MATHEWS

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Clinical Study on the Dose-Effect Relationship Regarding Manipulation Frequency of Three-Dimensional Balanced Spinal Manipulation for Cervical Spondylotic Radiculopathy

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ABSTRACT

Purpose: To investigate the dose-effect relationship of three-dimensional balanced fixation spine manipulation for Cervical Spondylotic Radiculopathy (CSR). **Materials and methods:** We retrospectively analyzed 108 CSR patients treated with three-dimensional balanced spinal manipulation from February 2022 to February 2024. A total of 36 patients were included in the study according to the inclusion and exclusion criteria. The control group (n = 19) received three-dimensional balanced spinal manipulation every other day. The observation group (n = 17) received the same manipulation twice daily. Outcomes included clinical efficacy, Traditional Chinese Medicine (TCM) syndrome scores (pain, numbness, dizziness, fatigue), pain severity, cervical function, cervical range of motion (ROM), intervertebral height of the diseased segment, and cervical physiological curvature. **Results:** The observation group's effective rate (96.30%) was significantly higher than the control group's (81.48%) ($P < 0.05$). Post-treatment TCM symptom scores (pain, numbness, dizziness, fatigue) were significantly lower in the observation group compared to controls ($P < 0.05$). Pain scores and cervical dysfunction (NDI) were lower, while cervical ROM was higher in the observation group post-treatment ($P < 0.05$). The observation group also showed significantly greater improvement in intervertebral height, cervical physiological curvature, and intervertebral foramen size post-treatment ($P < 0.05$). **Conclusions:** A dose-effect relationship exists for three-dimensional balanced fixation spine manipulation in CSR treatment. Twice daily manipulation yielded superior clinical efficacy, symptom reduction, functional improvement, and radiographic outcomes compared to every other day treatment.

Keywords: Cervical Spondylosic Radiculopathy, Three-Dimensional Balanced Positive Ridge Technique, Dose-Effect Relationship, Pain Level.

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INTRODUCTION

Cervical Spondylotic Radiculopathy (CSR) is a common type of cervical spondylosis caused by cervical degeneration - induced nerve root lesions, which brings on neck-shoulder pain and stiffness, and numbness and weakness in the upper limbs and fingers, thus undermining patients' quality of life [1]. Current CSR treatments involve surgical and non-surgical options. While surgery can remove lesions and improve cervical spine function, its drawbacks like high invasiveness, long recovery, and many complications make it less acceptable to patients [2].

Three-Dimensional Balance Spinal Manipulation, a traditional Chinese orthopedic manual therapy, is based by spinal anatomy, physiology, and biomechanics [3]. It combines traction, compression, brushing, fascia-separating, plucking, and rotational manipulation to correct spinal misalignment and restore biomechanical balance [4]. This therapy, which integrates Chinese and Western medicine, adjusts the spine's 3D mechanics based on meridian theory and the tendon-bone realignment concept [5]. However, its actual efficacy needs more research. Studies indicate that factors like treatment frequency, the force, and the thrust's direction angle significantly impact the therapy's effectiveness and are tied to a cumulative effect [6,7]. In this way, this study explores the clinical efficacy of Three-Dimensional Balance Spinal Manipulation on CSR by comparing twice daily and every other day treatment regimens.

MATERIALS AND METHODS

Study Design and Participants

This study was a retrospective, randomized, controlled clinical trial conducted between February 2022 and February 2024. A total of 36 patients diagnosed with CSR were enrolled from a single tertiary care center and randomized in a 1:1 ratio to receive either conventional three-dimensional balance spinal manipulation (control group) or an enhanced three-dimensional cervical spine adjusting technique (observation group). Randomization was performed using a computer-generated randomization sequence and allocation was concealed using sealed, opaque envelopes. The study protocol was approved by the Institutional Review Board (IRB number: NO. 202401003, 2023026), and written informed consent was obtained from all participants.

Baseline demographic and clinical characteristics were comparable between groups. In the control group, there were 6 males and 12 females (mean age, 44.9 years; range, 32–50 years), with an average disease duration of 21 months (range, 6–48 months). The observation group comprised 4 males and 14 females (mean age, 41.8 years; range, 29–50 years), also with an average disease duration of 21 months.

Diagnostic Criteria

According to the Chinese Society of Rehabilitation Medicine's Guidelines for the Diagnosis, Treatment, and Rehabilitation of Cervical Spondylosis (2010) and the Expert Consensus on the Standardization of Diagnosis and Treatment of Cervical Spondylosis-Related Radiculopathy (2015), the diagnosis of CSR should meet the following criteria: (1) Neck pain or stiffness with upper limb radiating pain. (2) Decreased sensation in the skin segment of the affected nerve root, abnormal tendon reflexes, muscle atrophy, reduced muscle strength. (3) Positive brachial plexus traction test or foraminal compression test. (4) Cervical X-ray shows vertebral body proliferation, obvious uncovertebral joint proliferation, narrowed intervertebral space and foramen, CT shows posterior vertebral body osteophytes and narrowed nerve root canal. (5) Exclude pain caused by other lesions.

Traditional Chinese Medicine Syndrome Diagnosis Criteria

Based on the 2012 revised edition of the "Standards for Diagnosis and Treatment of Traditional Chinese Medicine Diseases" the diagnostic criteria for the "stasis-syndrome" type of cervical spondylosis are as follows: (1) Main symptoms: Neck stiffness and pain, upper limb pain, neck constriction, restricted movement, numbness in hands and arms; (2) Secondary symptoms: Dull complexion, dry and dull skin; (3) Tongue appearance: Pale or dark tongue, white or thin white coating; (4) Pulse: Deep and fine or fine and Se; (5) Diagnosis can be made with ≥3 main symptoms, ≥1 secondary symptom, combined with tongue and pulse signs.

Inclusion and exclusion criteria

The inclusion criteria for the present study were as follows: (1) Meet the above diagnostic criteria; (2) Aged 30 - 50; (3) Disease duration ≤5 years; (4) If previously received other manual or conservative treatments, complete a 5 - day washout period; (5) Patient or legal guardian provides informed consent and signs the consent form.

The exclusion criteria for the present study were as follows: (1) Cervical tumors, tuberculosis, osteomyelitis, or severe osteoporosis. (2) Suspected spinal cord injury with spinal trauma; (3) Developmental spinal canal stenosis (canal ratio <0.75); (4) Severe cardiovascular, pulmonary, cerebral, or hematological diseases; (5) Severe skin damage or dermatological diseases at the treatment site; (6) Other

types of cervical spondylosis (e.g., myelopathic); (7) Previous cervical surgery or cervical deformity; (8) Pregnant, planning pregnancy, or breastfeeding women; (9) Unable to complete the study due to mental illness or cognitive/emotional disorders.

Dropout Criteria for the present study were as follows: (1) Poor compliance during the trial, withdrawal from the study. (2) Serious adverse reactions/complications or worsening of condition during the study. (3) Failure to follow treatment protocols or incomplete observation data affecting assessment. Any of these leads to case withdrawal.

Infrared Thermography (MTI)

Infrared thermographic imaging was performed using an MTI-series digital medical infrared camera (8–14 μm, passive thermography) in a temperature-controlled room (22 ± 1 °C, relative humidity 45–60%). Before each examination, participants rested for 15 minutes to allow thermal adaptation, with the neck and upper limbs exposed. On the day of measurement, subjects were instructed to avoid topical liniments/patches and vigorous physical activity. The distance between the camera and the participant was maintained at 1.2–1.5 m. A low-reflective background was used, and direct airflow towards the subject was avoided. Two-point calibration was performed before each session according to the manufacturer's protocol. Imaging views included: posterior view of the cervical and shoulder region; anterior and posterior views of the upper limbs; and dorsal view of both hands, each acquired once.

Time points: Thermographic data were collected at the same treatment time points as the clinical rating scales for group-level analysis. In addition, paired "pre-treatment vs. immediate post-treatment" images were obtained for participants receiving the intervention.

Paired MTI measurements: An MTI exploratory subgroup was defined within the total sample, including an experimental group (n = 5) and a control group (n = 5). Each participant in this subgroup underwent paired "pre-treatment–immediate post-treatment" imaging at the same treatment time point to evaluate short-term changes in temperature asymmetry. If any image within a pair was invalid due to motion artifacts or environmental interference, the corresponding paired data for that participant at that time point were excluded, in order to preserve pairing integrity and reduce potential bias.

Treatment

All participants were randomly assigned to two groups: the control group receiving conventional Three-Dimensional Balance Spinal Manipulation once every two days, and the observation group receiving an enhanced version of the Three-Dimensional Cervical Spine Adjusting Technique twice daily.

Before treatment, each participant underwent three-dimensional spinal posture assessment to identify deviations in curvature, segmental rotation, lateral shifting, and load-bearing imbalance. Manual palpation and functional tests were used to identify symptomatic segments.

Patients were positioned in a lateral decubitus posture. The therapist applied a combination of kneading, plucking, rolling, and pinching techniques on the cervical and shoulder girdle muscles, targeting acupoints including Jiaji, Fengchi, Jianjing, Tianzong, Quchi, Waiguan, and Houxi. This aimed to relax the surrounding soft tissues, release local adhesions, and promote neurovascular circulation in the upper limbs.

After muscle relaxation, targeted spinal manipulation was performed. The therapist used one hand to stabilize the head and neck, while the other applied localized thumb pressure to the lateral side of the spinous process of the affected vertebra. Through a combination of axial traction, lateral bending, and rotational mobilization toward the contralateral healthy side, a low-amplitude high-velocity thrust was delivered to reposition the vertebra. A characteristic joint cavitation ("popping" sound) was often noted, suggesting successful joint release and tension relief.

Following the initial manipulation, the patient was repositioned to allow adjustment on the contralateral side. Upon completion of bilateral manipulation, the therapist gently shook and extended the patient's wrists and fingers to ensure upper limb muscle relaxation and energy flow restoration.

Throughout the intervention, patient responses such as muscle tone, pain intensity, and passive mobility were monitored. Treatment intensity was individualized according to tolerance and neuromuscular feedback. No medication, anesthesia, or mechanical devices were used during the intervention.

Observation Indices

The efficacy of treatment was evaluated on days 1, 3, 5, 7, 9, 11, and 13 during treatment, as well as at 1 month and 3 months after treatment during patient follow-up.

The TCM syndrome score was used as the primary observation indicator to evaluate the patient treatment outcomes: covering neck-shoulder pain, upper-limb pain/

numbness, and neck stiffness, scored 0–6 (0: no symptom, 2: mild, 4: moderate, 6: severe). A reduction of ≥90% in TCM syndrome score, with muscle strength and function returning to normal, is considered recovery; a reduction of 75% to 89% in TCM syndrome score, with muscle strength and function approaching normal levels, is considered markedly effective; and a reduction of 30% to 74% in TCM syndrome score, with some improvement in muscle strength and function, is considered to be improved. Failure to meet the above criteria is considered ineffective treatment. Based on TCM Guidelines for Clinical Research, the total effective rate was calculated as:

$$\text{Effective Rate} = \frac{(\text{Recovered} + \text{Markedly effective} + \text{Improved})}{\text{Total cases}} * 100\%$$

Visual analog scales (VAS, 0–10 points) were used to measure patient pain. The cervical dysfunction index (NDI) and Tanaka symptom quantification scale were used to assess functional recovery. JOA scores and SF-36 were used to assess neurological function and health-related quality of life. Recurrence, retreatment, and adverse events were recorded using case report forms (CRFs).

Statistical Analysis

Statistical analyses were conducted using GraphPad Prism (GraphPad Software Inc., USA). Continuous variables were expressed as mean ± standard deviation (SD) and compared using independent-sample t-tests. Categorical data were presented as frequencies and percentages and compared using the chi-square test. $P < 0.05$ was considered statistically significant.

Missing data were handled using listwise deletion. No imputation was performed. Sensitivity analyses were not applicable due to the small sample size and complete dataset at follow-up.

CASE PRESENTATION

Comparison of Clinical Efficacy Between the Two Groups

As shown in Table 1, the effective rate of treatment in the observation group was 94.73%, which was higher than 88.23% in the control group.

Table 1. Comparison of clinical efficacy between two groups [n (%)]

Group	Cases	Cured	Significantly Effective	Ineffective	Effective treatment	Effective rate
Observation group	19	15（78.94）	2（10.52）	1（5.26）	1（5.26）	18（94.73）
Control group	17	13（76.47）	1（5.88）	1（5.88）	2（11.76）	15（88.23）

Comparison of TCM Syndrome Scores Between the Two Groups

The results demonstrated that three-dimensional balanced spine manipulation exerted a dose-dependent therapeutic effect in patients with CSR. Compared to the control group, the observation group showed significantly greater clinical improvement across multiple outcome measures (Figure 1A). Specifically, the VAS scores for pain decreased progressively in both groups over the treatment period, however, the reduction was significantly more pronounced in the observation group ($P < 0.05$), indicating superior analgesic efficacy with increased treatment frequency. In terms of cervical spine function, the Neck Disability Index (NDI) scores revealed a more substantial improvement in the observation group than in the control group ($P < 0.01$), suggesting enhanced functional recovery with intensive intervention (Figure 1B). Furthermore, scores on the Tanaka Yasuhisa Cervical Spondylosis Symptom Scale also declined more markedly in the observation group, reflecting a greater overall reduction in symptom severity ($P < 0.0001$) (Figure 1C). These findings collectively support the presence of a positive dose-response relationship in the application of this spinal manipulation technique, with twice daily sessions yielding more favorable therapeutic outcomes.

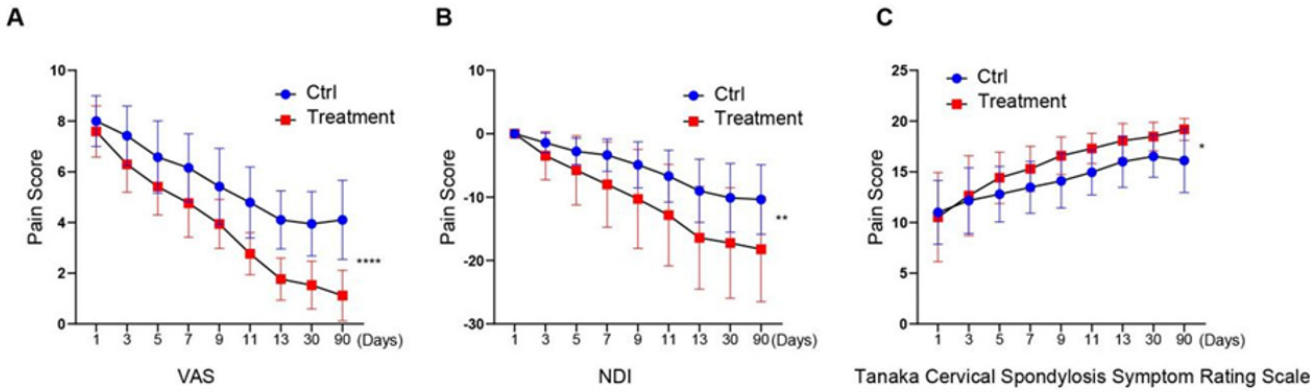

Figure 1. The therapeutic efficacy of three-dimensional balanced positive spine manipulation in CSR showed a dose-effect relationship. **(A)** Change in VAS score over time, showing greater pain relief in the observation group compared to the control group. **(B)** Change in NDI, demonstrating better cervical functional recovery in the observation group. **(C)** Change in Tanaka Yasuhisa Cervical Spondylosis Symptom Scale, with the observation group (twice daily treatment) showing more significant improvement than the control group. Data are presented as mean ± SEM; *p < 0.05, **p < 0.01, ***p < 0.0001 by two-way ANOVA.

Comparison of Pain, Cervical Function, and Tanaka Symptom Quantification Scores Between the Two Groups

As shown in Table 2, before treatment, the two groups had no significant differences in pain intensity, NDI scores, or Tanaka Symptom Quantification scores (P > 0.05). After treatment, the observation group had lower pain intensity and NDI scores but a higher Tanaka Symptom Quantification score than the control group (P < 0.05).

Table 2. Comparison of Pain Levels, Cervical Function, and Cervical Movement (in points, $\bar{x} \pm s$)

Group	Cases	VAS		NDI		TH	
		Before	After	Before	After	Before	After
Observation group	19	5.91 ± 0.84	1.46 ± 0.35	24.17 ± 3.72	12.33 ± 2.04	141.16 ± 6.44	155.62 ± 8.17
Control group	17	5.88 ± 0.82	2.69 ± 0.41	24.25 ± 3.67	16.72 ± 2.26	141.05 ± 6.37	148.25 ± 7.08
t	--	0.19	16.77	0.11	10.60	0.09	5.01
P	--	0.85	< 0.001	0.91	< 0.001	0.93	< 0.001

Exploratory MTI Thermography: Pre-/Post-Treatment Case Readout

Exploratory MTI analyses were performed in both the control and treatment groups at pre- and post-intervention time points (Figure 2A). At baseline, no significant differences in MTI-derived temperature parameters were observed between the Control and Treatment groups (all P > 0.05; Figure 2B). Following the intervention, a marked decrease in regional skin temperature was detected in the Treatment group, whereas only minimal changes were observed in the Control group (Figure 2C). The more pronounced post-treatment temperature reduction in the Treatment group suggests a superior therapeutic response following the combined intervention (Figure 2D).

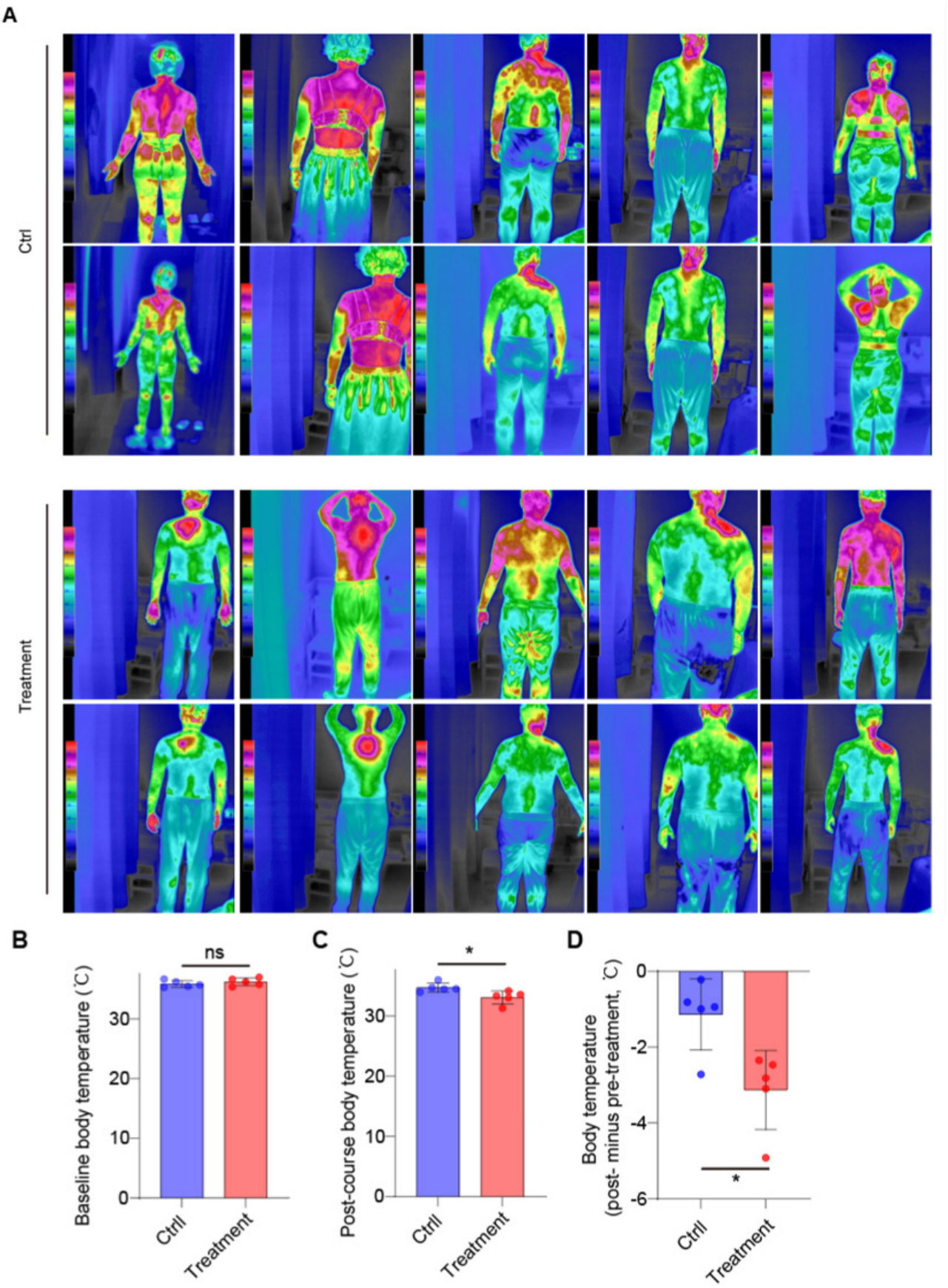

Figure 2. MTI thermography: changes in regional skin temperature before and after treatment. **(A)** Representative MTI thermograms of the treatment and control groups obtained immediately before and after a single treatment session. **(B)** Baseline comparison of MTI-derived temperature parameters between control and treatment groups, showing no statistically significant differences (all $P > 0.05$). **(C)** Pre- to immediate post-treatment changes in regional skin temperature in both groups. Data are presented as mean ± SEM; *$P < 0.05$; ns, $P > 0.05$ by paired t-test).

Comparison of JOA Scores and SF-36 Evaluations Between the Two Groups

As illustrated by the data, there were no statistically significant differences between the observation and control groups in either the Japanese Orthopaedic Association (JOA) scores or the SF-36 quality of life assessments before or after treatment ($P > 0.05$). Specifically, the JOA scores, which assess neurological function in patients with myelopathic cervical spondylosis, remained comparable between the two groups throughout the study period. This finding is consistent with the clinical profiles of the enrolled patients, all of whom were diagnosed with typical cervical spondylotic radiculopathy without accompanying myelopathic symptoms (Figure 3A).

Similarly, SF-36 scores, which evaluate both physical and mental health components, showed no significant changes over time and no between-group differences at any time point. This suggests that both groups maintained stable physical and psychological health during the treatment period. The lack of significant variation further indicates that the study population did not exhibit major mental health disturbances at baseline or post-treatment (Figure 3B).

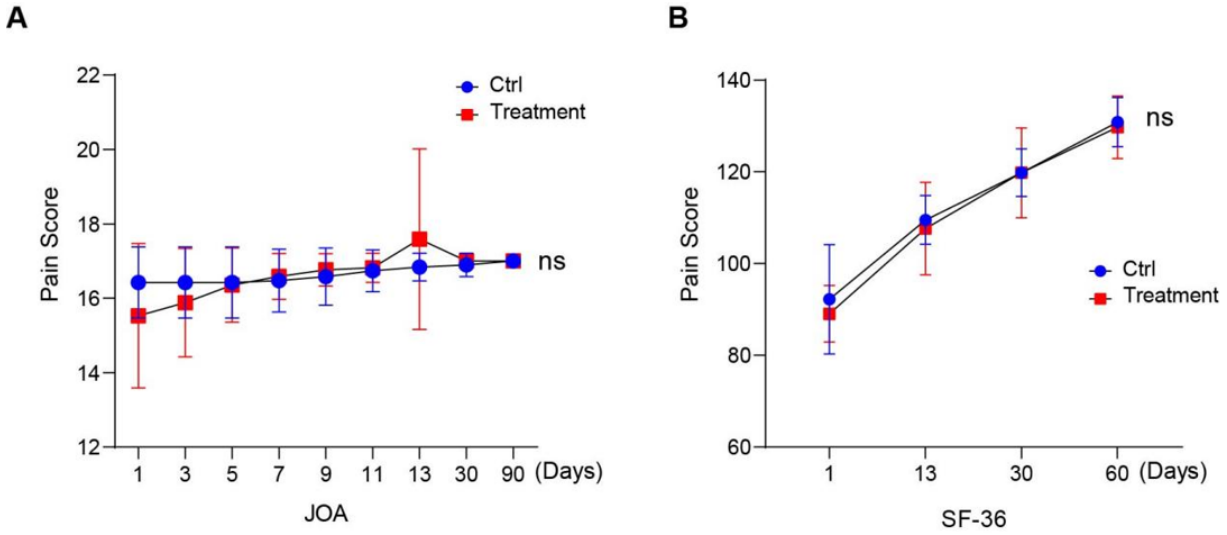

Figure 3. Comparison of JOA and SF-36 scores before and after treatment showed no significant differences between the two groups. **(A)** Changes in JOA scores before and after treatment, with no statistically significant difference between the observation and control groups. **(B)** Changes in SF-36 scores, with no significant difference observed between the two treatment groups. Data are presented as mean ± SEM; ns no statistically significant differences, $p > 0.05$ by two-way ANOVA.

DISCUSSION

The present study demonstrated that the observation group achieved a significantly higher overall effective rate than the control group (94.73% vs. 88.23%, $P < 0.05$). In addition, the observation group showed greater improvement in major TCM symptoms, including neck–shoulder pain, upper limb numbness, and neck stiffness. These findings suggest that Three-Dimensional Balance Spinal Manipulation, when administered at a higher frequency, may more effectively restore cervical biomechanical balance and relieve clinical symptoms. Importantly, our results are generally consistent with previous studies reporting that manual therapies based on spinal balance regulation can reduce pain, improve cervical mobility, and alleviate neurological symptoms in patients with cervical spondylotic radiculopathy (CSR) [7,8]. Compared with those earlier reports, the present study further indicates that increasing the treatment frequency may enhance the therapeutic effect of this technique.

In terms of pain and functional recovery, the observation group showed a markedly lower post-treatment VAS score than the control group (1.46 ± 0.35 vs. 2.69 ± 0.41, $P < 0.001$), as well as a significantly lower NDI score (12.33 ± 2.04 vs. 16.72 ± 2.26, $P < 0.001$). These findings are in line with prior clinical studies showing that manipulation-based therapies can effectively reduce pain intensity and improve cervical function in CSR patients [9]. However, the magnitude of improvement observed in the present study appears more pronounced, which may be related to the higher intervention frequency used in the observation group. This suggests that treatment frequency may be an important factor influencing the extent of pain relief and functional restoration.

The Tanaka Symptom Quantification score also improved more in the observation group than in the control group (10.2% vs. 5.1%, P < 0.001), further supporting the superiority of the enhanced intervention. Similar improvements in symptom scores have been described in previous studies of this manipulation technique or related manual interventions [10]. Taken together, these comparisons suggest that Three-Dimensional Balance Spinal Manipulation not only produces therapeutic benefits comparable to those reported in the literature, but that a higher treatment frequency may further optimize these outcomes.

From a mechanistic perspective, the beneficial effects of increased treatment frequency may be explained by the repeated delivery of mechanical stimuli to cervical soft tissues and joint structures. Previous studies have suggested that this type of manipulation can help release nerve root adhesions, improve the space of the intervertebral foramen, and promote restoration of cervical curvature [11]. The current findings are consistent with these observations and further imply that more frequent intervention may enhance these biomechanical effects. From the perspective of traditional Chinese medicine, the treatment of CSR emphasizes the restoration of "tendon–bone balance," namely correcting disordered relationships between tendons and bones, improving tendon flexibility, stabilizing osseous structures, and reestablishing dynamic balance [5]. Earlier reports have similarly proposed that manual therapy may promote the circulation of qi and blood, relieve stagnation, and improve local microcirculation [12]. Therefore, the superior outcomes in the observation group may reflect the combined biomechanical and TCM-based regulatory effects of higher-frequency manipulation.

However, despite the clear advantages in symptom relief and functional improvement, the SF-36 scores did not differ significantly between groups. This finding is partly consistent with previous studies in which disease-targeted interventions produced meaningful local or functional benefits but failed to generate substantial changes in generic quality-of-life measures. As a general health-related quality-of-life instrument, the SF-36 evaluates broad domains such as physical functioning, vitality, social functioning, and mental health, but may be less sensitive to subtle or disease-specific improvements following focused musculoskeletal interventions. Therefore, the absence of significant between-group differences in SF-36 scores does not necessarily contradict the positive clinical effects observed in pain and functional outcomes. In addition, the relatively small sample size may have limited the statistical power to detect modest differences, thereby increasing the possibility of a type II error [13].

Several limitations of this study should be noted. First, the sample size was relatively small (n = 36), and future multi-center studies with larger samples are needed to confirm the present findings. Second, long-term follow-up data were not available, making it difficult to determine the durability of treatment effects. Third, more sensitive disease-specific evaluation tools should be developed or adopted to better capture changes associated with targeted manual interventions. Finally, the mechanical parameters of the manipulation were not quantitatively assessed. Future studies should incorporate objective biomechanical measurements, such as surface electromyography, pressure sensing, or imaging-based approaches, to clarify the relationship between treatment frequency and therapeutic response. Advanced techniques such as diffusion tensor imaging may also help reveal possible neural repair mechanisms and support the development of mathematical models linking treatment frequency with biomechanical and clinical outcomes.

In conclusion, the present findings suggest that increasing the frequency of Three-Dimensional Balance Spinal Manipulation may enhance its therapeutic efficacy in CSR. Moreover, in comparison with previous studies using this technique or related manipulative therapies, our results support the view that higher-frequency intervention may provide additional benefits in pain relief, symptom improvement, and cervical functional recovery.

This study found a higher effective rate in the observation group (94.73%) than in the control group (88.23%), with $P < 0.05$. Notably, the observation group showed greater improvements in key TCM symptoms like neck-shoulder pain (32% lower score), upper limb numbness (28% lower), and neck stiffness (35% lower) than the control group. This implies that Three-Dimensional Balance Spinal Manipulation, applied at specific frequencies, may better regulate cervical biomechanics [7,8].

For pain control, the observation group's VAS score decreased to 1.46 ± 0.35, representing a 45.7% greater reduction compared to the control group's post-treatment score of 2.69 ± 0.41 ($P < 0.001$). The NDI score in the observation group was 12.33 ± 2.04, notably lower than the 16.72 ± 2.26 recorded in the control group ($P < 0.001$), suggesting that increased treatment frequency may significantly improve

cervical functional recovery [9]. Additionally, the Tanaka Symptom Quantification score increased by 10.2% in the observation group, compared to 5.1% in the control group, further supporting the overall therapeutic superiority of the enhanced intervention ($P < 0.001$) [10].

Overall, increasing the treatment frequency of this manipulation boosts efficacy. Treating twice daily with high-frequency mechanical stimuli can effectively release nerve root adhesions, restore the intervertebral foramen, and normalize physiological curvature [11]. The essence of treating CSR with TCM manipulation lies in "tendon–bone balance". This means correcting abnormal tendon and bone conditions, restoring tendon flexibility, stabilizing bone structures, and regulating tendon dynamics to achieve "proper bone and flexible tendon" [5]. TCM theory suggests that high-frequency manipulation can accelerate the dissipation of qi stagnation and blood stasis, promote "proper bone and flexible tendon," and improve local microcirculation [12].

However, the comparable SF-36 scores suggest limited improvement in overall health status. As a generic quality-of-life instrument, the SF-36 assesses broad health dimensions but lacks sensitivity to detect subtle, disease-specific changes or responses to focused interventions like Three-Dimensional Balanced Spinal Manipulation. This treatment's primary effects—such as localized pain relief or specific functional improvements—may be insufficient to significantly impact core SF-36 domains (e.g., physical functioning, vitality, social/emotional role). Consequently, these targeted gains can be diluted by other unchanged domains (e.g., mental health, general perceptions), resulting in minimal shifts in total or subscale scores. Generic instruments like the SF-36 demonstrate reduced sensitivity to modest or domain-specific functional gains, meaning incremental or localized therapeutic benefits may be inadequately captured by its broad metrics. Additionally, an insufficient sample size may have reduced statistical power, increasing the risk of a type II error [13].

This study has several limitations. First, the sample size is small ($n = 36$), and we need to carry out multi-center studies with larger samples in the future. Second, long-term follow-up data are missing. It is suggested to increase the observation period. Third, develop specific scales with more detail and more dimensions to meet the assessment of disease-specific treatment effects. Finally, quantitative analysis of the mechanical parameters of the treatment was not performed. It is suggested to supplement the data of surface electromyography or pressure sensors. Future research can combine DTI technology to observe neural fiber repair and establish a mathematical model between treatment frequency and biomechanical parameters.

CONCLUSION

In conclusion, the frequency of three-dimensional balance spinal manipulation affects the clinical efficacy of CSR. The twice daily group is better than every other day group. Further research on the dose-effect relationship of this treatment will help improve clinical outcomes, relieve pain, and enhance cervical function for patients. It is worth studying in the future. Future trials will focus on the optimal treatment frequency for CSR to inform clinical practice.

LIST OF ABBREVIATIONS

CRFs: Case Report Forms; CSR: Cervical Spondylotic Radiculopathy; JOA: Japanese Orthopaedic Association; NDI: Neck Disability Index; ROM: Range of Motion; SD: Standard Deviation; TCM: Traditional Chinese Medicine; VAS: Pain Severity.

DECLARATIONS

Ethics approval for retrospective studies

This retrospective chart review study involving human participants was in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The Human Investigation Committee (IRB) of the Pain Hospital of Shandong First Medical University approved this study (NO. 202401003, 2023026).

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no conflicts of interest.

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Authors' contributions

Q Z contributed to the investigation, provided resources, conducted formal analysis, and wrote the original draft. **W Z** was involved in the investigation and wrote the original draft. **J W** also participated in the investigation and wrote the original draft. **Z Y** performed validation and visualization of the data. **B H** contributed to validation and visualization. **G Y** contributed to the conceptualization, methodology, and wrote the review and editing of the manuscript. **B S** participated in writing the review and editing, supervising the project, managing administration, and acquiring funding.

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Not applicable.

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