73 ±3.43	0.010	0.991
	After treatment	7.53 ±3.12	9.13 ±2.41	1.636	0.111
	t value	4.857	2.402		
	P-value	< 0.001	0.023		
Knee-related quality of life	Before treatment	11.05 ±1.22	11.67 ±1.95	1.135	0.264
	After treatment	9.42 ±1.98	9.73 ±1.44	0.508	0.614
	t value	3.055	3.099		
	P-value	0.004	0.004		
Total score	Before treatment	81.05 ±12.59	75.07 ±14.64	1.280	0.209
	After treatment	48.21 ±15.96	60.33 ±8.68	2.643	0.012
	t value	7.041	3.354		
	P-value	< 0.001	0.002		

Table IV. Comparison of imaging angles and changes in angles between the two groups before and after treatment (mean ± SD)

Index	Study (n = 19)	Control (n = 15)	t value	P-value
Angle difference before and after treatment	1.68 ±0.84	–0.19 ±1.26	5.182	< 0.001
Before treatment	98.10 ±2.56	98.56 ±2.80	–0.499	0.621
After treatment	99.78 ±2.45	98.37 ±2.96	0.830	0.413
t value	2.066	0.180		
P-value	0.046	0.857		

Table V. Comparison of anterior knee temperature before and after treatment between the two groups (mean ± SD)

Areas	Time	Study (n = 19)	Control (n = 15)	t value	P-value
Anterior knee					
AAT-inner lower	Before T	31.43 ±1.51	31.30 ±0.59	0.314	0.337
	After T	30.20 ±1.65	29.93 ±3.76	0.281	0.780
	t value	2.397	1.394		
	P-value	0.020	0.174		
AAT-outer lower	Before T	32.01 ±1.45	31.68 ±3.54	0.370	0.713
	After T	30.73 ±1.62	30.21 ±3.90	0.527	0.601
	t value	2.566	1.080		
	P-value	0.015	0.288		
AAT-outer upper	Before T	30.81 ±1.41	30.53 ±0.70	0.702	0.487
	After T	29.41 ±1.52	29.45 ±3.86	0.041	0.967
	t value	2.943	1.066		
	P-value	0.005	0.295		
AAT-inner upper	Before T	30.85 ±1.58	30.77 ±0.80	0.178	0.859
	After T	29.83 ±1.44	29.63 ±3.91	0.206	0.837
	t value	2.079	1.106		
	P-value	0.044	0.278		
AAT-comprehensive	Before T	31.29 ±1.46	31.06 ±0.55	0.577	0.567
	After T	30.14 ±1.52	29.80 ±3.85	0.352	0.726
	t value	2.378	1.255		
	P-value	0.022	0.219		

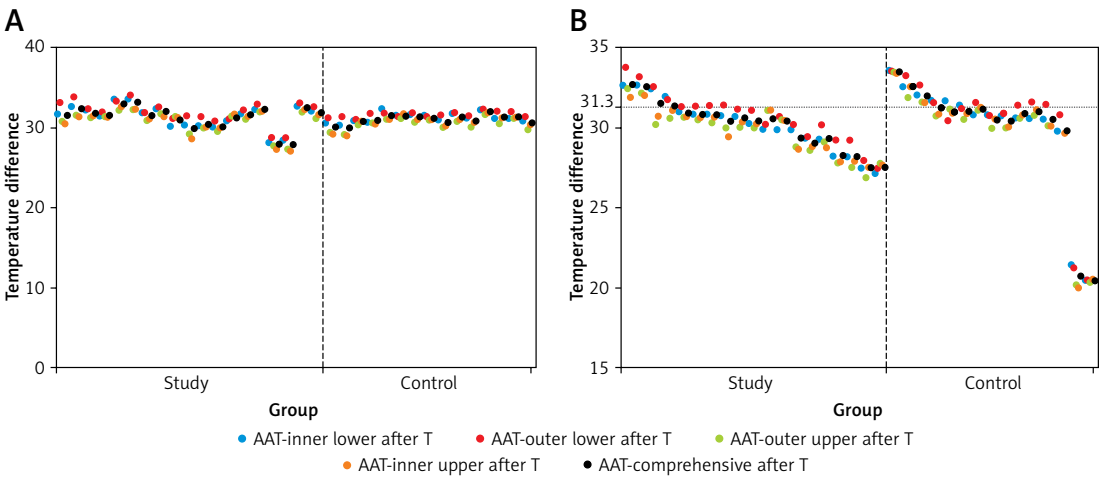

Figure 3. Mean temperature of anterior knee before (**A**) and after (**B**) treatment

temperature between the two groups ($p > 0.05$). After treatment, posterior knee temperatures in the inferomedial, superolateral, superomedial, and overall regions decreased significantly from baseline in the study group ($p < 0.05$), whereas the change in the inferolateral region was not statistically significant ($p > 0.05$). No statistically significant within-group differences were observed in the control group ($p > 0.05$). There were no statistically significant between-group differences in posterior knee temperature after treatment ($p > 0.05$) (Table VI).

Further analysis identified one outlier in the control group using Grubbs' test ($p < 0.05$). In a sensitivity analysis excluding this outlier, post-treatment posterior knee temperature was significantly lower in the treatment group than in the control group ($p < 0.05$). This finding should be interpreted cautiously because the outlier may reflect genuine individual variation (Figure 4). After treatment, most anterior and posterior knee temperature measurements decreased in the study group (Figure 5), whereas temperatures generally increased in the control group (Figure 6). In the study group, the largest de-

Table VI. Comparison of posterior knee temperature before and after treatment between the two groups (mean ± SD)

Areas	Time	Study (n = 19)	Control (n = 15)	t value	P-value
Posterior knee					
AAT-inner lower	Before treatment	31.25 ±1.53	31.31 ±0.57	0.143	0.443
	After treatment	30.10 ±1.45	29.93 ±3.93	0.174	0.862
	t value	2.378	1.345		
	P-value	0.022	0.189		
AAT-outer lower	Before treatment	31.20 ±1.48	31.30 ±0.77	0.237	0.814
	After treatment	30.42 ±1.42	29.86 ±3.94	0.575	0.569
	t value	1.657	1.389		
	P-value	0.106	0.175		
AAT-outer upper	Before treatment	31.46 ±1.39	31.54 ±0.71	0.202	0.841
	After treatment	30.45 ±1.46	30.24 ±3.83	0.220	0.827
	t value	2.183	1.292		
	P-value	0.035	0.206		
AAT-inner upper	Before treatment	31.85 ±1.42	31.97 ±0.61	0.303	0.763
	After treatment	30.80 ±1.44	30.62 ±3.84	0.188	0.851
	t value	2.263	1.344		
	P-value	0.029	0.189		
AAT-comprehensive	Before treatment	31.42 ±1.44	31.54 ±0.63	0.300	0.766
	After treatment	30.41 ±1.42	30.16 ±3.89	0.259	0.796
	t value	2.176	1.356		
	P-value	0.036	0.186		

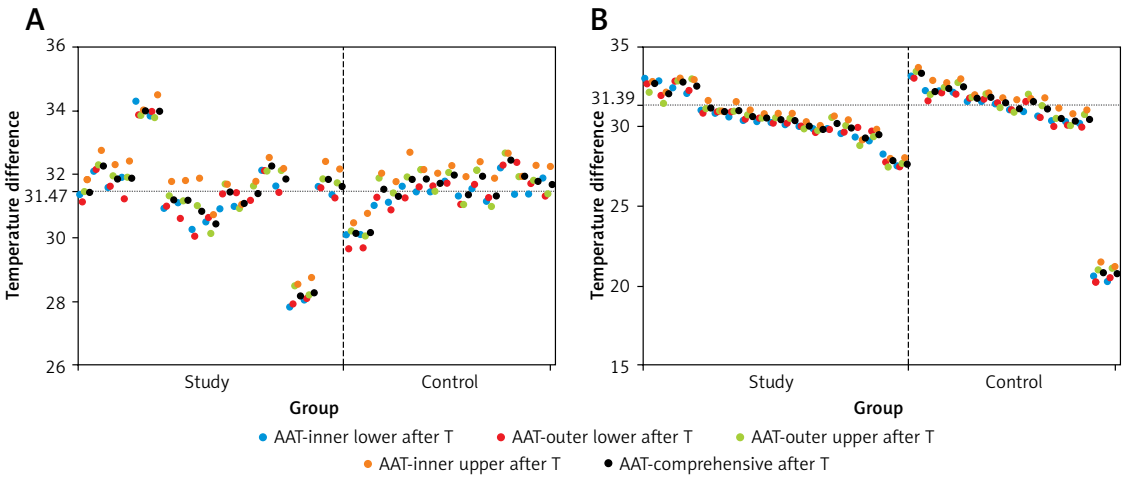

Figure 4. Mean temperature of posterior knee before (**A**) and after (**B**) treatment

crease in anterior knee temperature occurred in the inferolateral region, followed by the inferomedial region. For the posterior knee, the largest decrease occurred in the superomedial region, followed by the superolateral region (Figure 7).

Discussion

Epidemiological investigation shows that KOA is more common in middle-aged and elderly people, and its prevalence is higher in women than in men. The prevalence of KOA is reported to be 10–17% in people aged 40, 50% in people over 60, and 80% in people over 75 [12]. Age-related changes in periarticular ligaments may contribute to joint instability, altered load distribution, and cartilage damage, potentially contributing to the development of KOA [13–15]. The main risk factors for KOA include aging, genetic predisposition, mechanical stress, obesity, underlying anatomical abnormalities, and trauma [16, 17]. Abnormal loading of articular cartilage and mechanical wear may be important contributors to KOA develop-

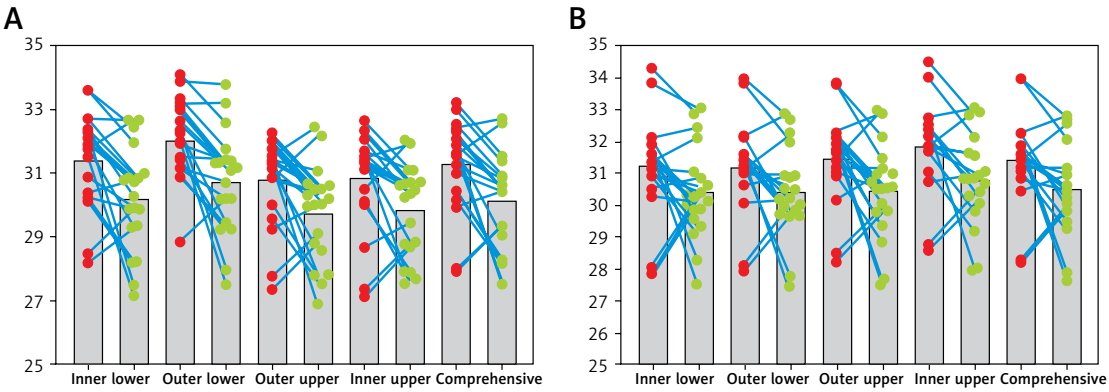

Figure 5. Temperature before and after treatment in study group (**A** – anterior knee, **B** – posterior knee)

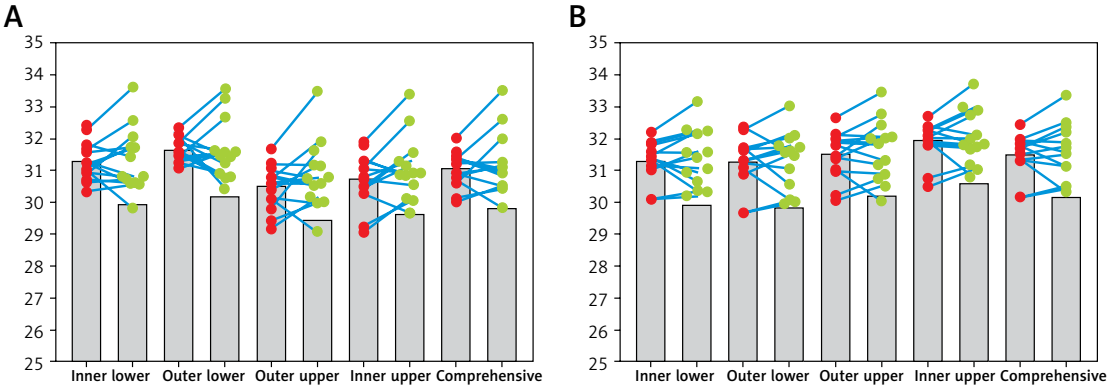

Figure 6. Temperature before and after treatment in control group (**A** – anterior knee, **B** – posterior knee)

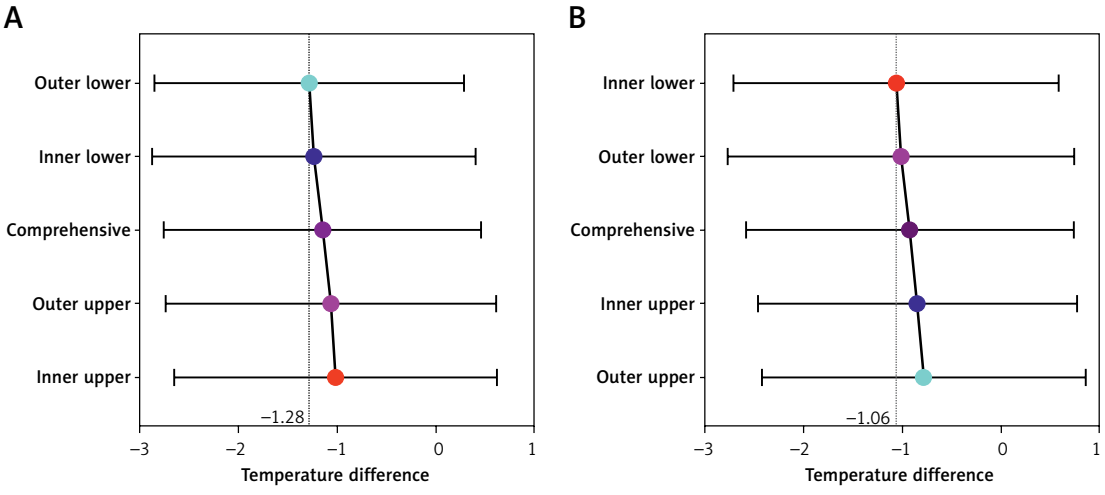

Figure 7. Temperature difference before and after treatment in study group (**A** – anterior knee, **B** – posterior knee)

ment [18–20]. It is widely recognized that changes in lower-limb alignment and the resulting alterations in joint loading are associated with the occurrence and development of knee osteoarthritis [21, 22]. Therefore, maintaining or improving lower-limb alignment and knee joint load distribution may be relevant to KOA management [23–25]. However, although knee replacement can correct lower-limb alignment in selected patients with advanced KOA, it is an invasive procedure with potential complications, including postoperative pain, infection, and limited functional recovery [26, 27]. Other treatments may provide symptomatic relief, but their long-term benefits vary [28].

The authors' clinical observations suggested that the heights of the medial and lateral knee reference points differed in patients with KOA, with the medial point generally higher than the lateral point. Following knee joint resistance rotation therapy, the difference in height appeared to change rapidly. The authors also observed improvements in knee pain, reduced range of motion, and other clinical symptoms, as well as swelling, effusion, and palpable nodular cords. These changes were accompanied by a perceived return of the skin and fascia around the knee to their normal flexibility and pliability.

In this study, both the treatment group and the control group showed a significant decrease in VAS scores after treatment, indicating improvements in pain in both groups. However, the treatment group showed significantly lower KOOS scores for pain, activities of daily living, and the total score than the control group. Given the reverse-scoring method used in this study, these findings may indicate greater improvement in the treatment group, provided that the scoring and reported statistics are correct. Imaging measurements showed that the angle between the tibial articular surface and the long axis of the femur in the treatment group increased significantly after treatment, while there was no significant change in the control group. Although the between-group difference in change was statistically significant, these findings do not by themselves establish that the technique corrects knee alignment by altering the relative position of the tibial plateau. Abnormal lower limb alignment is considered an important risk factor for the progression of KOA, and manual intervention to correct abnormal alignment may delay the degenerative process of articular cartilage [29]. Although the 15° knee flexion imaging position used in this study may have limited the accuracy of alignment assessment, the between-group difference in angle change suggests that the technique may influence the measured imaging angle; its clinical significance remains uncertain.

Infrared thermography showed decreases in temperature in some regions of the knee after treatment. Local temperature increases are usually related to synovial inflammation, release of pro-inflammatory factors (such as IL-6 and TNF-α), and synthesis of prostaglandins [30, 31]. However, surface temperature changes alone cannot establish changes in synovial inflammation or inflammatory mediator activity. Although studies of similar manual therapies may provide a rationale for further investigation [32–34], the proposed anti-inflammatory mechanism was not directly tested in this study.

Although fascial tension, ligament biomechanics, and specific inflammatory mediator levels were not directly measured in this study, possible mechanisms of the technique were explored based on clinical observations and studies of similar interventions. These hypotheses concern the potential roles of spiral force transmission and fascial tension. Patients with KOA may experience altered muscle activation and joint loading, potentially contributing to changes in joint space and cartilage loading [30]. Studies have suggested that resistance exercise can activate the core muscles and the gluteus medius–iliotibial band kinetic chain, potentially modifying lower-limb loading and improving joint stability [35]. Resistance training has also been associated with reduced serum IL-6 and TNF-α levels in patients with KOA [33]. Myofascial compression therapy may alter tissue mobility through mechanical shear, potentially affecting tissue sliding and the viscoelastic properties of the extracellular matrix [34]. Low-intensity resistance training based on myofascial chains may also modify tension distribution between the superficial anterior and posterior lines, potentially reducing anterior knee soft-tissue tension and strengthening the posterior muscle groups [36]. Whether these changes can alter the relative position of the tibial plateau remains uncertain.

Knee joint resisted rotation manipulation combines patient-generated isometric resistance with manual mechanical stimulation of the periarticular tissues. It is hypothesized that these components may influence muscle activation, tissue mobility, and joint loading, potentially contributing to changes in symptoms and measured alignment. However, the present study did not directly assess these mechanisms. The proposed roles of fascial tension, spiral force transmission, and inflammatory modulation should therefore be regarded as hypotheses rather than conclusions supported by the study data. Future research incorporating biomechanical assessments, appropriate imaging methods, and measurements of inflammatory biomarkers could help test these

hypotheses and clarify the mechanisms, if any, underlying the clinical effects of resisted knee rotation manipulation.

This study has several limitations. First, multiple-comparison correction was not performed, and it is unclear whether the outlier-handling procedures were prespecified, potentially increasing the risk of false-positive findings. The sample size was small, the design was single-center, and the follow-up time was insufficient, affecting the extrapolation of results and long-term efficacy assessment. X-ray measurements were affected by patient positioning, while infrared thermography was susceptible to environmental influences, potentially reducing measurement accuracy. The intervention was compared only with conventional Tuina, without direct comparisons with other treatment approaches, and its proposed mechanisms of action were not directly investigated. Furthermore, the potential for attrition bias was not adequately assessed, and baseline characteristics were not compared between participants who completed the study and those who withdrew. The lack of stratified analyses by KOA severity may have obscured differences in treatment response among patients with different levels of disease severity. The relationships between biomechanical measurements and clinical outcomes were also not examined, limiting the interpretation of the proposed mechanisms.

Future studies should address these limitations through larger, multicenter trials with longer follow-up, appropriate active comparators, and better control of potential confounding factors. Outlier-handling procedures should be prespecified, and appropriate methods for addressing multiple comparisons should be considered. X-ray positioning protocols should be standardized, and environmental conditions for infrared thermography carefully controlled. Attrition bias should be assessed by comparing baseline characteristics between participants who complete the study and those who withdraw, and appropriate methods should be used to address missing outcome data. Stratified analyses by KOA severity could help identify potential differences in treatment response. Finally, analyses of the associations between biomechanical measurements and clinical outcomes may help evaluate the proposed mechanisms, although direct mechanistic studies would be needed to establish them.

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Ethical approval

This study was approved by the Medical Ethics Committee of the Affiliated Hospital of Shandong University of Traditional Chinese Medicine, Batch number: (2020) Lunshen No. (031) – KY.

Conflict of interest

The authors declare no conflict of interest.

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