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Cervical Rotation-Traction Manipulation for Cervical Radiculopathy: A Systematic Review and Meta-Analysis of Randomized Control Trials

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Background: Cervical radiculopathy (CR) is a common musculoskeletal disorder worldwide. Cervical rotation-traction manipulation (CRTM) is one of the representative technique in traditional Chinese orthopedics.

Objective: This systematic review and meta-analysis aims to evaluate the effectiveness and safety of CRTM in treating CR.

Methods: A comprehensive literature search was conducted through eight databases to identify the relevant randomized controlled trials (RCTs) from inception to December 2023. The primary outcome was the Visual Analogue Scale (VAS). The secondary outcomes included Neck Disability Index (NDI), Japanese Orthopaedic Association (JOA), Cervical Range of Motion, cervical curvature, and adverse reactions and events. Two researchers independently screened literature, extracted data, and assessed the risk of bias in included studies. Meta-analysis was performed using RevMan 5.4 and Stata 15.0 software, and the Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) system was used to assess the quality of the evidence.

Results: A total of 9 RCTs involving 904 patients were included. The results indicated that CRTM significantly reduced VAS scores compared to control groups with low-quality evidence [n=534, WMD=−1.27, 95% CI (−1.66, −0.87), $p<0.00001$, I^2=59%]. Subgroup analysis showed that differences in control group categories, sample sizes, and intervention durations may contribute to the observed heterogeneity. Besides, CRTM significantly improved cervical range of motion of lateral flexion and rotation with very low-quality evidence. However, no statistically significant differences were observed in NDI scores, JOA scores, or cervical curvature between CRTM and control groups. No adverse reactions and events related to CRTM were reported in included studies, demonstrating its high safety.

Conclusion: Cervical rotation-traction manipulation appears to be an effective and safe option for managing cervical radiculopathy, significantly improving pain and cervical mobility. However, further high-quality randomized controlled trials and methodological studies should be conducted to reinforce the evidence base for its clinical practice.

Keywords: cervical rotation-traction manipulation, cervical radiculopathy, randomized control trial, pain, cervical range of motion, systematic review, meta-analysis

Introduction

Cervical radiculopathy (CR) is a major musculoskeletal problem worldwide, characterized by the intense radicular pain, numbness, paraesthesia, or muscle weakness, among other symptoms.[1,2] CR is related to compression and/or irritation of one or more cervical nerve roots,[3] and the majority of patients attributed to a combination of degenerative changes and a minority resulting from cervical disc herniations.[4,5] The reported annual age-adjusted incidence of CR was 83.2 per 100,000 persons (107.3 for men and 63.5 for women).[6] As a disabling disease, CR significantly hampers a person's

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physical function, daily activities, psychological well-being, and social participation,[7,8] which are associated with the substantial burdens of personal life, the healthcare system, and the social economy. With the advent of an ageing society, the population of patients with CR is expected to rapidly increase.[9,10] The widespread adoption of electronic work environments has also accelerated the trend of CR towards younger demographics. Therefore, the treatment and management strategies for this condition have sparked considerable interest among healthcare professionals and patients worldwide.

Conservative management is generally recommended as first-line treatment option for patients with CR.[11] Several (inter)national clinical practice guidelines[12–14] suggest that effective non-surgical management strategies could predominantly include patient education, exercise therapy, nonsteroidal anti-inflammatory drugs (NSAIDs), manual therapy, cervical steroid injection, and the use of cervical collar. The majority of patients report symptomatic improvement outcomes in pain, neck movement, and function by using the non-operative management.[5,15] However, certain conservative treatment approaches have demonstrated significant drawbacks, leading to some side effects and constraints. The use of oral NSAIDs as a primary treatment for chronic pain conditions can notably impact the gastrointestinal, cardiovascular, and renal systems, and the risk of adverse reactions escalates with higher doses and prolonged usage.[16,17] Furthermore, the peak incidence of CR appears in the fifth and sixth decade for both genders.[6] There's a consistent rise in the number of patients experiencing multiple coexisting diseases simultaneously in the middle-aged and elderly population,[18] which is gradually posing considerable challenges to pharmacotherapy for patients. And further investigation is warranted into the adverse reactions resulting from the concomitant use of various types of medications. Thus, there arises a need to explore non-pharmacological complementary therapies to augment the existing array of treatment options and meet clinical needs of different conditions.

Manual therapy can be defined as the application of a manual force to the patient by a trained practitioner to improve pain-related symptoms and mobility in areas that are restricted or injured,[19] which encompasses a range of physical techniques such as massage, soft tissue stretching, neurodynamic mobilization, traction, therapeutic exercises, and manipulation techniques aimed at reducing pain, improving range of motion, and facilitating recovery.[20,21] Manual therapy is often used in the management of CR, and offers non-invasive and effective option for CR patients.[5,12–15] Cervical rotation-traction manipulation (CRTM), a representative physical technique of traditional Chinese orthopedics, has undergone refinement and innovation on the basis of cervical rotational manipulation under the principles of traditional Chinese tendons-bones theory. The most prominent feature of CRTM is that it decomposes the core operations of rotary-thrust into three steps: subject's active rotary-position, operator's pretraction, and operator's upward-thrust.[22] Scholars have conducted extensive research elucidating its mechanical characteristics, preliminarily affirming its effectiveness and safety, and gradually probing its underlying mechanisms.[23–26] However, its further external promotion and application necessitate higher levels of evidence from evidence-based medicine.

Over the past two decades, researchers have progressively initiated multiple randomized controlled trials (RCTs) to investigate CRTM's effect in treating CR. Preliminary findings suggest its beneficial effects on pain, cervical function, and quality of life outcomes. However, the research landscape remains relatively fragmented, lacking integrated evidence. In this study, we aim to conduct a systematic review and meta-analysis of published RCTs to further corroborate the effectiveness and safety of CRTM in managing CR patients. This will furnish clinical evidence to support its broader dissemination and application, provide non-pharmacological treatment option for clinicians and CR patients, and serve as a reference for researchers in this field.

Methods

This systematic review and meta-analysis was conducted in accordance with the Preferred Reporting Items of Systematic Reviews and Meta Analysis (PRISMA) guidelines.[27] The predefined protocol for this study was registered on the international prospective register of systematic reviews (PROSPERO) with the registration number: CRD42024532211.

Search Strategy

A systematic literature search was conducted through eight electronic databases including PubMed, Embase, Cochrane Library, Web of Science, Chinese Biological Medicine (CBM), Chinese National Knowledge Infrastructure (CNKI), WanFang Database and Chongqing VIP Database to identify all the relevant studies from inception to December 2023. There were no restrictions on the publication language. The search terms for this study were identified through literature review, in-depth conference discussions, and expert opinion. The search strategy was formed using the following keywords in combination:

> rotation-traction manipulation, rotation traction manipulation, cervical rotation-traction manipulation, neck pain, spondylosis, radiculopathy, cervical radiculopathy, cervical spondylotic radiculopathy, nerve-root type cervical spondylosis, cervical spondylosis.

Additional potential studies were manually searched by reviewing reference lists of the included articles and related reviews. The comprehensive search was performed by two independent researchers blinded to each other's results (Feng TX and Wang X). The complete search strategy can be found in the Supplementary Material 1.

Inclusion Criteria and Exclusion Criteria

Inclusion Criteria

(1) Type of studies: RCTs assessing the effects of CRTM in the treatment of CR were eligible. (2) Type of participants: Patients above the age of 18 years presenting in the clinical settings with CR were included regardless of the differences in gender, ethnicity, region, or disease duration. (3) Type of Interventions: CRTM alone or combined with the control interventions. The operational procedures of CRTM are illustrated in Figure 1. (4) Type of comparators: The control included sham (placebo) therapy, no treatment, and conventional treatments based on the recommendations of clinical practice guidelines[12–14,28] such as patient education, exercise therapy, NSAIDs, Chinese herbal compound, Chinese patent medicine, cervical traction, manipulation, and some physiotherapies. (5) Type of outcomes: The primary outcome was the Visual Analogue Scale (VAS). The secondary outcomes included Neck Disability Index (NDI), Japanese Orthopaedic Association (JOA), Cervical Range of Motion (CROM), cervical curvature, and adverse reactions and events.

Exclusion Criteria

(1) The study did not explicitly specify the research population as CR patients; (2) CR combined with other diseases; (3) Duplicate publication; (4) Protocols of RCTs; (5) RCTs whose full text could not be accessed.

Study Selection and Data Extraction

Two reviewers (Feng TX and Wang X) independently conducted study selection and data extraction. Discrepancies in summarizing the results were resolved by discussion between the two reviewers or asking a third reviewer (Wei X) to arbitrate. Researchers imported the search results into Endnote X9.3 software, and duplicate records were automatically removed by the duplicate checking function of the software. Inconsistent documents were excluded by reading the titles and abstracts. Then eligible RCTs were identified based on full-text assessment, and the reasons for exclusion were recorded, which can be found in the Supplementary Material 2. For each included study, the following data were extracted using a predefined information table, where available: the first author, year of publication, country, simple size, age, gender, duration, intervention type, number of sessions, frequency of manipulation per week, course of treatment, assessment tools, outcome indicators, and outcome capture time. The reviewers inquired the missing information by sending an Email to the author. To ensure the consistency of data extraction results, two researchers underwent systematic training prior to the data extraction process, and the extracted results were subjected to Kappa consistency test. The result of Kappa consistency test [Kappa: 0.87, 95% confidence intervals (CI): 0.66 to 1.00, $P<0.05$] indicated a high level of consistency of data extraction between the two researchers.

Methodological Quality Assessment of the Included Studies

We rated the quality of eligible studies through the assessment of their risk of bias, which was assessed by the two independent reviewers (Feng TX and Bu HM) using the criteria outlined in the Cochrane Collaboration Risk of Bias tool 2.0 (RoB).[29] The key assessment areas included: (1) random sequence generation, (2) allocation concealment, (3)

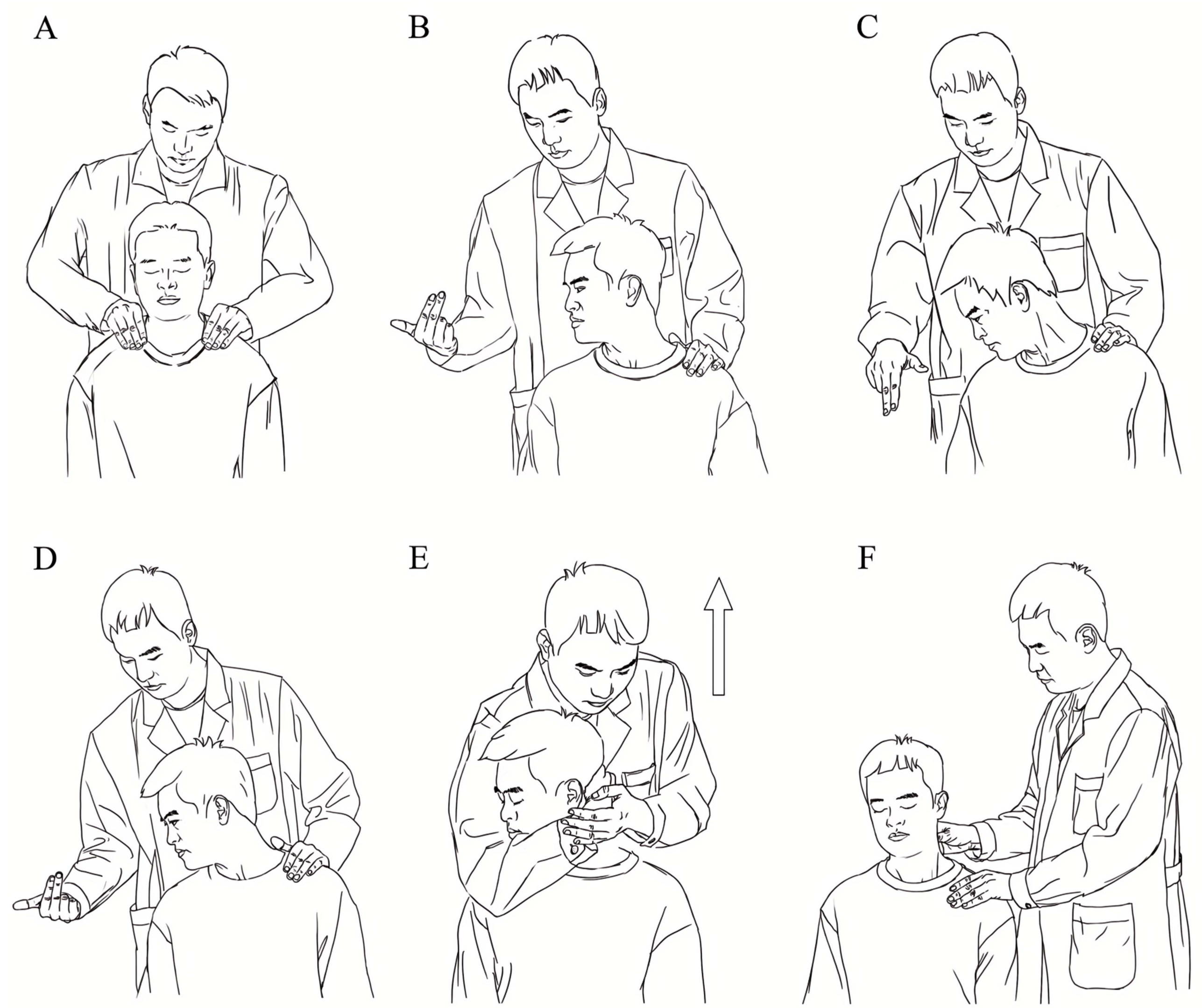

Figure 1 The procedure of CRTM. **(A)** The patient is seated, and their neck is allowed to relax. The doctor applies massage techniques to relax the muscles around the neck area for approximately 5 to 10 minutes. (**B–D**) The patient is then instructed to rotate their head horizontally, flex it, and then rotate it again to its maximum limit while maintaining a sense of fixation. (**E**) The doctor supports the patient's chin with their elbow and gently preloads upward for 3 to 5 seconds. The patient is then asked to fully relax, and the doctor applies a quick, short upward thrust with the elbow, which may result in audible sounds. (**F**) Subsequently, massage techniques are applied to further relax the muscles around the neck and shoulders, with each session of CRTM lasting approximately 10 to 15 minutes.

blinding of participants and personnel, (4) blinding of outcome assessment, (5) incomplete outcome data, (6) selective reporting, and (7) other source of biases. After evaluating each study based on these items, we classified it into the following three category: (1) high risk, (2) low risk, or (3) unknown risk. Disagreements between two reviewers were resolved by consensus through discussion or asking a third expert reviewer (Wei X).

Quality Assessment of the Evidence

The quality of evidence was assessed by the two reviewers (Feng TX and Bu HM) independently using the Grading of Recommendations, Assessment, Development, and Evaluations (GRADE),[30] which was used to the rate the overall confidence of evidence in the treatment effect estimates of a study outcome obtained from the systematic review and meta analysis. The disagreements were resolved through discussion with the third expert reviewer (Wei X). The quality of evidence was obtained by examining five domains including inconsistency, risk of bias, indirectness, imprecision, and publication bias. Then the overall quality of evidence is rated as high, moderate, low, or very low.

Statistical Analysis

The eligible studies were pooled using Review Manager 5.4 (The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark) for meta-analysis. For continuous variables, since the assessment tools used in the included RCTs are consistent, the outcomes were expressed as weighted mean difference (WMD) and 95% CI. Heterogeneity will be detected with the Q test with the associated I^2 test and p value. If p>0.1 and I^2 <50%, the fixed-effects model will be used. If p <0.1 and I^2 ≥50%, the random effects model will be adopted in the study. Subgroup analyses based on different control measures, sample sizes, and intervention durations were used when there was obvious clinical heterogeneity, as necessary. Sensitivity analyses were conducted by sequentially excluding individual studies. We assessed the potential publication bias by conducting an informal visual examination of a funnel plot using Stata 15 software (Texas, Stata Corp). To further evaluate publication bias accurately, we performed Begg's and Egger's tests. The Kappa consistency test was conducted based on Stata 15 software.

Results

Study Selection

We initially identified 437 relevant articles through database searches (435 articles) and manual supplementation (2 articles). After removing duplicates, we obtained 182 relevant articles. Following title and abstract screening, 151 articles were excluded as they did not meet the inclusion criteria, resulting in 31 articles for initial inclusion. Upon full-text review, 22 articles were further excluded based on predefined criteria, leading to a final inclusion of 9 articles. The list of excluded articles along with reasons for exclusion at this stage is provided in Supplementary Material 2. The process and outcomes of literature screening are depicted in Figure 2.

Characteristics of the Included Studies

The nine RCTs[31–39] included in this meta-analysis were all conducted in China and published between 2008 and 2023. Sample sizes ranged from 30 to 210 participants, with a total of 904 participants across all studies. Regarding intervention strategies, five studies[34,36–39] compared CRTM with cervical traction, three studies[31–33] compared combined CRTM with Jingtong granule against Jingtong granule alone, and one study[35] compared the efficacy of a comprehensive treatment regimen combining CRTM with electroacupuncture and Western medicine against electroacupuncture and Western medicine alone as the baseline treatment. In terms of the frequency of CRTM intervention, seven studies[31–33,36–39] implemented CRTM treatment once every other day for a total of seven sessions, one study[34] implemented CRTM treatment once daily for a total of ten sessions, and one study[35] implemented CRTM treatment once every three days for a total of five sessions. Regarding the duration of intervention, eight studies[31–33,35–39] opted for a two-week intervention period, while one study[34] conducted a ten-day intervention. Outcome measures varied, with six studies[31–34,37,38] reporting primary outcome measures and three studies[35,36,39] reporting only secondary outcome measures. Table 1 summarizes the basic characteristics of the included studies.

The results of Methodological Quality Assessment

In terms of random sequence generation, eight studies[31–33,35–39] were deemed at low risk. Among these, four utilized[31,36,37,39] computer-generated randomization, while the remaining four[32,33,35,38] employed random number tables. One additional study[34] reported randomization without specifying the methodology, hence categorized as unclear risk. Allocation concealment was addressed by four studies[31,36,37,39] through a central randomization system, receiving a low risk. However, the remaining literature[32–35,38] lacked explicit reporting, leading to an unclear assessment. Blinding procedures were explicitly reported in two studies[37,39] for outcome assessors, indicating a low risk of bias. Regarding outcome data completeness, four studies[31,32,37,39] encountered missing cases and conducted per-protocol (PP) analyses, thus marked as high risk. Conversely, studies[33–36,38] reporting complete outcome data were rated as low risk. Concerning selective reporting, five studies[31–33,37,39] reported study results without selectivity, resulting in a low risk assessment, while the risk assessment of the remaining studies[34–36,38] was deemed unclear. The risk of bias assessment for other

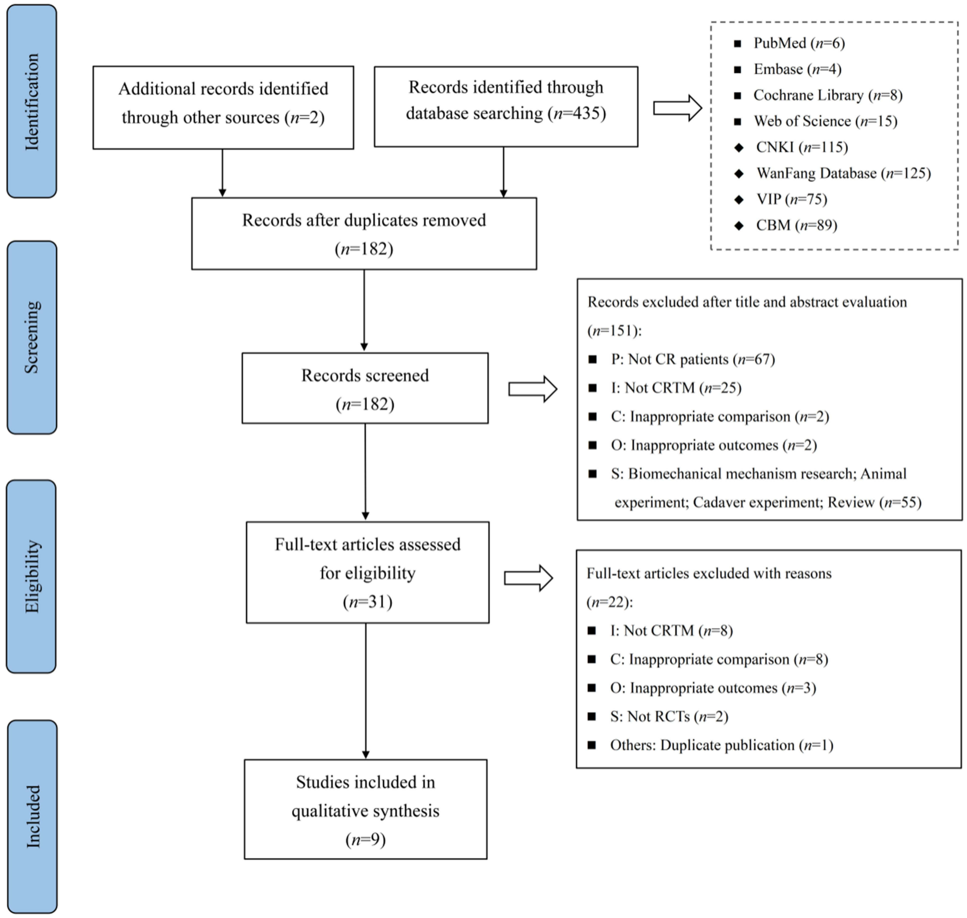

Figure 2 PRISMA flow diagram.
Abbreviations: P, population; I, intervention; C, comparison; O, outcome; S, study type.

potential biases was unclear due to incomplete reporting of information across included studies.[31–39] The risk of bias assessment results of the included studies are shown in Table 2.

The Result of Meta-Analysis

The meta-analysis indicate that CRTM significantly improves both pain and cervical range of motion in patients with CR compared to the control group. Moreover, CRTM demonstrates adequate safety. However, there is notable heterogeneity among the included studies. Subgroup analyses were conducted for the outcome measures to explore the sources of heterogeneity. The summarized results of the meta-analysis and subgroup analyses are presented in Table 3.

VAS Scores

Six studies[31–34,37,38] investigated the effectiveness of CRTM in reducing pain VAS scores in CR patients. The random-effects model meta-analysis revealed a significant reduction in VAS scores with CRTM compared to the control group [n=534, WMD=−1.27, 95% CI (−1.66, −0.87), p<0.00001, I^2=59%]. The forest plot of VAS scores is depicted in Figure 3. Given the high heterogeneity, subgroup analyses were performed based on different control measures, sample sizes, and intervention durations (see Supplementary Material 3).

Subgroup analysis based on different control measures showed the following results (see Supplementary Figure 1): After CRTM, patients' VAS scores were significantly lower than those in the cervical traction group [n=416, WMD= −1.50, 95% CI (−2.11,-0.89), p<0.00001, I^2=74%].[34,37,38] When CRTM was combined with Jingtong granule treatment, patients' VAS scores were significantly lower than those with Jingtong granule alone [n=118, WMD=−0.95, 95% CI (−1.36,-0.54), p<0.00001, I^2=0%].[31–33] Subgroup analysis based on different sample sizes revealed the following

Table 1 Characteristics of Included Studies

Study ID	Country	Sample Size		Gender (Male)		Age Range		Intervention		Main Details of Intervention	Duration of Intervention	Outcome
		T	C	T	C	T	C	T	C			
Gu, 2023[31]	China	15	15	3	5	38.27 ±5.85	39.93 ±5.30	CRTM+JT granule	JT granule	CRTM: Once every other day for a total of 7 sessions; JT granule: 4g per time, and 3 times per day	2 weeks	A,B,C,D,F
Yong, 2022[32]	China	29	28	11	9	41.68 ±6.79	41.55 ±6.80	CRTM+JT granule	JT granule	CRTM: Once every other day for a total of 7 sessions; JT granule: 4g per time, and 3 times per day	2 weeks	A,B,C,F
Wang, 2022[33]	China	15	16	6	6	30.00 ±4.68	35.50 ±5.34	CRTM+JT granule	JT granule	CRTM: Once every other day for a total of 7 sessions; JT granule: 4g per time, and 3 times per day	2 weeks	A,B,D,F
Qiu, 2020[34]	China	48	48	17	14	21–68	22–63	CRTM	CT	CRTM: Once per day for a total of 10 sessions; CT: Once per day for a total of 10 sessions	10 days	A,F
Li et al, 2020[35]	China	40	40	23	22	49.70 ±7.20	48.20 ±6.50	CRTM+ET +Medication	ET +Medication	CRTM: Once every 3 day for a total of 5 sessions; AT: Once every other day for a total of 7 sessions; Medication: Loxoprofen sodium tablet: 60mg per time, and 3 times per day; Eperisone hydrochloride tablet: 50mg per time, and 3 times per day; Mecobalamin tablet: 0.5mg per time, and 3 times per day	2 weeks	E
Liu et al, 2011[36]	China	40	40	13	12	45–60	45–65	CRTM	CT	CRTM: Once every other day for a total of 7 session; CT: Once per day for a total of 14 sessions	2 weeks	D
Zhu et al, 2009[37]	China	106	104	31	32	53.59 ±5.60	52.68 ±6.12	CRTM	CT	CRTM: Once every other day for a total of 7 sessions; CT: Once per day for a total of 14 sessions	2 weeks	A
Wang et al, 2009[38]	China	54	56	30	29	45–65	45–63	CRTM	CT	CRTM: Once every other day for a total of 7 sessions; CT: Once per day for a total of 14 sessions	2 weeks	A
Zhu et al, 2008[39]	China	106	104	31	32	53.59 ±5.60	52.68 ±6.12	CRTM	CT	CRTM: Once every other day for a total of 7 sessions; CT: Once per day for a total of 14 sessions	2 weeks	E

Notes: A: Visual Analogue Scale; B: Neck Disability Index; C: Japanese Orthopaedic Association; D: Cervical curvature (Borden's measurement); E: Cervical Range of Motion; F: adverse reactions and events.
Abbreviations: T, treatment group; C, control group; JT granule, Jingtong granule; CT, cervical traction; ET, electroacupuncture therapy.

Table 2 Risk of Bias Assessment

Study ID	Random Sequence Generation	Allocation Concealment	Blinding of Participants and Personnel	Blinding of Outcome Assessment	Incomplete Outcome Data	Selective Reporting	Other Bias
Gu, 2023[31]	Low[A]	Low[C]	Unclear	Unclear	High[D]	Low[F]	Unclear
Yong, 2022[32]	Low[B]	Unclear	Unclear	Unclear	High[D]	Low[F]	Unclear
Wang, 2022[33]	Low[B]	Unclear	Unclear	Unclear	Low[E]	Low[F]	Unclear
Qiu, 2020[34]	Unclear	Unclear	Unclear	Unclear	Low[E]	Unclear	Unclear
Li et al, 2020[35]	Low[B]	Unclear	Unclear	Unclear	Low[E]	Unclear	Unclear
Liu et al, 2011[36]	Low[A]	Low[C]	Unclear	Unclear	Low[E]	Unclear	Unclear
Zhu et al, 2009[37]	Low[A]	Low[C]	Unclear	Low	High[D]	Low[F]	Unclear
Wang et al, 2009[38]	Low[B]	Unclear	Unclear	Unclear	Low[E]	Unclear	Unclear
Zhu et al, 2008[39]	Low[A]	Low[C]	Unclear	Low	High[D]	Low[F]	Unclear

Notes: [A]computer-generated randomization; [B]random number table; [C]central randomization system; [D]PP analysis with missing data; [E]did not selectively report study results; [F]complete outcome data.

Table 3 The Results of Meta-Analysis

Outcomes	Number of Included Studies	Total Sample Size	Results Of Heterogeneity Tests		Effect Model	Results of Meta-Analysis	
			P	I^2 (%)		Effect Size (95% CI)	P
VAS scores	6[31]	534	0.03	59	Random	WMD −1.27 (−1.66, −0.87)	<0.00001
Subgroup 1: different control measures							
CRTM vs CT	3	416	0.02	74	Random	WMD −1.50 (−2.11, −0.89)	<0.00001
CRTM+JT granule vs JT granule	3	118	0.37	0	Fix	WMD −0.95 (−1.36, −0.54)	<0.00001
Subgroup 2: different sample sizes							
Sample size≤100	4	214	0.01	73	Random	WMD −1.33 (−2.06, −0.60)	0.0003
Sample size>100	2	320	0.34	0	Fix	WMD −1.20 (−1.52, −0.89)	<0.00001
Subgroup 3: different intervention durations							
Duration of intervention<2 weeks	1[34]	96	-	-	Fix	WMD −2.32 (−3.11, −1.53)	<0.00001
Duration of intervention = 2 weeks	5[31–33,38,39]	438	0.43	0	Fix	WMD −1.11 (−1.36, −0.86)	<0.00001
Cervical range of motion							
Flexion	2[35,39]	290	<0.00001	98	Random	WMD 6.96 (−2.33, 16.25)	0.14
Extension	2[35,39]	290	<0.00001	96	Random	WMD 7.28 (−2.50, 17.06)	0.14
Left lateral flexion	2[35,39]	290	0.04	77	Random	WMD 4.37 (1.90, 6.85)	0.0005
Right lateral flexion	2[35,39]	290	0.007	86	Random	WMD 5.60 (0.23, 10.97)	0.04
Left rotation	2[35,39]	290	0.002	90	Random	WMD 8.93 (2.31, 15.54)	0.008
Right rotation	2[35,39]	290	<0.00001	96	Random	WMD 9.21 (1.15, 17.28)	0.03
NDI scores	3[31–33]	118	0.0002	88	Random	WMD −3.04 (−6.56, 0.48)	0.09
JOA scores	2[31,32]	87	0.16	50	Random	WMD −0.11 (−0.53, 0.31)	0.61
Cervical curvature	3[31,33,36]	141	0.008	79	Random	WMD 0.69 (−0.39, 1.76)	0.21

results (see Supplementary Figure 2): Four studies[31–34] with sample sizes ≤100 showed that CRTM led to lower VAS scores compared to the control group [*n*=214, WMD=−1.33, 95% CI (−2.06,-0.60), *p*=0.0003, I^2=73%]. Similarly, two studies[37,38] with sample sizes>100 indicated that CRTM was superior to the control group in pain improvement [*n*=320, WMD=−1.20, 95% CI (−1.52,-0.89), *p*<0.00001, I^2=0%]. Subgroup analysis based on different intervention durations indicated the following results (see Supplementary Figure 3): Meta-analysis of five studies[31–33,38,39] using CRTM for 2 weeks (14 sessions) showed significantly lower pain scores compared to the control group [*n*=438, WMD=−1.11, 95% CI (−1.36,-0.86), *p*<0.00001, I^2=0%]. One study[34] using CRTM for 10 days (10 sessions) also yielded similar results [*n*=96, WMD=−2.32, 95% CI (−3.11,-1.53), *p*<0.00001]. Subgroup analysis results suggest that differences in control group categories, sample sizes, and intervention durations may contribute to the observed heterogeneity.

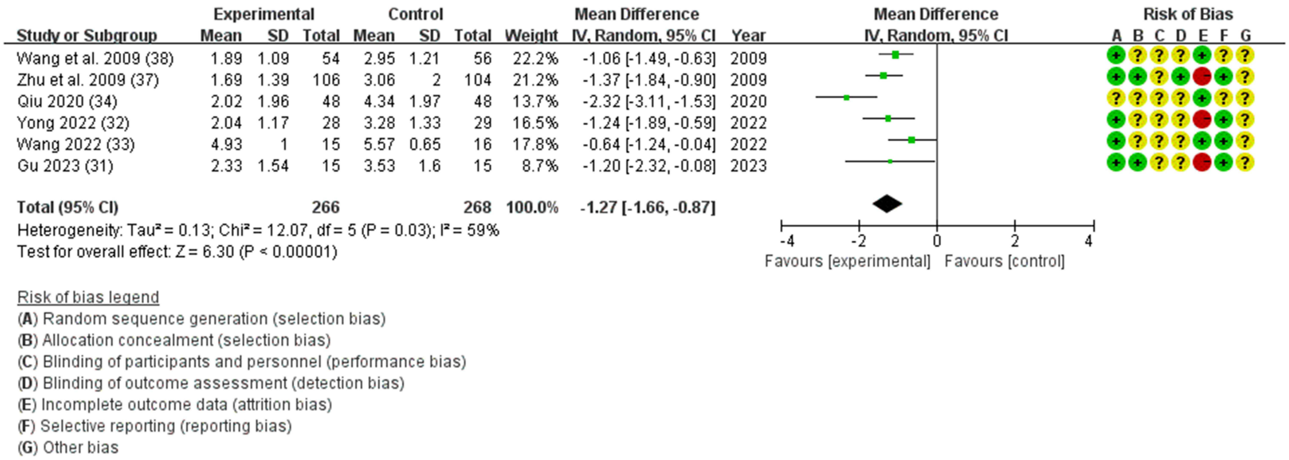

Figure 3 The forest plot of VAS scores.

Cervical Function

Two RCTs[35,39] evaluated cervical range of motion between experimental and control group, comprising 290 patients. Random-effects model meta-analysis revealed significant increases in cervical spine left flexion [WMD=4.37, 95% CI (1.90, 6.85), p=0.0005, I^2=77%], right flexion [WMD=5.60, 95% CI (0.23, 10.97), p=0.04, I^2=86%], left rotation [WMD=8.93, 95% CI (2.31, 15.54), p=0.008, I^2=90%], and right rotation [WMD=9.21, 95% CI (1.15, 17.28), p=0.03, I^2=96%] following CRTM intervention compared to the control group. However, there was no statistically significant difference in cervical spine flexion [WMD=6.96, 95% CI (−2.33, 16.25), p=0.14, I^2=98%] and extension [WMD=7.28, 95% CI (−2.50, 17.06), p=0.14, I^2=96%] between the two groups. Three studies[31–33] utilized NDI scores to assess cervical function. Meta-analysis using a random-effects model indicated no statistically significant difference in NDI scores between the two groups [n=118, WMD=−3.04, 95% CI (−6.56, 0.48), p=0.09, I^2=88%]. Two studies[31,32] used JOA scores to evaluate cervical function. Meta-analysis results using a random-effects model demonstrated no statistically significant difference in JOA scores between the two groups [n=87, WMD=−0.11, 95% CI (−0.53, 0.31), p=0.61, I^2=50%]. The forest plot of outcomes related to cervical function are depicted in Supplementary Material 4 (see Supplementary Figures 4–11).

Cervical Curvature

Three RCTs utilized Borden's measurement to assess cervical curvature on lateral cervical spine X-rays in two groups. The meta-analysis results using random-effects model indicated no statistically significant difference in cervical curvature between the two groups [n=141, WMD=0.69, 95% CI (−0.39, 1.76), p=0.21, I^2=79%]. The forest plot of cervical curvature is provided in Supplementary Material 5 (see Supplementary Figure 12).

Safety

Four RCTs[31–34] evaluated the safety of CRTM. The results indicated no occurrence of adverse reactions and events related to the CRTM technique, suggesting its high safety.

The Results of Sensitivity Analysis

Sensitivity analysis was conducted by sequentially excluding individual studies, and the results showed no directional change, indicating the stability of the meta-analysis findings.

The Results of Publication Bias

For the primary outcome measure of VAS scores, a funnel plot was constructed to assess publication bias, revealing a symmetrical distribution of studies around the mean effect size (Figure 4). Further analysis using Egger's (p=0.550) and

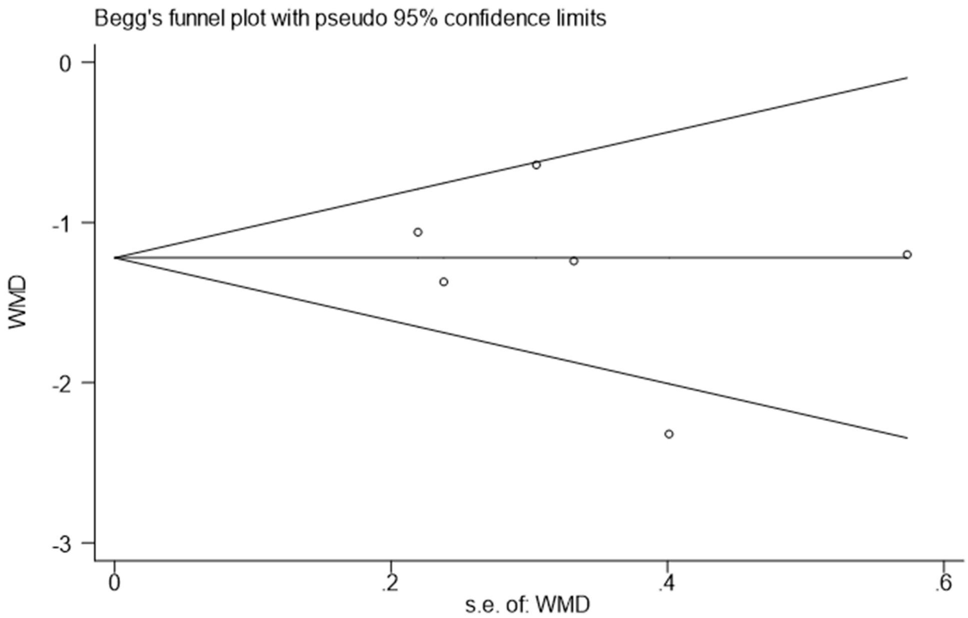

Figure 4 The funnel plot of VAS score.

Begg's (p=0.707) tests indicated the absence of significant publication bias. Due to the limited number of included studies for the remaining outcome measures, publication bias testing was not conducted.

The Results of Evidence Quality Assessment

Based on the GRADE approach, the evidence quality for each body of evidence was evaluated. The results indicate an overall insufficient evidence quality, characterized by very low to low strength of evidence, including two outcomes of low quality and ten outcomes of very low quality, as shown in Table 4. The low quality of evidence suggests that CRTM is superior to the control group in improving pain among CR patients. The very low quality of evidence suggests that CRTM is superior to the control group in enhancing patients' cervical range of motion of lateral flexion and rotation. Primary factors contributing to downgrading include: (1) The experiment's design exhibits significant bias in randomization, allocation concealment, or blinding. (2) The I^2 statistic indicates substantial heterogeneity. (3) The sample of the included studies is small. (4) A limited number of studies are included, raising concerns about potential publication bias.

Discussion

To our knowledge, this is the first systematic review and meta-analysis on the use of a specific traditional Chinese manual therapy for CR. Traditional Chinese manual therapies have a rich history in China, with diverse schools of practice and distinctive characteristics. Over thousands of years of clinical practice, they have developed unique theoretical frameworks and comprehensive treatment principles, resulting in a variety of specialized techniques for treating musculoskeletal disorders. Similar to acupuncture and herbal medicine, traditional Chinese manual therapies have gradually become significant representatives and gateways for the international promotion of traditional Chinese medicine (TCM). However, the multitude of traditional Chinese manual therapy techniques and the relatively scattered research have led to a lack of systematic evaluations of individual manual therapy. Most studies have focused on integrating clinical evidence for a particular category or all categories of manual therapies, which does not facilitate the provision of specific guidance for clinical decision-making. CRTM was developed under the guidance of TCM's theory of tendons-bones balance, by scholars of the Qing Dynasty's Imperial Bone-setting school, building upon innovations in cervical rotational techniques. Over the past two decades, numerous clinical and basic research studies have preliminarily confirmed the efficacy and mechanisms of CRTM. To provide high-level clinical evidence support for the further promotion of CRTM

Table 4 The Results of Evidence Quality Assessment

Outcomes	Number Of Included Studies (Total Sample Size)	Effect Size (95% CI)	Risk of Bias	Inconsistency	Indirectness	Imprecision	Publication Bias	Quality of Evidence
VAS scores	6 (534)[31–34,37,38]	WMD −1.27 (−1.66, −0.87)	−1[A]	−1[B]	0	0	0	Low
CRTM vs CT	3 (416)[34,37,38]	WMD −1.50 (−2.11, −0.89)	−1[A]	−1[B]	0	0	0	Low
CRTM+JT granule vs JT granule	3 (118)[31–33]	WMD −0.95 (−1.36, −0.54)	−1[A]	0	0	−1[C]	−1[D]	Very low
Cervical range of motion: flexion	2 (290)[35,39]	WMD 6.96 (−2.33, 16.25)	−1[A]	−1[B]	0	−1[C]	−1[D]	Very low
Cervical range of motion: extension	2 (290)[35,39]	WMD 7.28 (−2.50, 17.06)	−1[A]	−1[B]	0	−1[C]	−1[D]	Very low
Cervical range of motion: left lateral flexion	2 (290)[35,39]	WMD 4.37 (1.90, 6.85)	−1[A]	−1[B]	0	−1[C]	−1[D]	Very low
Cervical range of motion: right lateral flexion	2 (290)[35,39]	WMD 5.56 (0.10, 11.02)	−1[A]	−1[B]	0	−1[C]	−1[D]	Very low
Cervical range of motion: left rotation	2 (290)[35,39]	WMD 8.93 (2.31, 15.54)	−1[A]	−1[B]	0	−1[C]	−1[D]	Very low
Cervical range of motion: right rotation	2 (290)[35,39]	WMD 9.21 (1.15, 17.28)	−1[A]	−1[B]	0	−1[C]	−1[D]	Very low
NDI scores	3 (118)[31–33]	WMD −3.04 (−6.56, 0.48)	−1[A]	−1[B]	0	−1[C]	−1[D]	Very low
JOA scores	2 (87)[31,32]	WMD −0.11 (−0.53, 0.31)	−1[A]	−1[B]	0	−1[C]	−1[D]	Very low
Cervical curvature	3 (141)[31,33,36]	WMD 0.69 (−0.39, 1.76)	−1[A]	−1[B]	0	−1[C]	−1[D]	Very low

Notes: [A]The experiment's design exhibits significant bias in randomization, allocation concealment, or blinding. [B]The I^2 statistic indicates substantial heterogeneity. [C]The sample is small. [D]A limited number of studies are included, raising concerns about potential publication bias.

and to advance its clinical application from empirical to evidence-based medicine, we conducted this systematic review and meta-analysis of CRTM for the treatment of CR.

Key Findings of This Study

In this systematic review and meta-analysis, we included a total of nine RCTs,[31–39] conducted in various provinces and regions of China. Meta-analysis results demonstrate that for primary outcome measure, CRTM significantly reduces patients' VAS scores, outperforming the control group in alleviating patients' pain symptoms. Subgroup analysis suggests that whether used in combination with Jingtong granule or applied alone, the effectiveness of CRTM in improving pain surpasses that of the control group. Radicular pain is the primary symptom manifestation in cervical radiculopathy patients and a major reason for seeking medical attention.[40] Our study indicates a significant improvement in patients' pain symptoms after CRTM treatment, suggesting that CRTM may be an effective treatment modality for individual or comprehensive management of CR patients. For secondary outcome measures, CRTM significantly enhances patients' cervical lateral flexion and rotation range of motion, improving cervical function. In CR patients, cervical lateral flexion and rotation often induce traction or stimulation of cervical nerve roots, exacerbating radicular pain and restricted cervical motion, with positive results in brachial plexus traction tests and intervertebral foramen compression tests. Our study findings reveal a significant improvement in patients' cervical lateral flexion and rotation range of motion after two weeks of CRTM treatment, with superior efficacy compared to the control group, indicating CRTM's potential to enhance cervical function. Regarding safety, four RCTs[31–34] observed the safety of CRTM, with results indicating no adverse reactions or events related to CRTM, suggesting its relatively high safety. Methodological quality assessment results indicate insufficient reporting in aspects such as random sequence generation, allocation concealment, blinding, incomplete outcome data, and selective reporting, suggesting potential risks of bias. GRADE evidence level assessment results indicate low quality and very low quality evidence for VAS and cervical ROM, respectively. The downgrade factors are related to the potential bias risks, high heterogeneity, and the limited number and sample size of included studies.

In addition, three studies[31–33] evaluated the cervical function of patients with NDI score, while two studies[31,32] utilized the JOA score. However, the meta-analysis results suggest that there were no significant differences compared to the control group. Three studies[31,33,36] employed the Broden method to measure cervical curvature on lateral cervical spine X-rays, and the pooled results indicate no significant differences in cervical curvature between the two groups of patients. This could be attributed to factors such as the limited number of included studies, mostly exploratory trials, and potential risk of bias, indicating the need for further high-quality RCTs.

The Potential Mechanisms of Cervical Rotation-Traction Manipulation

Due to the lack of a recognized animal model for CR and the difficulty of simulating CRTM in experimental animals, existing research on the mechanisms of CRTM mainly originates from human, cadaveric, and biomechanical models. This multifaceted approach gradually elucidates the mechanisms by which CRTM exerts its therapeutic effects, further elucidating the scientific significance of the technique. Wang et al[23] evaluated the immediate effects of CRTM treatment on cervical soft tissue tension in 30 patients with CR using a soft tissue tension tester. The results showed a significant decrease in cervical soft tissue tension in patients with CR after CRTM treatment compared to before treatment, and CRTM could balance the asymmetric tension between symptomatic and asymptomatic sides. Han et al[24] implanted miniature pressure sensors into the nucleus pulposus of seven human cervical spine specimens to measure intradiscal pressure, simulated CRTM and cervical traction operations using the biomechanical tester, and evaluated the effect of CRTM on intradiscal pressure under different loads (50N, 150N, and 250N), comparing the difference in intradiscal pressure between CRTM and cervical traction. The results showed that CRTM significantly reduced intradiscal pressure during preloading and thrusting phases of each intervertebral disc. Furthermore, when adjusting thrust parameters, a discernible decrease in intradiscal pressure was observed with increasing thrust force. Comparative analysis showed that CRTM was more effective in significantly reducing intradiscal pressure than cervical traction. Feng et al[41] used motion capture technology to explore the effect of CRTM on the displacement of the lower cervical spine (C4-C7) based on human cervical spine specimens. The results showed that CRTM could adjust the displacement of the lower cervical vertebrae with the largest displacement occurring on the contralateral side of rotation, and the displacement being correlated with the magnitude of the traction force. Liu et al[42] used human cervical spine specimens and virtual reality technology to investigate the changes in intervertebral foramen structure after CRTM. The results showed that bilateral intervertebral foraminal height and area increased to a certain extent after CRTM with a greater change in area on the contralateral side. The study suggested that CRTM had a certain effect on the structure of the cervical intervertebral foramen, which may help to release adhesions of nerve roots, thereby relieving symptoms of radiculopathy. Similarly, Wang et al[43] established a biomechanical model of C3-T1 using three-dimensional finite element analysis and loaded mechanical parameters of CRTM on this basis. The results showed that CRTM could significantly increase the area of the contralateral intervertebral foramen, achieving physical decompression of the nerve roots. In another three-dimensional finite element analysis, Bu et al[44] established a biomechanical model of C3-C7 and loaded mechanical conditions of CRTM, finding that CRTM significantly improved the stress distribution of bilateral facet joint cartilage. In summary, the therapeutic effect of CRTM on CR may be related to aspects such as improving cervical soft tissue tension, reducing nucleus pulposus pressure, adjusting vertebral displacement, enlarging intervertebral foraminal area, and improving facet joint cartilage stress.

The safety of manipulation has always been a hot topic of concern for researchers, especially high-speed low-amplitude manipulation. Previous studies have reported adverse events associated with manipulation, such as spinal cord-related and vascular-related events.[45–47] Several clinical practice guidelines[12,48,49] also emphasize the need for clinicians to pay full attention to the potential adverse events associated with manipulation. The included four RCTs did not report any adverse reactions or events related to CRTM, suggesting that CRTM has high safety. Moreover, several biomechanical studies further demonstrate the safety of CRTM. Zhu et al[22] quantified the kinematic parameters of CRTM using the motion capture systems, and revealed the motion ranges obtained during CRTM were well below the active range of motion reported in the literature. Huang et al[26] compared the mechanical parameters and motion trajectories of cervical oblique pulling manipulation with CRTM employing similar motion capture technology, showed the latter's smaller thrust amplitude, and thus demonstrated clinical safety. Lin et al[50] used motion capture technology to compare the differences in cervical spine range of motion after two types of cervical manipulation above. The results showed that the subphysiological range of motion of the cervical spine during CRTM was smaller than that during oblique pulling manipulation, and the subphysiological range of motion on both sides of the cervical spine during CRTM was similar, while there were differences in the oblique pulling manipulation, indicating that CRTM is safer and more stable to perform. Furthermore, Three-dimensional finite element analysis[25] revealed that CRTM could maintain disc stress levels below the threshold for disc damage or fibrous annulus disruption, and thus demonstrated clinical safety.

Strengths and Limitations

As the first systematic review and meta-analysis evaluating a specific traditional Chinese manual therapy for treating musculoskeletal disorders, this study largely demonstrates the effectiveness and safety of CRTM in treating CR. It provides concrete and operable manual therapy protocol for clinical practice, thereby promoting the further dissemination and application of CRTM. However, several limitations exist in this study. Firstly, the number of included studies is limited. Although numerous RCTs on CRTM for CR have been conducted in China, many of them investigate the effectiveness and safety of comprehensive TCM treatments including CRTM, while studies specifically focusing on the effects of CRTM alone are insufficient. Moreover, many RCTs exhibit unreasonable and unacknowledged phenomena in the selection of control groups and outcome indicators, resulting in an inadequate number of included studies. This may also be a significant reason why this study did not yield positive results in terms of NDI scores, JOA scores, and cervical curvature. Secondly, the methodological quality of the included studies is insufficient. Currently, research still primarily consists of exploratory trials with small sample sizes, and many studies do not clearly report the methods of random sequence generation and allocation concealment. Due to the nature of manual therapy, it is challenging to blind patients and researchers in clinical trials, resulting in the majority of clinical studies failing to clearly report the methods of blinding implementation. These deficiencies in the clinical trial potentially lead to a risk of bias. The evidence quality of the included studies is mainly low and very low, which needs further improvement. Thirdly, the subjects included in the studies are predominantly Chinese, lacking clinical observations of foreign patients from different cultural backgrounds and healthcare policies, which may limit the generalizability of the study results.

Implications for Future Research

The limitations of current research point towards directions for further investigation. Firstly, researchers need to continue conducting high-quality clinical studies on CRTM for CR to further explore its effectiveness and safety, especially regarding cervical function and quality of life. In the phase of clinical research design, researchers should invite multidisciplinary experts to review and standardize the research design and reporting, enhancing the transparency and scientific rigor of the studies. Secondly, researchers should actively conduct methodological studies related to manual therapy: (1) The absence of placebo/sham manual therapy control has become a bottleneck restricting the generation of high-quality evidence, leading to limited international recognition of TCM manual therapy research. The establishment of placebo/sham manual therapy control groups is aimed at scientifically exploring and verifying the efficacy of manual therapy. A reasonable placebo control should adopt blinding, and require the appearance and feeling to be basically the same as the real manual therapy to eliminate the influence of psychological factors of the subjects. Researchers should actively conduct methodological studies on placebo/sham control, establish a unified placebo/sham control operation process based on broad consensus, and promote it, as well as strengthen the development of relevant auxiliary tools. (2) Currently, the outcome indicators of clinical research on TCM manual therapy mostly rely on subjective scale outcomes reported by patients, lacking objective evaluation tools. Developing a core outcome set for clinical research on TCM manual therapy is an important path to address the above problems, to improve the quality and recognition of research results. Thirdly, researchers need to deepen international scientific cooperation to investigate the effectiveness of CRTM in foreign populations, thereby increasing the generalizability of research findings. After nearly twenty years of research, Zhu et al[51,52] have developed the third-generation CRTM intelligent teaching robot, which can provide manual quality control tools and standards for further clinical research, as well as auxiliary tools for teaching, training, and international promotion of CRTM.

Conclusions

In summary, the meta-analysis indicates that cervical rotation-traction manipulation significantly improves pain and cervical range of motion in patients with cervical radiculopathy, with a high level of safety. However, given the limited quality of included studies, future research should continue to conduct high-quality randomized controlled trials on cervical rotation-traction manipulation, building upon standardized research designs. Furthermore, researchers should conduct further methodological studies related to manual therapy, thus promoting the application and dissemination of cervical rotation-traction manipulation.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

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