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ORIGINAL RESEARCH

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Effect of thoracic manipulation on neck pain in the mobility group: A randomized controlled trial

Ryota Yoshida[1,2] | Kazuna Ichikawa[1] | Hiraku Nagahori[3] | Tomohiro Tazawa[4] | Hironobu Kuruma[1]

[1]Department of Physical Therapy, Tokyo Metropolitan University: 7-2-10 Higashiogu, Arakawa-ku, Tokyo, Japan

[2]Yomiuri Clinic: 1-7-1 Otemachi, Chiyoda-ku, Tokyo, Japan

[3]Seijo Surgery Orthopedic Clinic: 2-35-18 Seijo, Setagaya-ku, Tokyo, Japan

[4]Sonodakai joint replacement center hospital: 1-21-10 Hokuima, Adachi-ku, Tokyo, Japan

Correspondence

Ryota Yoshida, Department of Physical Therapy, Tokyo Metropolitan University: 7-2-10 Higashiogu, Arakawa-ku, Tokyo 116-8551, Japan.

Email: physio.yoshida@gmail.com

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Abstract

Background and aims: Thoracic spine manipulation (TSM) increases the thoracic spine's range of motion (ROM), effectively reducing pain intensity and disability in patients with mechanical neck pain. We aimed to determine the effect of TSM on neck pain intensity and functional impairment in patients classified under the "mobility" category in Childs' classification.

Methods: In this randomized controlled trial, patients with mechanical neck pain who met the inclusion criteria were randomly assigned to either the TSM ($n = 21$) or sham manipulation ($n = 20$) group. The primary outcomes were pain during neck rotation and subjective improvement assessed using the Numerical Pain Rating Scale (NPRS) and Global Rating of Change (GROC), respectively. The secondary outcomes were NPRS at rest, disability (assessed using the Neck Disability Index [NDI]), and ROM of the cervical and thoracic spine rotation. Outcome measurements were performed at baseline, immediately after treatment, 1 week after treatment, and at the 4-week follow-up. Linear mixed models were used to analyze the NPRS, NDI, and ROM. The GROC was analyzed using a chi-square test for the percentage recording ≥+4; the means of each group were compared using an unpaired t-test.

Results: The NPRS with neck rotation, neck and thoracic ROM, and NDI showed significant interactions between the groups. The NPRS with neck rotation was significantly lower in the TSM group than in the sham group at all time points after the treatment ($p < 0.001$). There was no difference between the groups in the proportion showing moderate (≥+4) improvement according to the GROC; however, there was a significant difference in the mean values ($p = 0.013$).

Conclusion: Incorporating TSM into treatment protocols may improve clinical outcomes in patients with neck pain, potentially leading to better pain management and functional recovery. Therefore, physiotherapists should consider TSM as a viable and effective intervention to improve patient outcomes in neck pain rehabilitation.

Study registration: The study was registered at the University Hospital Medical Information Network (R000058343).

KEYWORDS
mobility, neck pain, neck rotation, range of motion, thoracic spine manipulation, treatment-based classification

1 | INTRODUCTION

Neck pain is one of the most common conditions worldwide, with a prevalence of 2443.9–6151.2 cases per 100,000 people.[1] In addition, of all 291 conditions examined in the Global Burden of Disease 2010 study, neck pain ranks fourth in terms of disability, as measured by years lived with disability.[2] Its prevalence has been steadily increasing worldwide, with a 21% increase from 2006 to 2016.[3] Additionally, neck pain caused 25 million Americans to miss work, with an average of 11.4 days of absence per person.[4] In Ontario, 14.2% of claimants experienced multiple episodes of absenteeism due to neck pain, accounting for 40.4% of all days lost.[5] Thus, neck pain has significant health and economic impacts, leading to increased health care costs and impact on employment.[6]

Neck pain is a multifactorial condition caused by various factors. Conservative treatments such as pharmacotherapy, physical therapy, and exercise are recommended for most cases.[7,8] Given the complexity of neck pain, a comprehensive evaluation is essential for effective treatment.

The concept of "regional interdependence" suggests that primary symptoms may be related to other body regions, implying that treatment of areas beyond the symptomatic site may improve the primary symptoms.[9,10] This concept is based on Steindler's "kinetic chain," which posits that all joints are interconnected,[11] thus emphasizing the interconnectedness of the body's musculoskeletal system.

An important application of this concept in the evaluation of neck pain is the role of the thoracic spine. Malalignment and decreased range of motion (ROM) of the thoracic spine are associated with neck pain.[12] Further, patients with neck pain often have decreased thoracic spine rotation compared to healthy individuals.[13,14] Numerous studies have demonstrated the efficacy of thoracic spine interventions for neck and shoulder pain, further emphasizing the principle of regional interdependence.[15–21]

Thoracic spine manipulation (TSM) is effective in increasing the ROM of the thoracic spine. A systematic review by Tsegay et al.[22] concluded that TSM reduces pain intensity and disability in patients with mechanical neck pain. However, Masaracchio et al.[20] reported no significant difference between TSM and sham thoracic manipulation, likely because specific causes of neck pain were not considered. Gross et al.[23] suggested that subgrouping of participants' neck pain is necessary to improve the quality of TSM research. Additionally, Verhagen[24] stated that because neck pain comprises subcategories, it is essential to specifically treat each subgroup. Furthermore, because neck pain has different subcategories, each requiring tailored treatment, Childs' classification system, which uses symptoms, clinical findings, and duration of illness, may be valuable for such subgrouping.[25]

This study focuses on the "mobility" group in Childs' classification system, where ROM limitations are more likely to contribute to neck pain. We aimed to determine the effect of TSM on neck pain intensity and functional impairment in this specific subgroup and provide targeted insight into the clinical utility of TSM.

2 | METHODS

2.1 | Study design

This study is a randomized controlled trial, approved by the Research Ethics Review Committee of the Tokyo Metropolitan University, Arakawa Campus (approval number: 22086). Informed consent was obtained from all the participants. The study was registered at the University Hospital Medical Information Network (R000058343) and follows the Consolidated Standards of Reporting Trial.

2.2 | Participants

The participants were recruited from a clinic in Tokyo between April 2023 and January 2024. The inclusion criteria were age between 18 and 60 years, baseline Neck Disability Index (NDI) ≥ 10/50, and falling under the "mobility" category in Childs' classification. Two physical therapists determined this separately based on a classification algorithm, and only those who agreed to participate were included. The exclusion criteria were as follows: symptoms such as pain or numbness in the upper extremities, a history of cervical or thoracic spine surgery, red flags, pregnancy or possible pregnancy, receiving treatment for neck pain, and having received a steroid injection within the past 3 months.

2.3 | Procedures

All participants underwent baseline cervical and thoracic rotational ROM measurements after providing demographic information and completing a questionnaire related to neck pain. A physical therapist, different from the intervention provider, performed all the measurements. After baseline measurements, the participants were randomly assigned to receive TSM (TSM group) or sham manipulation (sham group). A random, simple assignment was developed by placing a piece of paper containing the intervention in an envelope and having the intervention provider draw it out.

Follow-up measurements were performed immediately, 1 week, and 4 weeks after the intervention. Participants were blinded to the group assignments.

2.4 | Interventions

The interventions were performed by an orthopedic manipulative physical therapist with 12 years of clinical experience. Both groups underwent TSM or sham manipulation plus standard physiotherapy interventions based on the results of individual physiotherapy assessments. Standard physical therapy consisted of soft tissue mobilization of the neck, deep cervical muscle exercises, instructions on proper posture and movement patterns, environmental adjustments, and home exercise instructions. Patients undergoing interventions in the thoracic region were excluded. Exercises for the deep cervical muscles were performed using a biofeedback pressure meter (Stabilizer™, Chattanooga Group Inc., Chattanooga, TN).[26,27] TSM and sham manipulation were performed only at the initial intervention. Subsequently, both groups underwent standard physical therapy. The intervention time was 40 min per session, and the frequency was once a week. Before manipulation, all participants underwent a segmental mobility examination from the seventh cervical vertebra to the ninth thoracic vertebra.[28] TSM or sham manipulation was performed on up to three segments that showed particularly strong hypomotility.

TSM group: The participants were placed in a relaxed supine position on the bed with their arms crossed in front of the chest. Thereafter, the participant's body was turned sideways toward the therapist; then, the therapist held one hand in a pistol grip and secured it to the lower segment to be manipulated (Figure 1A). Afterward, the therapist supported the participant while gradually returning the trunk to the supine position. The participant took deep breaths in that position, and the therapist performed low-amplitude, high-velocity manipulations in response to the participant's exhalations[15,29] (Figure 1B).

Sham group: Participants lay supine with arms crossed. The therapist rotated them to the side similarly but placed an open hand one segment lower than that targeted for the sham intervention (Figure 1C). Although the participants breathed deeply, as in the TSM group, no manipulation was performed[15] (Figure 1D).

The participants in both groups were instructed to refrain from performing exercises or activities other than the prescribed home exercises until their subsequent session.

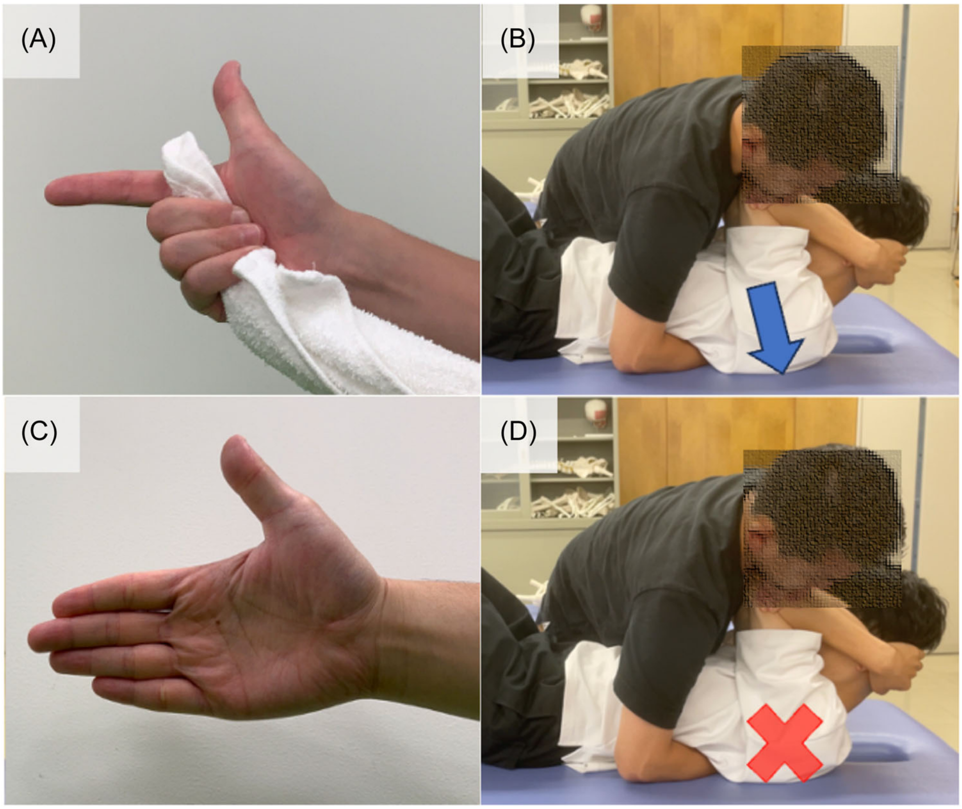

FIGURE 1 Thoracic spine (A, B) and sham (C, D) manipulations. A: In thoracic manipulation, the hand fixed to the spine extends the first and second fingers, and the other fingers are flexed. B: The therapist performs thoracic spinal manipulation from anterior to posterior with the participant exhaling. C: The hand fixed to the spine during sham manipulation is open with all fingers extended. D: Participants are instructed to take deep breaths, but no manipulation is performed. Five deep breaths are recorded per target segment.

2.5 | Outcomes

The primary outcome was the intensity of neck pain during neck rotation (assessed using the Numerical Pain Rating Scale [NPRS]) and 15-point subjective improvement after the treatment intervention (assessed using the Global Rating of Change [GROC]) after the treatment intervention. Secondary outcomes were the NPRS at rest, NDI, cervical ROM, and thoracic ROM.

The NPRS, NDI, and cervical and thoracic ROMs were measured four times: before intervention, immediately after intervention, 1 week after intervention, and 4 weeks after intervention. Any missing values were supplemented by the last observation carried forward method; the GROC was assessed at the final measurement at 4 weeks post-intervention. All measurements were performed in a blinded manner.

1) NPRS

In the present study, the NPRS score was recorded at rest and during maximum neck rotation. The reliability score (ICC, intraclass correlation coefficient) for the NPRS in patients with mechanical neck pain without upper extremity symptoms is ICC = 0.67 (95% confidence intervals [CI]: 0.27–0.84), indicating moderate reliability. The validity (area under the curve [AUC]) is 0.81 (95% CI: 0.73–0.90), and NPRS is considered to have good validity.[15]

2) GROC

The GROC assessment was performed using a 15-point scale ranging from −7 (very much worse) to +7 (very much improved). The test-retest reliability score (ICC) for the GROC in patients with neck pain is reported to be 0.92–0.99, indicating very high reliability. The validity is reported to be moderately correlated between GROC scores and the NDI (Pearson's $r = 0.51$, 95% CI: 0.43–0.58; Spearman's $\rho = 0.56$, 95% CI: 0.41–0.68).[30]

3) NDI

The test-retest reliability (ICC) of the NDI for patients with mechanical neck pain without upper extremity symptoms is reported to be 0.88 (95% CI: 0.63–0.95), indicating high reliability. Additionally, the NDI has good responsiveness, with an AUC of 0.86 (95% CI: 0.79 to 0.93), indicating its ability to accurately detect changes in the patient's level of disability.[15]

In the present study, the Japanese version of the NDI (NDI-J) was used. The NDI-J has been shown to be a reliable, valid, and responsive tool, making it useful for assessing neck pain in Japanese outpatient populations.[31]

4) Cervical rotational ROMs using a digital goniometer

The ROM of neck rotation was measured in the sitting position. In patients with neck pain, the measurement of neck rotation using an electronic goniometer has been shown to have very high intra- and inter-rater reliabilities.[32]

5) Thoracic rotational ROMs using a digital goniometer

Thoracic spine rotation ROM was measured with the Lumber lock rotation test, which is suggested to be highly reliable.[33–35] Yoshida and Kuruma[36] reported high intra- and inter-rater reliabilities, even when applied to patients with neck pain. Furthermore, Ichikawa et al.[37] reported a strong correlation between the thoracic rotation angle measured using MRI and the ROM obtained with the lumbar spine locking rotation test.

The success of blinding in the group assignments was evaluated by asking all participants at the second follow-up (1 week later) whether they had received more intensive physical therapy.

2.6 | Sample-size calculation

The sample size was calculated using G*POWER© software (ver.3.1.9.2, Heinrich-Heine University, Düsseldorf, Germany) with an a priori testing approach. The calculation focused on detecting group interactions, with the primary outcome variable being the intensity of pain during neck rotation. The parameters used for the calculation were an effect size of 0.40, an alpha level of 0.05, and a power level of 80%. Based on these parameters, it was determined that a sample size of 22 participants per group was required.

2.7 | Data analysis

The IBM SPSS Statistics ver. 27.0 (IBM Corporation, Armonk, NY, USA) was used for statistical analyses, with a significance level of 5%.

2.7.1 | Primary outcomes

Primary outcomes

A linear mixed model, with group and measurement time points as factors, was used for the primary analysis of the NPRS. When a significant interaction was found, the NPRS scores at the three follow-up time points were compared between the groups using the Bonferroni-corrected multiple comparison method as a post-hoc test. Furthermore, we calculated the mean change in the NPRS score for neck pain from baseline to immediately, 1 week, and 4 weeks after treatment within each group. Additionally, we calculated the between-group differences in the change in the NPRS scores at each time point. The 95% CIs and effect sizes (Cohen's d) were calculated for all variables.

The GROC scores were dichotomized for statistical analysis, and participants who reported a GROC score of at least +4 (moderately good) were classified as having a moderate-to-large change in neck symptoms.[15] Odds ratios and 95% CIs were calculated for those who scored at least +4 on the GROC for neck pain 4 weeks post-intervention. Additionally, we compared between groups the percentage that recorded ≥+4 using the chi-square test and compared the means for each group using an unpaired t-test.

2.8 | Secondary outcomes

A linear mixed model, with group and measurement time points as factors, was used for the primary analysis of the NPRS at rest, NDI, cervical ROM, and thoracic ROM. When a significant interaction was found, each score at the three follow-up time points was compared between the groups using multiple comparisons with the Bonferroni correction as a post-hoc test. Furthermore, we used the chi-square test to examine whether the proportion of participants who answered "yes" to "Do you think you received more aggressive physical therapy?" differed.

3 | RESULTS

A total of 112 individuals were screened for eligibility. Forty-one participants who met the eligibility criteria and agreed to participate were enrolled. The participants were randomly assigned to either the TSM (*n* = 21) or sham (*n* = 20) groups (Figure 2). The demographic and general characteristics of patients at baseline are shown in Table 1. There were no differences between both group in terms of sex, age, height, weight, and days since the onset of neck pain ($p > 0.05$ for all).

3.1 | Primary outcomes (Table 2)

3.1.1 | NPRS score with neck rotation

There was a significant difference in the NPRS score between the group and the time-point interaction terms ($p < 0.001$). In the post-hoc test, the TMS group had a significantly lower NPRS score than the sham group at all time points (Figure 3). The NPRS at each time point of data collection is shown in Table 2.

3.2 | GROC

The percentage of patients reporting a GROC score of +4 or higher (at least moderate improvement) was 75.0% in the TSM group and 52.9% in the sham group, with no significant difference between the two groups ($p = 0.22$). In contrast, the odds ratio for GROC was 2.7, suggesting that the TSM group improved more than the sham group. The mean GROC score was significantly higher in the TSM group than in the sham group (4.7 vs. 3.6, $p = 0.013$).

3.3 | Secondary outcomes (Figure 4)

3.3.1 | NPRS score at rest

There was no significant difference in the interaction term between the group and time point ($p = 0.74$) or in the main effect of the time point ($p < 0.001$).

TABLE 1 Baseline patient demographics.

Characteristic	TSM Group (*n* = 21)	Sham Group (*n* = 20)	*p* value
Age (years)	49.6 ± 7.2	51.3 ± 8.4	0.30
Sex (male), *n* (%)	9 (42.8)	8 (40.0)	0.70
Height (m)	1.67 ± 0.1	1.64 ± 0.1	0.26
Weight (kg)	59.7 ± 11.3	56.1 ± 8.2	0.25
Days since onset	16.8 ± 7.5	14.1 ± 8.5	0.28

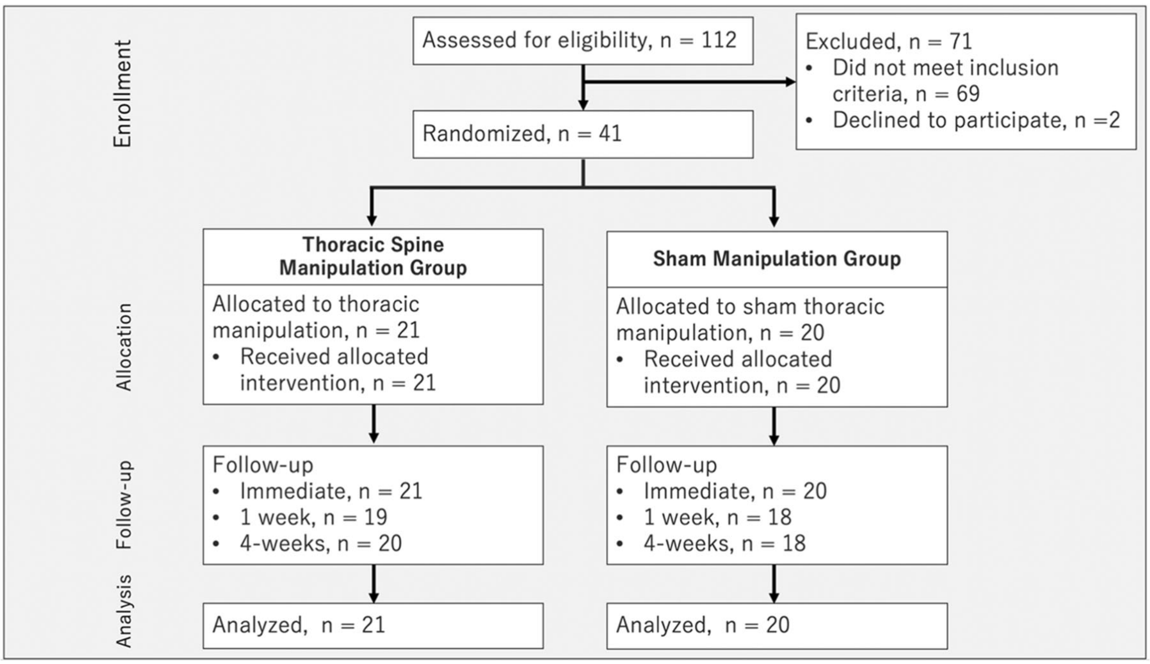

FIGURE 2 CONSORT flow diagram.

TABLE 2 Primary outcomes at each data collection time point.

Outcome/Time Point	TSM Group (n = 21)	Sham Manipulation Group (n = 20)	Between-Group Differences	Odds Ratio	p value
NPRS for neck pain					
■ Baseline	4.9 ± 1.1	5.1 ± 1.2			
■ Immediate	2.5 ± 0.9	4.4 ± 1.0	−1.8 (−2.5, −1.2)		<0.001
— Change from baseline	2.4 (1.8, 2.9), d = 3.2	0.7 (0.4, 1.0), d = 1.0	1.7 (1.3, 2.3), d = 2.3		
■ 1 week	2.0 ± 0.9	3.5 ± 0.8	−1.5 (−2.0, −0.9)		<0.001
— Change from baseline	2.9 (2.4, 3.4), d = 3.0	1.7 (1.0, 1.9), d = 1.4	1.2 (0.6-2.0), d = 1.8		
■ 4 weeks	1.0 ± 0.7	2.5 ± 0.9	−1.4 (−1.9, −0.9)		<0.001
— Change from baseline	3.9 (3.4, 4.3), d = 3.5	2.5 (2.1, 3.1), d = 1.8	1.4 (0.6, 2.1), d = 1.6		
GROC for neck symptoms,					
n (% improved)	15 (75)	10 (52.9)		2.7	n.s.
average	4.7	3.6			p = 0.013

Values are mean ± SD unless otherwise indicated.

Values in parentheses are 95% confidence interval.

d = Cohen's d (effect size).

NPRS, numeric pain-rating scale; GROC, global rating of change.

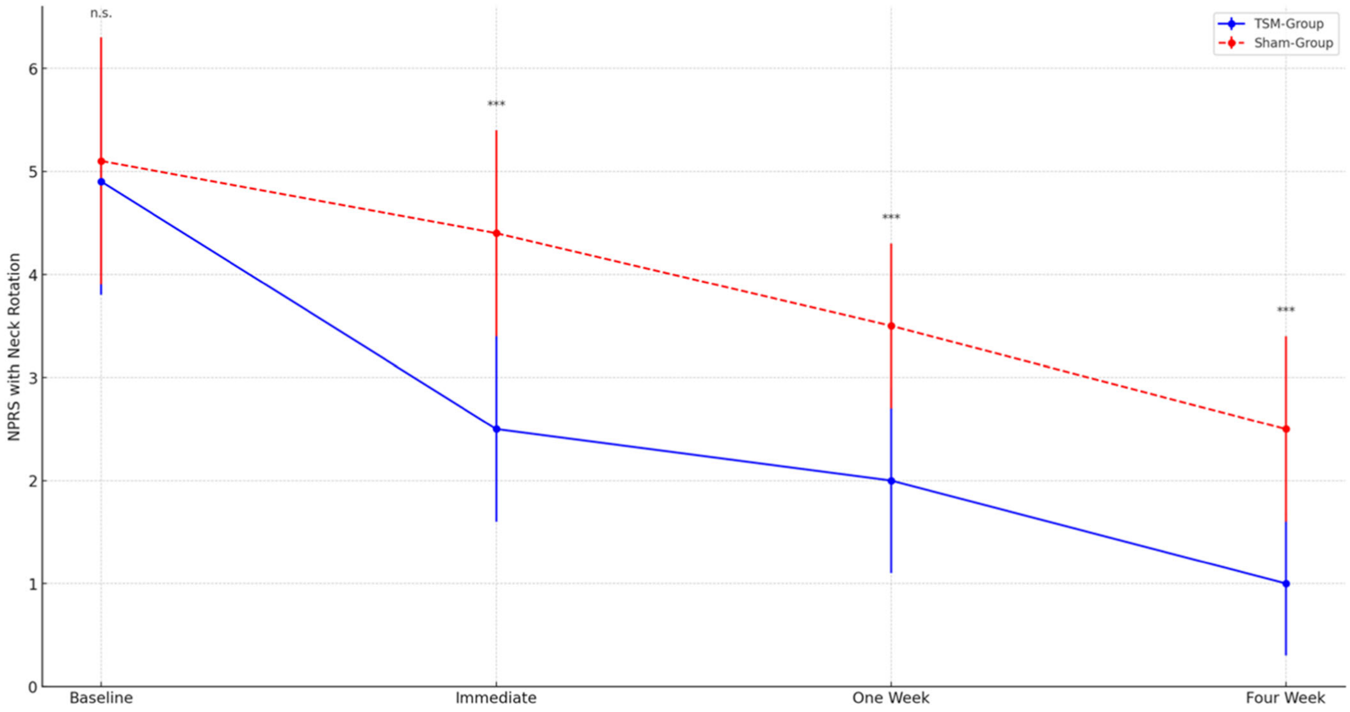

FIGURE 3 Time-point analysis of NPRS with neck rotation between the TSM and sham groups. TSM, thoracic spine manipulation; NPRS, Numerical Pain Rating Scale.

3.3.2 | Neck rotation ROM

There was a significant difference in the interaction term between the groups and time points ($p < 0.001$). The baseline neck rotation ROM was significantly different between the two groups at baseline ($p < 0.05$). Post-hoc tests showed no simple main effect of the group at any time point after the intervention.

3.3.3 | Thoracic rotation ROM

There was a significant difference in the interaction term between the groups and time points ($p < 0.001$). Post-hoc tests showed that the TMS group had a significantly greater range of thoracic spine rotation motion immediately, 1 week, and 4 weeks after the intervention than the sham group ($p < 0.05$).

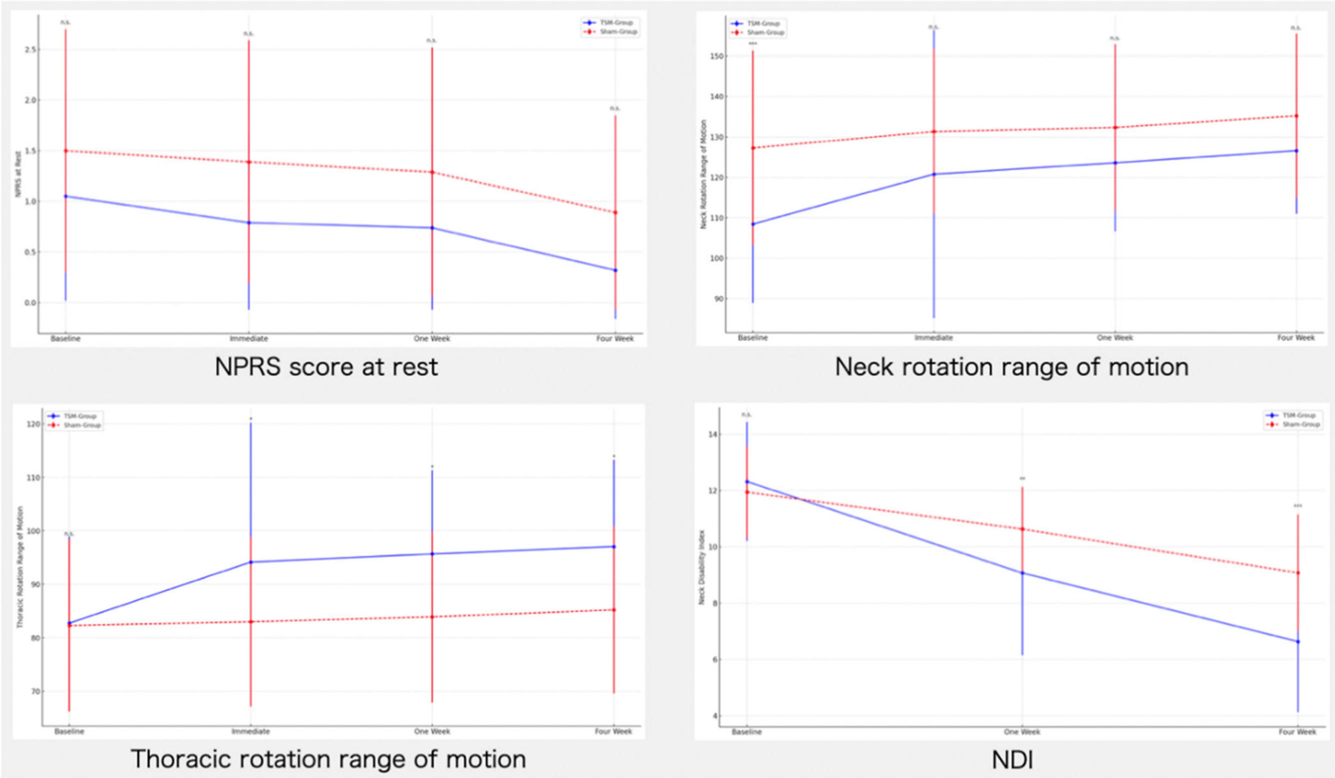

FIGURE 4 Secondary outcomes. NPRS, Numerical Pain Rating Scale; NDI, Neck Disability Index.

3.3.4 | NDI

There was a significant difference in the interaction term between the groups and time points ($p < 0.001$). Post-hoc tests showed that the TMS group had a smaller NDI than the sham group at 1 and 4 weeks after the intervention ($p = 0.007$ and $p < 0.001$, respectively).

3.3.5 | Percentage of participants perceiving their physical therapy as more aggressive

In total, 95% (20/21) of participants in the TSM group and 85% (17/20) of participants in the sham group responded "yes" to the question "Do you think you received more aggressive physical therapy?"

4 | DISCUSSION

This study aimed to determine the effect of TSM on neck pain intensity and functional impairment in patients classified under the "mobility" category in the Childs' classification system. We hypothesized that TSM would significantly reduce neck pain and improve functional outcomes. Our findings confirmed this hypothesis by showing that TSM, compared to sham manipulation, significantly reduced neck pain during rotation and improved cervical and thoracic ROM and NDI scores. These results were observed immediately after the intervention and persisted for up to 4 weeks.

The major findings of this study are:

1. TSM significantly reduced neck pain during rotation at all time points post-intervention.
2. The TSM group showed a higher mean improvement in the GROC scores; the proportion of patients reporting moderate or greater improvement was not significantly different between the groups.
3. There was no significant difference in NPRS scores at rest between the TSM and sham groups, indicating that TSM did not significantly affect neck pain at rest.
4. The cervical and thoracic ROM significantly improved in the TSM group compared to the sham group.
5. The TSM group showed significant improvement in the NDI scores, indicating reduced functional impairment.

Our findings thus suggest that TSM can be an effective intervention for reducing pain and improving functional outcomes in patients with mechanical neck pain, specifically those categorized in the "mobility" group in Childs' classification system. This agrees with the "regional interdependence" concept, which posits that treating areas adjacent to the primary site of pain can influence outcomes. The significant improvements in ROM and NDI scores indicate that TSM alleviates pain and enhances mobility and daily functioning, which are crucial for patient recovery and quality of life.

4.1 | Primary outcomes

4.1.1 | NPRS score with neck rotation

Young et al.[15] examined the effects of TSM and sham manipulation in patients with cervical radiculopathy. They reported a decrease of 1.9 and 0.1 in the NPRS score in the TSM and sham groups, respectively, with a difference of 1.8. Regarding the NPRS score immediately after TSM and sham manipulation, the decrease in each group in the present study was slightly larger than those reported by Young et al. This may be because the present study included patients classified under the "mobility" category in Childs' classification, whereas the previous study included patients with cervical radiculopathy. Additionally, a previous study compared the effects of TSM or sham manipulation alone. In contrast, the present study may have been influenced by the fact that conventional physiotherapy was performed in addition to each manipulation. Young et al.[15] and Cleland et al.[38] reported the minimal clinically important difference (MCID) of the NPRS scores in patients with mechanical neck pain to be 1.5 and 1.3, respectively. The reduction in the NPRS score obtained between pre-intervention and immediate post-intervention in this study was 2.4 ± 0.9 (95% CI: 1.8, 2.9) in the TSM group and 0.7 ± 0.2 (95% CI: 0.4, 1.0) in the sham group, with only the TSM group exceeding the MCID. The difference in the reduction between the groups also exceeded the MCID at 1.7 (95% CI: 1.3, 2.3), and only the TSM group showed a statistically significant difference between the time points before and immediately after the intervention ($p < 0.001$), indicating a significant immediate effect of TSM on pain during neck rotation.

In contrast, the NPRS score was 0.5 between the immediate post-intervention and 1-week post-intervention time points. Between the 1- and 4-week post-intervention time points, the decrease was 1.0. Although the reduction in the NPRS score was smaller during the follow-up period than between the pre-intervention and immediate post-intervention time points, there was a significant change ($p < 0.001$) between the 1- and 4-week post-intervention time points. There was no significant difference between the immediate and 1-week post-intervention time points ($p = 0.067$). The mean difference was 1.8 immediately after the intervention, 1.5 at 1 week, and 1.4 at 4 weeks, with a significantly lower NPRS score in the TSM group than in the sham group at all time points. These results suggest that TSM has the most significant immediate effect on neck pain and that this effect persists for at least 4 weeks.

One mechanism related to pain reduction with spinal manipulation is the neurophysiological effect. Pickar reported that spinal manipulation increases pain threshold. A possible mechanism for this is that spinal manipulation may affect sensory input to the central nervous system by stimulating muscle spindles and Golgi tendon organs.[39] Additionally, reflexive stimulation of muscles and visceral organs may alter neural output and exctability, resulting in immediate and sustained changes in pain levels. Bialosky et al.[40] suggested that this mechanism could be explained by neurophysiological factors such as placebo effects and patient expectations. Meanwhile, other studies report that spinal manipulation does not affect the activity of the autonomic nervous system.[41] Furthermore, it has been shown that spinal manipulation does not affect the neuroimmune response (blood levels of IL-1β and TNF-α) in patients with nonspecific neck pain.[42] Therefore, the neurophysiological effects and mechanisms of spinal manipulation need to be further validated. Another mechanism is the biomechanical effect of spine manipulation. Norlander et al. found that biomechanical defects in the thoracic spine segment are responsible for neck pain. Moreover, Yoshida et al. reported a reduced ROM of the upper thoracic spine during cervical rotation in neck pain patients compared to healthy participants. Thus, correcting these defects may improve pain.

This concept is consistent with the biomechanical explanation of the "kinetic chain" of interregional dependence. The cervical and thoracic spine are adjacent regions, and their biomechanical kinetic chains directly affect each other. Therefore, the biomechanical effects of TSM may spread to the cervical spine. While it is difficult to infer the mechanisms from the results of this study, the improvement in pain along with the rotational ROM in the cervical and thoracic spines suggests that biomechanical mechanisms may also be involved. Further research is needed to elucidate these mechanisms.

4.1.2 | GROC

Regarding the GROC due to TSM implementation, a previous study reported that 69% of patients with neck pain who received TSM and exercise therapy showed moderate or greater improvement (GROC ≥ 10 on a scale of 0–13) 4 weeks after the implementation.[43] In the present study, 75.0% of patients in the TSM group showed moderate or greater improvement, similar to the results of a previous study. However, no significant differences were observed between the TSM and sham groups. This may be because 52.9% or more of the participants in the sham group also received the usual physical therapy, showing moderate or greater improvement. In contrast, the odds ratio was 2.7, suggesting that the TSM group improved more than did the sham group. Additionally, a comparison of the mean values showed that the sham group had a mean GROC score of 3.6, which was below the criterion value of 4 for moderate improvement. In contrast, the mean score of the TSM group was 4.7, indicating a significant difference between the two groups ($p = 0.013$).

4.2 | Secondary outcomes (Figure 4)

4.2.1 | NPRS score at rest

Baseline resting NPRS scores were lower in both groups (TSM vs. sham: 1.05 vs. 1.50). The participants of the current study were classified under the "mobility" category of Childs' classification, which is characterized by limited movement and pain associated with neck movement.[44] Therefore, all participants had low neck pain intensity from baseline at rest; although it decreased over time in both groups, we do not believe that there was an interaction.

4.2.2 | Neck rotation ROM

Fritz and Brennan[44] reported a mean range of neck rotation motion of 116.7 ± 29.3°in 48 participants with neck pain classified under the "mobility" category. The mean baseline value for all participants in this study was 118.5 ± 23.5°, similar to the value reported by Fritz et al. The baseline range of cervical rotation motion was 108.9° for the TSM group and 12.4° for the sham group, resulting in a significant average group difference of 15.3°($p < 0.05$). Although the participants in this study were divided into two groups by simple randomization, this difference may have occurred incidentally.

Immediately after the intervention, the sham group improved by 0.6°, whereas the TSM group improved by 12.4°, showing a significant improvement between pre-intervention and immediate post-intervention. Additionally, the significant difference between the groups found at baseline was resolved. Krauss et al. examined the effect of TSM on patients with neck pain and found an average increase in neck rotation ROM of 15.3°.[16] Further, González-Iglesias et al.[21] found that TSM for patients with neck pain increased the range of neck rotation by an average of 18°. The results obtained in this study support the findings of these previous studies, and TSM is likely to immediately improve the range of cervical rotational motion.

4.2.3 | Thoracic rotation ROM

The most crucial goal of TSM is to improve the ROM of the concerned segment. Immediately after manipulation, the sham group showed a change of 0.6°, whereas the TSM group showed an improvement of 12.5°. Although many previous studies have reported the effect of TSM on neck ROM, the ROM of the thoracic spine is yet to be examined. One reason for this is that there is no established method for clinically evaluating the ROM of the thoracic spine. The lumbar lock rotation test used in this study has been shown to have high inter- and intra-rater reliabilities in healthy participants and patients with neck pain.[33–36,45] Additionally, Ichikawa et al.[37] compared the thoracic rotation angle measured using magnetic resonance imaging with the ROM obtained using the lumbar lock rotation test and reported a high correlation between the two. Therefore, the results obtained in this study reflect the ROM of thoracic spine rotation, and indicate that TSM increases the ROM of the thoracic spine.

4.2.4 | NDI

The NDI has excellent reliability in patients with mechanical neck pain without upper extremity symptoms, with an MCID of 5.5 points.[38] Griswold et al.[46] compared the effectiveness of cervical and TSM and mobilization in patients with mechanical neck pain. They reported that both approaches significantly reduced NDI at follow-up; however, there was no significant difference between the approaches. In contrast, the present study found that the NDI was considerably smaller in the TMS group than in the sham group at 1 and 4 weeks post-intervention ($p = 0.007$ and $p < 0.001$, respectively).

There are three possible reasons for this difference in results. First, the intervention method of the control group was different. In this study, the control group intervention was sham manipulation comprising only deep breathing. In contrast, Griswold et al. used an oscillatory technique (mobilization) in which the grade and duration were determined based on individual assessments. Second, there was a difference in the instructions for home exercises. In this study, all participants were limited to home thoracic exercises and activities involving large movements of the thoracic spine throughout the intervention period. In contrast, all participants in the previous study were instructed to perform ROM exercises for the cervical and thoracic spines and were encouraged to be active. Home exercises and increased daily activities may have had positive effects on functional improvement. Third, there were differences in the demographics of the participants between the two studies. The participants in the present study were in the "mobility" category in Childs' classification. One of the conditions was that the disease onset had to be within 30 days, and the mean duration of disease onset for all participants was 15.4 ± 8.4 days.

In contrast, in David et al.'s study, the participants had a very long disease duration: 67.6 ± 108.3 and 66.2 ± 143.1 weeks in the control and intervention groups, respectively. Aerobic exercises, self-exercises, and active daily activities help improve chronic pain and dysfunction of the musculoskeletal system. Therefore, in addition to the intervention effects unique to each group in the previous study, self-exercise and increased activity recommendations common to both groups may have positively affected neck dysfunction.

4.3 | Limitation

One of the major limitations of this study is the limited external validity of the findings, as this study was conducted in a single center. Future studies should replicate this study in different centers and with patients from diverse backgrounds.

5 | CONCLUSION

We investigated the impact of TSM on patients categorized under "mobility" according to Childs' Classification System for Neck Pain. Our results indicate that TSM significantly improves neck pain intensity, NDI scores, and ROM in the cervical and thoracic spines compared with sham manipulation. Notably, these benefits were observed immediately after treatment and persisted for up to 4 weeks. The findings suggest that TSM is a viable treatment option for patients with "mobility"-type neck pain, offering immediate and short-term relief. This study contributes to the growing body of evidence supporting targeted physical therapy interventions based on specific patient classifications, reinforcing the importance of personalized treatment approaches in physiotherapy. Future studies should validate these findings in a broader patient population and investigate the long-term outcomes of the TSM in neck pain management.

AUTHOR CONTRIBUTIONS

Ryota Yoshida: Conceptualization; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Writing—original draft. **Kazuna Ichikawa**: Conceptualization; Formal analysis; Funding acquisition; Methodology; Project administration; Supervision; Validation; Writing—review and editing. **Hiraku Nagahori**: Conceptualization; Investigation; Methodology; Writing—review and editing. **Tomohiro Tazawa**: Conceptualization; Investigation; Methodology; Writing—review and editing. **Hironobu Kuruma**: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Supervision; Writing—review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest directly relevant to the content of this article.

DATA AVAILABILITY STATEMENT

Data available upon request to the corresponding author (Ryota Yoshida).

ETHICS STATEMENT

The study design was approved by the Research Ethics Review Committee of the Tokyo Metropolitan University, Arakawa Campus (approval number: 22086), and informed consent was obtained from all the participants.

TRANSPARENCY STATEMENT

The lead author Ryota Yoshida affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

ORCID

Ryota Yoshida http://orcid.org/0000-0001-5811-0702
Hironobu Kuruma http://orcid.org/0000-0003-3550-4519

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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