RESEARCH PAPER

Cervicothoracic Spinal Manipulation Added to Physiotherapy for Chest Expansion and Pulmonary Function in Chronic Neck Pain with Forward Shoulder Posture: A Randomized Controlled Trial

Ashish Tyagi[1], Tabish Fahim[2], Manish Kumar[3], Md Furquan[4], Sachin Kumar[5], Babina Rani[6]

[1] PhD Scholar, School of Health and Allied Sciences (SOHAS), GD Goenka University, Sohna, Gurugram, India. Email: bkashutyagi08@gmail.com. ORCID: 0009-0005-6167-4169.
[2] TAssociate Professor, School of Health and Allied Sciences (SOHAS), GD Goenka University, Sohna, Gurugram, India. Email: drtabishfahim4u@gmail.com. ORCID: 0000-0001-8480-2593.
[3] Ex-Associate Professor, School of Health and Allied Sciences (SOHAS), GD Goenka University, Sohna, Gurugram, India. Email: mkumar.physio@gmail.com. ORCID: 0000-0001-9181-2319.
[4] Master's student, Centre for Physiotherapy and Rehabilitation Sciences, Jamia Millia Islamia, New Delhi-110025, India. Email: furquanobaid@gmail.com. ORCID: 0009-0000-7309-8713.
[5]Master's student, Centre for Physiotherapy and Rehabilitation Sciences, Jamia Millia Islamia, New Delhi-110025, Email: sachinkumar230600@gmail.com, ORCID ID: 0009-0006-1036-7318
[6]Physiotherapy Section, Department of Physical Rehabilitation and Medicine, Post Graduate Institute of Medical Education and Research, Chandigarh, India. Email: says2babina@gmail.com. ORCID: 0000-0001-9107-5187.

Corresponding author
Dr. Tabish Fahim, Associate Professor, School of Health and Allied Sciences (SOHAS), GD Goenka University, Sohna, Gurugram, Haryana, India. Email: drtabishfahim4u@gmail.com.

ABSTRACT

Background: Forward shoulder posture can restrict chest-wall mechanics and pulmonary function, but few randomized trials have tested whether spinal manipulation adds respiratory benefit when both groups receive active physiotherapy.

Objective: To determine whether adding cervicothoracic spinal manipulation to structured physiotherapy improves chest expansion and pulmonary function in adults with chronic neck pain and forward shoulder posture.

Methods: In this assessor-blinded randomized controlled trial, 55 adults were allocated to manipulation plus physiotherapy ($n = 27$) or physiotherapy alone ($n = 28$). Pulmonary function and chest expansion were measured at baseline, 4 weeks, and 8 weeks. A pre-specified mediation analysis tested whether early xiphoid chest expansion predicted later forced vital capacity. Trial registration: CTRI/2025/04/084722.

Results: Group-by-time interactions favored manipulation for forced vital capacity ($F(2,106) = 76.77$, $p < .001$), forced expiratory volume in 1 second ($F(2,106) = 72.56$, $p < .001$), peak expiratory flow rate ($F(2,106) = 6.00$, $p = .003$), and chest expansion at axillary, nipple, and xiphoid levels (all $p < .001$). The largest chest-expansion effect occurred at the xiphoid level ($d = 0.93$). The pre-specified chest-expansion-to-FVC mediation path was inconclusive (indirect effect 0.056, 95% confidence interval −0.039 to 0.160).

Conclusion: Adding cervicothoracic manipulation to structured physiotherapy improved respiratory and chest-wall outcomes even though neither arm performed breathing exercises. The greater chest-expansion change at the xiphoid level is consistent with a lower-thoracic mechanism but cannot confirm it, because no direct biomechanical measurements were obtained and the pre-specified respiratory mediation analysis was underpowered.

Keywords: neck pain; manipulation; posture; spirometry; respiration; mediation.

How to cite this article: Tyagi A, Fahim T, Kumar M, Furquan M, Kumar S, Rani B. Cervicothoracic spinal manipulation added to physiotherapy for chest expansion and pulmonary function in chronic neck pain with forward shoulder posture: a randomized controlled trial. Int J Drug Deliv Technol. 2026;16(73s): 24-32. DOI: 10.25258/ijddt.16.73s.3

INTRODUCTION

Chronic neck pain imposes a substantial personal and health-system burden, and forward shoulder posture can amplify that burden by sustaining cervical loading and compromising thoracic mechanics [1-5]. In this phenotype, shortened anterior shoulder tissues, scapular protraction, and altered thoracic shape can restrict chest-wall excursion and diminish ventilatory performance [2-5,28,31].

Exercise-based physiotherapy remains the usual conservative foundation for forward shoulder posture, with strengthening and stretching programs improving pain and alignment in selected cohorts

[24,25,29,30]. What remains less clear is whether a manual intervention that targets cervicothoracic and rib-related mechanical restriction adds measurable respiratory benefit when both groups receive a credible active physiotherapy program.

Because the thoracic spine and upper ribs are mechanically linked to the cervical spine and shoulder girdle, treating the thoracic region may influence cervical and postural presentations through regional interdependence [32,33]. Manual-therapy trials in neck pain support additive effects of thrust manipulation and nonthrust mobilization on pain and disability outcomes, and recent syntheses continue to suggest clinically relevant incremental benefit when manipulation is layered onto active care [6-11,36]. Those studies, however, have rarely centered pulmonary function or chest-wall mobility as primary mechanistic outcomes in people with chronic neck pain and forward shoulder posture.

The present companion paper therefore reports the respiratory and biomechanical arm of the trial. We tested whether adding cervicothoracic spinal manipulation to structured physiotherapy improves pulmonary function and chest expansion, and we examined whether early chest-expansion change plausibly predicts later respiratory improvement. Pain, disability, and acromion-to-wall outcomes from the same trial are reported separately in a companion manuscript under submission.

METHODS

Study design

This two-arm, parallel-group, assessor-blinded randomized controlled trial was conducted at the Physiotherapy Department, Jai Prakash Narayan Apex Trauma Centre, All India Institute of Medical Sciences, New Delhi, India, and is reported in line with the CONSORT 2010 statement [26]. Ethics approval was granted by the AIIMS Ethics Committee (AIIMSA3426/11.03.2025). The trial was prospectively registered with the Clinical Trials Registry – India (CTRI/2025/04/084722) on 15 April 2025, with first enrollment on the same date. A computer-generated 1:1 allocation sequence and sequentially numbered opaque sealed envelopes preserved allocation concealment. All participants provided written informed consent. Participant flow through screening, enrollment, allocation, follow-up, and analysis is shown in Figure 1.

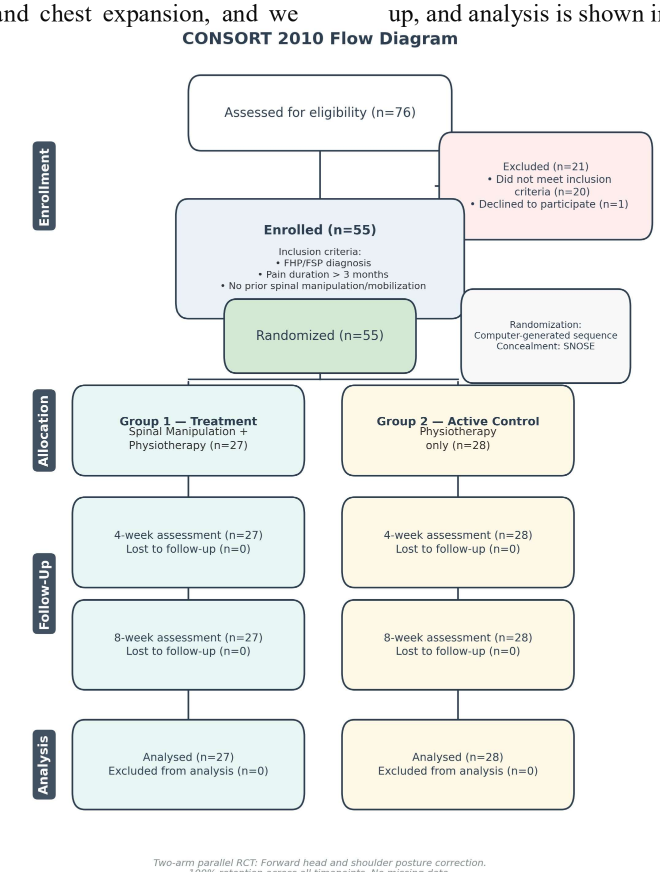

Figure 1. CONSORT 2010 flow diagram. Two-arm parallel randomized controlled trial of forward head and shoulder posture correction, showing screening, enrollment, allocation, follow-up, and analysis. Retention was 100% across all timepoints with no missing data.

Participants

Adults aged 18 to 50 years with chronic neck pain lasting at least 3 months, a Numeric Pain Rating Scale score of at least 3, and forward shoulder posture were screened at the study site. Forward shoulder posture was confirmed by a bilateral acromion-to-wall distance of at least 13 cm using the double-square method described by Borstad [12].

Exclusion criteria included prior spinal surgery, major trauma, pregnancy, recent manipulation or postural rehabilitation, medication affecting the autonomic nervous system, and major chronic-pain confounders. Seventy-six individuals were screened; 21 were excluded, leaving 55 randomized participants (27 manipulation plus physiotherapy, 28 physiotherapy alone).

Intervention

The experimental group received cervicothoracic high-velocity, low-amplitude manipulation directed to the lower cervical and upper thoracic regions in addition to the structured physiotherapy program. The comparator group received the identical supervised physiotherapy program without manipulation. Both groups attended three sessions per week for 4 weeks.

The shared physiotherapy program included moist heat, transcutaneous electrical nerve stimulation, myofascial release to the cervical and upper-thoracic musculature, pectoral stretching, chin-tuck exercises, and progressive W/Y/T scapular retraction exercises. No breathing exercises were included in either protocol. This omission was intentional because the respiratory hypothesis concerned indirect biomechanical effects of improved thoracic mobility rather than direct respiratory training.

Outcomes

The present study focused on pulmonary function and chest-wall mobility. Forced vital capacity (FVC, liters), forced expiratory volume in 1 second (FEV1, liters), the FEV1/FVC ratio (percent), and peak expiratory flow rate (PEFR, L/min) were measured with a calibrated RMS Helios 702 spirometer in standing using a nose clip (Figure 2A, 2B). All tests followed the American Thoracic Society / European Respiratory Society (ATS/ERS) guidelines for accuracy and reproducibility [13,14]. Standing posture was retained across repeat testing because it is acceptable under ATS/ERS guidance and yields slightly higher lung-volume values than sitting [13,15]. Three acceptable trials were obtained and the best value recorded. The clinically important threshold for FVC was 200 mL [16].

Chest expansion was measured at the axillary fold, fourth intercostal space (nipple level), and xiphisternal junction. Circumference at maximal expiration and maximal inspiration was recorded with a flexible tape, and the difference between those values defined the chest-expansion score (Figure 2C). Two trials were taken at each level and the greater value retained. Outcomes were collected at baseline, 4 weeks, and 8 weeks by the blinded assessor.

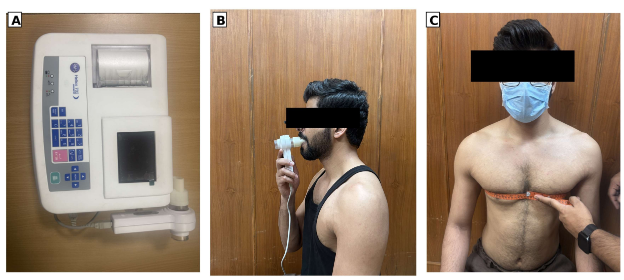

Figure 2. Outcome measurement procedures. (A) Calibrated RMS Helios 702 spirometer used for pulmonary function testing; (B) participant performing spirometry in standing with a nose clip in place; (C) chest-expansion measurement with a flexible tape at the xiphisternal level. Participant identity has been de-identified.

Statistical analysis

Group-by-time effects were estimated with two-way repeated-measures mixed ANOVA. Effect sizes are reported as partial eta squared for interactions and Cohen's d for 8-week between-group contrasts. Benjamini-Hochberg false-discovery-rate correction was applied within analysis families. Because baseline standardized mean differences exceeded 0.3 for FVC, FEV1, and PEFR, baseline-adjusted ANCOVA sensitivity analyses were pre-specified for those outcomes, following the general guidance of Vickers and Altman [17].

Mediation analysis followed the Baron and Kenny framework with bootstrap confidence intervals [18]. The pre-specified respiratory path tested manipulation → chest expansion (xiphoid, 4 weeks) → FVC (8 weeks). Given the sample size, indirect effects were interpreted cautiously because mediation tests are underpowered in small samples [19].

RESULTS

Recruitment took place between April and August 2025. Of 76 screened individuals, 55 were randomized and all completed every treatment session and follow-up assessment, yielding complete data at all three timepoints (Figure 1). Baseline pulmonary imbalances favored the manipulation group for FVC (standardized mean difference 0.47), FEV1 (0.42), and PEFR (0.61), so those variables were carried into the planned ANCOVA sensitivity analyses (Table 1).

Table 1. Baseline characteristics relevant to the respiratory manuscript

Characteristic	Manipulation + physiotherapy (n = 27)	Physiotherapy alone (n = 28)	p	SMD
Age, years	34.8 ± 6.8	36.1 ± 6.7	.458	−0.20
Female sex, n (%)	10 (37.0)	10 (35.7)	1.000	–
Body mass index, kg/m²	23.3 ± 1.3	22.7 ± 1.6	.178	+0.37
FVC, L	3.9 ± 0.5	3.7 ± 0.4	.085	+0.47
FEV1, L	3.2 ± 0.4	3.0 ± 0.4	.124	+0.42
FEV1/FVC, %	80.7 ± 1.8	81.2 ± 1.7	.286	−0.29
PEFR, L/min	375.2 ± 64.9	347.1 ± 10.8	.028	+0.61
Chest expansion – axilla, cm	2.3 ± 0.5	2.2 ± 0.3	.959	+0.01
Chest expansion – nipple, cm	2.3 ± 0.6	2.4 ± 0.4	.475	−0.19
Chest expansion – xiphoid, cm	2.4 ± 0.5	2.5 ± 0.3	.321	−0.27

Continuous variables are mean ± standard deviation. SMD = standardized mean difference.

Pulmonary outcomes favored manipulation over physiotherapy alone (Table 2; Figure 3). FVC showed a strong group-by-time interaction ($F(2,106) = 76.77$, $p < .001$, partial eta squared = 0.592). Mean FVC increased from 3.92 to 4.05 L in the manipulation group and from 3.70 to 3.75 L in the physiotherapy-alone group; the 8-week between-group difference was 0.29 L (95% confidence interval 0.04 to 0.54), with $d = 0.64$. FEV1 showed a similar pattern ($F(2,106) = 72.56$, $p < .001$, partial eta squared = 0.578), with an 8-week between-group difference of 0.24 L (95% confidence interval 0.04 to 0.45), again with $d = 0.64$. The FEV1/FVC ratio improved modestly in both groups ($F(2,106) = 7.05$, $p = .002$, partial eta squared = 0.117), consistent with parallel improvement in both lung volumes rather than a predominantly obstructive effect.

PEFR also favored manipulation ($F(2,106) = 6.00$, $p = .003$, partial eta squared = 0.102). Mean PEFR increased from 375.16 to 423.26 L/min in the manipulation group and from 347.07 to 378.31 L/min in the physiotherapy-alone group; the 8-week between-group difference was 44.95 L/min (95% confidence interval 14.78 to 75.12), with $d = 0.83$. Because the baseline PEFR imbalance was the largest in the dataset, a baseline-adjusted ANCOVA was examined separately and remained significant ($p = .029$), supporting the robustness of the finding.

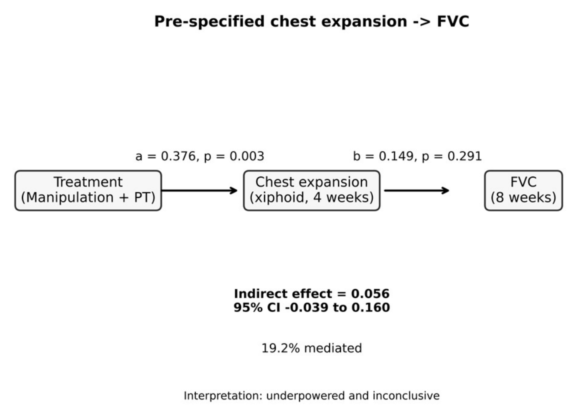

Figure 3. Pulmonary function outcomes over time by group (mean ± 95% confidence interval): (A) FVC, (B) FEV1, (C) FEV1/FVC, and (D) PEFR at baseline, 4 weeks, and 8 weeks.

Table 2. Respiratory and chest-expansion outcomes at 8 weeks

Outcome	Interaction statistic	8-week between-group difference (95% CI)	Effect size	Clinical interpretation
FVC, L	$F(2,106) = 76.77$, $p < .001$, $\eta p^2 = 0.592$	0.29 (0.04 to 0.54)	d = 0.64	Large additive gain in lung volume
FEV1, L	$F(2,106) = 72.56$, $p < .001$, $\eta p^2 = 0.578$	0.24 (0.04 to 0.45)	d = 0.64	Large additive gain in expiratory volume
FEV1/FVC, %	$F(2,106) = 7.05$, $p = .002$, $\eta p^2 = 0.117$	0.10 (−0.97 to 1.18)	d = 0.05	Parallel volume improvement in both groups

Outcome	Interaction statistic	8-week between-group difference (95% CI)	Effect size	Clinical interpretation
PEFR, L/min	$F(2,106) = 6.00$, $p = .003$, $\eta p^2 = 0.102$	44.95 (14.78 to 75.12)	d = 0.83	Remained significant after ANCOVA
Chest expansion – axilla, cm	$F(2,106) = 10.63$, $p < .001$, $\eta p^2 = 0.167$	0.45 (0.09 to 0.80)	d = 0.69	Modest but clinically relevant gain
Chest expansion – nipple, cm	$F(2,106) = 13.53$, $p < .001$, $\eta p^2 = 0.203$	0.42 (0.09 to 0.75)	d = 0.68	Similar magnitude to axillary level
Chest expansion – xiphoid, cm	$F(2,106) = 24.14$, $p < .001$, $\eta p^2 = 0.313$	0.64 (0.26 to 1.01)	d = 0.93	Largest effect at lower-thoracic level

CI = confidence interval; ηp^2 = partial eta squared; d = Cohen's d. ANCOVA = analysis of covariance.

Chest-expansion outcomes also favored manipulation, but the anatomical pattern was xiphoid-dominant rather than a simple monotonic gradient (Table 2; Figure 4). Axillary expansion showed $F(2,106) = 10.63$, $p < .001$, partial eta squared = 0.167, with an 8-week between-group difference of 0.45 cm (95% confidence interval 0.09 to 0.80) and d = 0.69. Nipple-level expansion showed $F(2,106) = 13.53$, $p < .001$, partial eta squared = 0.203, with an 8-week difference of 0.42 cm (95% confidence interval 0.09 to 0.75) and d = 0.68. Xiphoid expansion showed the largest effect, $F(2,106) = 24.14$, $p < .001$, partial eta squared = 0.313, with an 8-week difference of 0.64 cm (95% confidence interval 0.26 to 1.01) and d = 0.93.

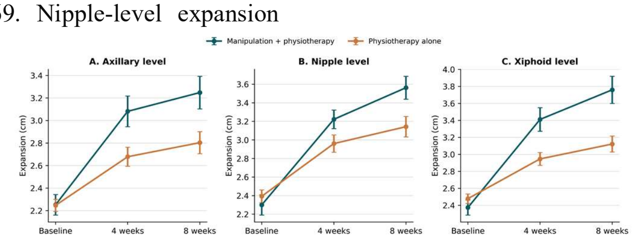

Figure 4. Chest expansion over time by group (mean ± 95% confidence interval) at the (A) axillary, (B) nipple, and (C) xiphoid levels at baseline, 4 weeks, and 8 weeks.

The pre-specified chest-expansion-to-FVC mediation path did not confirm mediation (Figure 5). The a-path from treatment to xiphoid chest expansion was significant ($a = 0.376$, $p = .003$), but the b-path from chest expansion to FVC was not ($b = 0.149$, $p = .291$). The indirect effect was 0.056, with a 95% bootstrap confidence interval from −0.039 to 0.160, corresponding to 19.2% mediated. We therefore interpret this path as underpowered and inconclusive rather than confirmatory.

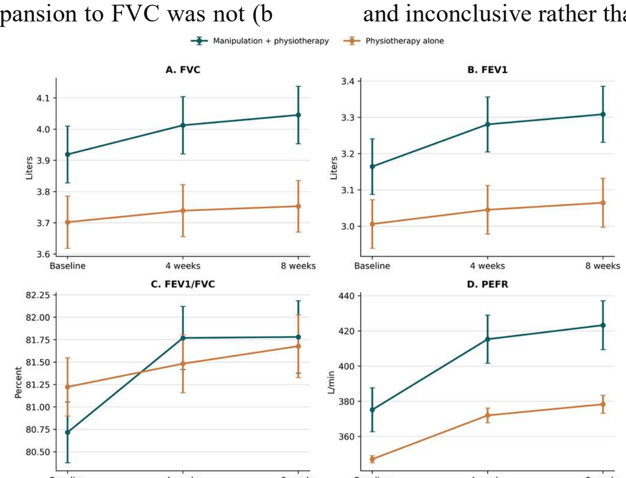

Figure 5. Pre-specified mediation model: treatment → xiphoid chest expansion (4 weeks) → FVC (8 weeks). The indirect effect was 0.056 (95% confidence interval −0.039 to 0.160; 19.2% mediated). The path was underpowered and inconclusive.

No serious adverse events occurred. Five participants in the manipulation group reported mild transient soreness that resolved within 24 hours without protocol modification.

DISCUSSION

Adding cervicothoracic spinal manipulation to a structured physiotherapy program improved chest expansion and pulmonary function more than physiotherapy alone in adults with chronic neck pain and forward shoulder posture. The most notable findings were the very large interaction effects for FVC and FEV1, the robust PEFR result despite baseline imbalance, and the xiphoid-dominant chest-expansion response. Because no breathing exercises were included in either group, the respiratory gains are unlikely to reflect direct ventilatory conditioning; they may instead be associated with improved thoracic mobility, although this interpretation remains inferential because no direct biomechanical measurements were obtained.

The chest-expansion pattern is descriptively informative. Xiphoid expansion showed a clearly larger treatment effect than either axillary or nipple measurements, while the axillary and nipple levels were similar to one another. This profile is consistent with — but does not establish — a lower-thoracic or diaphragmatic-articular contribution rather than a diffuse training effect [4,20,23]. Forward shoulder posture has been associated with altered thoracic shape and reduced respiratory function [3-5,28,31], and improved costovertebral or costotransverse mobility offers one plausible, though unmeasured, route through which manipulation might influence chest-wall compliance [20-22,27]. Because thoracic kinematics, diaphragm motion, and neuromuscular function were not assessed, these mechanistic accounts remain hypotheses generated by the observed associations rather than demonstrated pathways. This caution is reinforced by prior work in which thoracic manipulation improved symptoms without producing immediate measurable change in thoracic excursion or kinematics [35], underscoring that functional gains need not reflect a specific mechanical mechanism.

Our postural and chest-wall findings can be read alongside exercise-based approaches to the same phenotype. Corrective-exercise programs can reduce forward-head and forward-shoulder alignment over comparable timeframes [29], whereas the present results were obtained by adding a manual thoracic intervention to a physiotherapy program; this parallels the distant, regional-interdependence effects of thoracic and rib manipulation reported for the shoulder girdle [33,34]. The two literatures are complementary rather than competing, and our design cannot isolate which component drove the postural aspect of the response.

Our results also sit coherently within the broader neck-pain manual-therapy literature. Prior randomized trials and recent syntheses support incremental benefit from manipulation when added to active exercise-based management [6-11,32,36]. The present study extends that literature by showing that the added benefit is not limited to pain or disability metrics; it also reaches pulmonary function and chest-wall mobility. The respiratory signal was especially strong for FVC and FEV1, outcomes that are clinically relevant yet rarely centered in manipulation trials.

The baseline imbalance in pulmonary measures warrants explicit consideration. Despite concealed randomization, the manipulation group began with higher FVC, FEV1, and — most markedly — PEFR (standardized mean difference 0.61; $p = .028$), reflecting chance imbalance in a modest sample. Because a higher starting value can influence the magnitude of an observed between-group change, the unadjusted PEFR contrast may overstate the true additive effect. We therefore pre-specified baseline-adjusted ANCOVA for FVC, FEV1, and PEFR; the PEFR advantage remained significant after adjustment ($p = .029$), which reduces but does not eliminate this concern. The PEFR finding should thus be read as supportive rather than definitive, and confirmation in a baseline-balanced sample is warranted.

Two sources of bias inherent to manual-therapy trials merit acknowledgement. First, the manipulation group received the manipulation procedure in addition to the shared physiotherapy program, so that arm inevitably involved greater hands-on contact and therapist interaction time; part of the observed benefit could reflect non-specific effects of additional attention and touch rather than manipulation-specific mechanisms. Second, manual thrust techniques generate strong participant expectations, and because participants could not be blinded to whether they received manipulation, expectation effects may have contributed to the between-group differences. Assessor blinding and the use of objective spirometric outcomes mitigate but do not remove these influences, particularly for effort-dependent measures such as PEFR.

The mediation results require cautious interpretation. The pre-specified respiratory model did not show a significant indirect effect, so we cannot claim that chest expansion was the confirmed pathway driving FVC improvement. Although the point estimate was directionally consistent with partial mediation, the confidence interval crossed zero; with $n = 55$ the indirect-effect test was underpowered [19], and the analysis therefore provides no mechanistic confirmation of a chest-expansion–FVC pathway.

From a clinical perspective, the intervention should be understood as additive rather than substitutive. Both groups received a structured physiotherapy program, and the question answered here is whether manipulation adds value on top of active care. For the 8-week respiratory and chest-wall outcomes examined in this paper, the data indicate that it does.

LIMITATIONS

Several limitations should shape interpretation. First, no direct biomechanical measurements were obtained: thoracic and chest-wall kinematics, diaphragm motion, and neuromuscular activity were not recorded, so the proposed lower-thoracic mechanism remains inferential and cannot be confirmed from these data. Second, the trial was single-center and delivered by a single treating therapist, which limits external generalizability and prevents separation of therapist-specific from technique-specific effects. Third, the design cannot establish mechanistic causality; because the arms differed in hands-on contact time and participants were aware of their allocation, non-specific attention and expectation effects cannot be excluded as partial contributors. Fourth, the pre-specified chest-expansion-to-FVC mediation analysis was underpowered at n = 55 and returned a non-significant indirect effect, so it cannot resolve the pathway linking manipulation to pulmonary improvement. Fifth, baseline imbalances favored the manipulation group for FVC, FEV1, and especially PEFR; although pre-specified ANCOVA preserved the substantive conclusions, residual confounding cannot be fully excluded. Sixth, the follow-up horizon ended at 8 weeks, so longer-term durability remains unknown.

CONCLUSION

In adults with chronic neck pain and forward shoulder posture, adding cervicothoracic spinal manipulation to structured physiotherapy improved pulmonary function and chest expansion more than physiotherapy alone at 8 weeks. The xiphoid-dominant chest-expansion response is consistent with a lower-thoracic mechanical explanation but does not confirm it, because no direct biomechanical measurements were obtained; the pre-specified chest-expansion-to-FVC mediation analysis remained inconclusive and underpowered, and requires replication in a larger, adequately powered sample.

FUTURE WORK

Future trials should recruit larger multicenter samples, incorporate direct measures of diaphragmatic motion or chest-wall kinematics, and prospectively test respiratory mediation mechanisms in adequately powered samples. Longer follow-up is also needed to determine whether the respiratory gains remain stable once supervised care ends.

DECLARATIONS

Acknowledgements

The authors thank the trial participants and the physiotherapy staff at Jai Prakash Narayan Apex Trauma Centre for supporting recruitment and follow-up scheduling.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Competing interests

The authors declare that they have no known competing interests.

Data availability statement

Deidentified participant-level data and code-derived summary outputs are available from the corresponding author on reasonable request.

Artificial intelligence (AI) disclosure

Artificial intelligence tools were used during manuscript preparation under full human supervision. Tool and version: Claude (Opus 4.8), Anthropic; and Codex, OpenAI. Purpose of use: assistance with data-analysis workflows implemented in Python, language editing and formatting to the journal's requirements, and figure creation. Sections where AI assistance was applied: Results (data analysis and figure preparation) and the Methods, Results, and Discussion sections (language editing and formatting). The authors reviewed and verified all AI-assisted outputs, including every statistical result and figure, and accept full responsibility for the integrity and content of the manuscript. AI tools were not listed as authors and did not generate the study's scientific conclusions.

Author contributions (CRediT)

- Ashish Tyagi: Conceptualization; Methodology; Investigation; Data curation; Formal analysis; Writing – original draft.
- Tabish Fahim: Conceptualization; Methodology; Supervision; Writing – review and editing.
- Manish Kumar: Formal analysis; Writing – review and editing.
- Md Furquan: Writing – review and editing.
- Sachin Kumar - Validation; Visualization; Software; Resources
- Babina Rani: Writing – original draft; Writing – review and editing.

REFERENCES

[1] M Duenas, B Ojeda, A Salazar, JA Mico, I Failde. A review of chronic pain impact on patients, their social environment and the health care system. J Pain Res. 2016;9:457-467.

[2] D Singla, Z Veqar. Association between forward head, rounded shoulders, and increased thoracic kyphosis: a review of the literature. J Chiropr Med. 2017;16(3):220-229.

[3] HY Lee, MS Yong. Impact of forward head posture and round shoulder posture on muscle activation. J Korean Phys Ther. 2023;35(3):83-88.

[4] T Koseki, F Kakizaki, S Hayashi, N Nishida, M Itoh. Effect of forward head posture on thoracic shape and respiratory function. J Phys Ther Sci. 2019;31(1):63-68.

[5] MK Lauman, CG Anderson. Forward shoulder posture: a comprehensive review. J Bodyw Mov Ther. 2021;25:188-197.

[6] G Bronfort, R Evans, B Nelson, PD Aker, CH Goldsmith, H Vernon. A randomized clinical trial of exercise and spinal manipulation for patients with chronic neck pain. Spine (Phila Pa 1976). 2001;26(7):788-797.
[7] JR Dunning, JA Cleland, MA Waldrop, CF Arnot, IA Young, M Turner, G Sigurdsson. Upper cervical and upper thoracic thrust manipulation versus nonthrust mobilization in patients with mechanical neck pain: a multicenter randomized clinical trial. J Orthop Sports Phys Ther. 2012;42(1):5-18.
[8] ID Coulter, C Crawford, EL Hurwitz, H Vernon, R Khorsan, MS Booth, PM Herman. Manipulation and mobilization for treating chronic nonspecific neck pain: a systematic review and meta-analysis for an appropriateness panel. Pain Physician. 2019;22(2):E55-E70.
[9] B Reynolds, A McDevitt, J Kelly, P Mintken, D Clewley. Manual physical therapy for neck disorders: an umbrella review. J Man Manip Ther. 2024;33(1):18-35.
[10] M Wilhelm, J Cleland, A Carroll, M Marinch, M Imhoff, N Severini, M Donaldson. The combined effects of manual therapy and exercise on pain and related disability for individuals with nonspecific neck pain: a systematic review with meta-analysis. J Man Manip Ther. 2023;31(6):393-407.
[11] K Wu, R Deng, X Zhao, Z Wang, Q Ru, X Chen, et al. Cervical manipulation accelerates recovery and further correction of cervical alignment in mechanical neck pain patients with neck exercise: a randomized controlled trial. Complement Ther Clin Pract. 2025;59:101969.
[12] JD Borstad. Resting position variables at the shoulder: evidence to support a posture-impairment association. Phys Ther. 2006;86(4):549-557.
[13] BL Graham, I Steenbruggen, MR Miller, IZ Barjaktarevic, BG Cooper, GL Hall, et al. Standardization of spirometry 2019 update: an official American Thoracic Society and European Respiratory Society technical statement. Am J Respir Crit Care Med. 2019;200(8):e70-e88.
[14] MR Miller, J Hankinson, V Brusasco, F Burgos, R Casaburi, A Coates, et al. Standardisation of spirometry. Eur Respir J. 2005;26(2):319-338.
[15] MC Townsend. Spirometric forced expiratory volumes measured in the standing versus the sitting posture. Am Rev Respir Dis. 1984;130(1):123-124.
[16] R Pellegrino, G Viegi, V Brusasco, R Crapo, F Burgos, R Casaburi, et al. Interpretative strategies for lung function tests. Eur Respir J. 2005;26(5):948-968.
[17] AJ Vickers, DG Altman. Analysing controlled trials with baseline and follow up measurements. BMJ. 2001;323(7321):1123-1124.
[18] RM Baron, DA Kenny. The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. J Pers Soc Psychol. 1986;51(6):1173-1182.
[19] MS Fritz, DP MacKinnon. Required sample size to detect the mediated effect. Psychol Sci. 2007;18(3):233-239.
[20] SJ Edmondston, KP Singer. Thoracic spine: anatomical and biomechanical considerations for manual therapy. Man Ther. 1997;2(3):132-143.
[21] JE Bialosky, MD Bishop, DD Price, ME Robinson, SZ George. The mechanisms of manual therapy in the treatment of musculoskeletal pain: a comprehensive model. Man Ther. 2009;14(5):531-538.
[22] I Lascurain-Aguirrebena, D Newham, DJ Critchley. Mechanism of action of spinal mobilization: a systematic review. Spine (Phila Pa 1976). 2016;41(2):159-172.
[23] T Birinci, A Razak Ozdincler, S Altun, F Taspinar. The effects of pectoralis minor length on respiratory function tests in healthy young adults. J Back Musculoskelet Rehabil. 2020;33(2):241-247.
[24] V Aghav, P Gurudut, V Kage, A Welling. Global postural re-education versus Egoscue exercises in upper cross syndrome on neck pain, forward head and rounded shoulder posture: a randomized clinical trial. Comp Exerc Physiol. 2024;20(4):341-352.
[25] S Sepehri, R Sheikhhoseini, H Piri, P Sayyadi. The effect of various therapeutic exercises on forward head posture, rounded shoulder, and hyperkyphosis among people with upper crossed syndrome: a systematic review and meta-analysis. BMC Musculoskelet Disord. 2024;25:105.
[26] KF Schulz, DG Altman, D Moher. CONSORT 2010 statement: updated guidelines for reporting parallel group randomized trials. BMJ. 2010;340:c332.
[27] KJ Young, C Leboeuf-Yde, L Gorrell, C Bergstrom, DW Evans, I Axen, et al. Mechanisms of manipulation: a systematic review of the literature on immediate anatomical structural or positional changes in response to manually delivered high-velocity, low-amplitude spinal manipulation. Chiropr Man Therap. 2024;32:28.
[28] S Bakshian, MT Aghdasi. Comparison of the effect and sustainability of 8 weeks of corrective exercises based on the NASM approach and the Sahrman approach on forward head posture and neck pain in mobile phone users in young men of Tabriz. J Sport Biomech. 2022;8(2):168-184. Available from: http://biomechanics.iauh.ac.ir/article-1-292-en.html
[29] M Abdolahzadeh, H Daneshmandi. The effect of an 8-week NASM corrective exercise program on upper crossed syndrome. J Sport Biomech. 2019;5(3):156-167. doi:10.32598/biomechanics.5.3.3
[30] F Javazi, P Sedaghati, H Daneshmandi. The effect of selected corrective exercises with physioball on the posture of female computer users

with upper crossed syndrome. J Sport Biomech. 2019;5(2):112-123. doi:10.32598/biomechanics.5.2.5

[31] M Barghamadi, S Ghadimi KheshtMasjedi, E Piri. The effect of various exercise protocols on the improvement of upper crossed syndrome: a systematic review. J Sport Biomech. 2024;10(1):18-34. Available from: http://biomechanics.iauh.ac.ir/article-1-335-en.html

[32] JA Cleland, JD Childs, M McRae, JA Palmer, T Stowell. Immediate effects of thoracic manipulation in patients with neck pain: a randomized clinical trial. Man Ther. 2005;10(2):127-135. doi:10.1016/j.math.2004.08.005

[33] JB Strunce, MJ Walker, RE Boyles, BA Young. The immediate effects of thoracic spine and rib manipulation on subjects with primary complaints of shoulder pain. J Man Manip Ther. 2009;17(4):230-236. doi:10.1179/106698109791352102

[34] RE Boyles, BM Ritland, BM Miracle, DM Barclay, MS Faul, JH Moore, SL Koppenhaver, RS Wainner. The short-term effects of thoracic spine thrust manipulation on patients with shoulder impingement syndrome. Man Ther. 2009;14(4):375-380. doi:10.1016/j.math.2008.05.005

[35] JR Kardouni, PE Pidcoe, SW Shaffer, SD Finucane, SA Cheatham, CO Sousa, LA Michener. Thoracic spine manipulation in individuals with subacromial impingement syndrome does not immediately alter thoracic spine kinematics, thoracic excursion, or scapular kinematics: a randomized controlled trial. J Orthop Sports Phys Ther. 2015;45(7):527-538. doi:10.2519/jospt.2015.5647

[36] HMC Lau, TT Wing Chiu, TH Lam. The effectiveness of thoracic manipulation on patients with chronic mechanical neck pain: a randomized controlled trial. Man Ther. 2011;16(2):141-147. doi:10.1016/j.math.2010.08.003