Original Article

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Physiotherapy Section

Effect of Cervical Motor Control Exercises on Cranio-vertebral Angle in Asymptomatic individuals with Forward Head Posture: A Randomised Controlled Trial

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ABSTRACT

Introduction: Forward Head Posture (FHP) is a common musculoskeletal condition characterised by the displacement of the head anterior to the body's centre of gravity. FHP although asymptomatic, can lead to various structural and functional impairments. Motor control exercises focus on addressing habitual and incorrect motion patterns, thereby preventing the destabilisation of the cervical spine and the progression of FHP.

Aim: To assess the effectiveness of adding cervical motor control exercises to conventional exercises on Craniovertebral Angle (CVA), cervical range of motion, deep neck flexor strength and endurance, Joint Position Error (JPE), and motor control of cervical spine in asymptomatic individuals with FHP.

Materials and Methods: The present Randomised Controlled Trial (RCT) was conducted at DY Patil Hospital and Research Centre, Navi Mumbai, Maharashtra, India from October 2024 to March 2025 involving young adults (18-26 years) with asymptomatic FHP. Participants were randomly assigned to an experimental group (n=15) that received motor control exercises in addition to conventional physiotherapy treatment and a control group (n=15) that received conventional physiotherapy treatment. Intra-group Comparison and Inter-group comparison of pre and post-intervention outcomes including CVA, cervical range of motion, Cranio-Cervical Flexion Test (CCFT) activation score and performance index, JPE, and cervical motor control test were performed using paired t-tests and independent t-tests. The data was analysed using Statistical Package for the Social Sciences (SPSS) software, version 30.0. A p-value of <0.05 was considered statistically significant.

Results: A total of 30 participants completed the study and were included in the final analysis (n=15 per group). Significant within-group differences were observed between pre and post-intervention assessments for all outcome measures in both the conventional and experimental groups (p<0.05), except for JPE during extension in the conventional group. Inter-group comparison demonstrated a significantly greater improvement only in cervical spine motor control (p=0.003) in the experimental group compared with the conventional group. Although the experimental group demonstrated greater numerical improvements in CVA, CCFT activation score, and performance index, these between-group differences were not statistically significant (CVA: p=0.356; CCFT activation: p=0.154; Performance Index: p=0.194). Cervical Range of Motion (ROM) and cervical joint position error demonstrated differences only in selected movement directions.

Conclusion: These findings suggest that adding cervical motor control exercises to a conventional treatment protocol was more effective than conventional treatment alone in improving cervical motor control in individuals with asymptomatic forward head posture. Although greater numerical improvements were observed in postural alignment, deep cervical flexor strength, and endurance in the experimental group, these between-group differences were not statistically significant. Improvements in cervical range of motion and joint position error were evident only in selected movement directions.

Keywords: Exercise therapy, Kinetic control exercise, Motor skills, Neck muscles, Neuromuscular control, Posture

INTRODUCTION

The FHP is a common postural deviation where the head is positioned anterior to the body's center of gravity [1], accompanied by exaggerated flexion at the lower cervical and upper thoracic regions and compensatory upper cervical vertebrae and occiput (C1) extension [2]. Nowadays, prolonged sitting, sustained neck flexion during desk work, and increased use of digital devices, have contributed to rising prevalence of spinal postural abnormalities among young adults [3,4]. Because early symptoms are often subtle, the long-term effects of these postural habits frequently go unrecognised in this population.

Previous research indicates that FHP, even in asymptomatic individuals, can cause various structural and functional impairments. Structurally, variations in muscle length are observed, with shortening of the suboccipital extensors, the cervical extensors, and the sternocleidomastoid [5]. Deep cervical flexors, such as the longus colli, and occipital flexors, such as the anterior and lateral rectus capitis, are among the lengthened muscles [5]. The functional impairment includes weakness of deep neck flexor muscles, overactivity of the sternocleidomastoid muscle, reduced cervical proprioception [6,7], and impaired cervical joint position sense [8], pain [9], impaired respiratory function and decreased lung capacity [10]. There is a negative link between CVA and neck discomfort, which means that people with advanced FHP experience higher levels of symptoms [9,11].

Conventional corrective intervention of FHP primarily targets strengthening of weak muscles, stretching, and soft-tissue techniques, postural correction, pain management, and workplace ergonomic modifications; with reported improvements with combination of these approaches in forward head angle [12-14]. Conventional corrective interventions for asymptomatic FHP typically focus on symptom management and often overlook impaired movement control of the cervical spine. Emerging evidence indicates that individuals with asymptomatic FHP have altered movement control of the cervical spine [6,7], however movement control training exercises is not routinely incorporated in the management of FHP. Motor control training emphasises addressing habitual and incorrect movement patterns, thus preventing the destabilisation of the cervical spine and the development of FHP [15-17]. Given the impact of asymptomatic FHP on structural and functional impairments, this study aims to investigate the effect of cervical motor control exercises combined with conventional physiotherapy treatment on the CVA, cervical range of motion, deep neck flexor strength and endurance, JPE, and motor control of the cervical spine in asymptomatic individuals with FHP. The present study sought to inform preventive and health-promoting approaches in musculoskeletal care by evaluating the effectiveness of motor control exercises in the management of asymptomatic FHP.

MATERIALS AND METHODS

The present study was a single-blind, RCT study was conducted at DY Patil Hospital and Research Centre, Navi Mumbai, Maharashtra, India. The study was started in October 2024 and ended in March 2025. Ethical approval was obtained from the Institutional Ethical Committee (IEC) for Biomedical and Health Research at DY Patil School of Medicine, Navi Mumbai (IEC ref no: DYP/IECBH/2024/464).

Sample size calculation: The sample size was calculated using dispersion values of a previous study, using the formula:

$$n = \frac{2S^2(Z_{1-\alpha} + Z_{1-\beta})^2}{d^2}$$

Where, Z1–α/2= Z-value for α level (1.96 at 5% β error or 95% confidence). And Z1–β= Z-value for β level (0.84 at 10% β error or 80 % power). Here, d= Margin of error= 4, S= Pooled SD= (S1+S2)/2= 3.7) [18]. The sample size calculated was 28, with 14 individuals in each group. The final analysis was conducted on 30 participants, comprising 15 participants in each of the two groups.

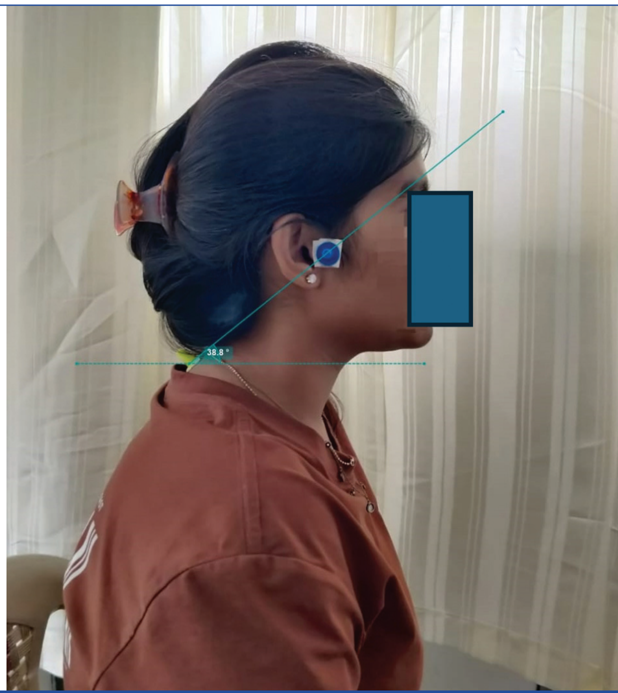
Inclusion and Exclusion criteria: Participants with asymptomatic FHP and a CVA of less than 48 degrees, between the ages of 18 to 26 years, were included in the study. Participants were excluded if they had experienced local or radiating neck pain or vestibular symptoms within the past three months. Those who had undergone spinal surgery or were affected by any systemic illness (rheumatoid arthritis) or psychological conditions (cognitive impairment) were also excluded. Additionally, individuals with traumatic (cervical spine fracture, whiplash-associated disorder), inflammatory (Rheumatoid Arthritis (RA), spondyloarthritis), infectious (cervical tuberculosis), or degenerative cervical spine disorders (cervical disc degeneration/herniation) were not included in the study.

Study Procedure

Informed consent was obtained from all participants who were willing to participate in the present study, and the procedure was explained to them. The participants were blinded and randomly assigned to one of two groups, either the experimental or control group, using a computer-generated random sequence.

In both groups, baseline measurements (pre-intervention) and post-intervention measurements were taken on the following outcome measures:

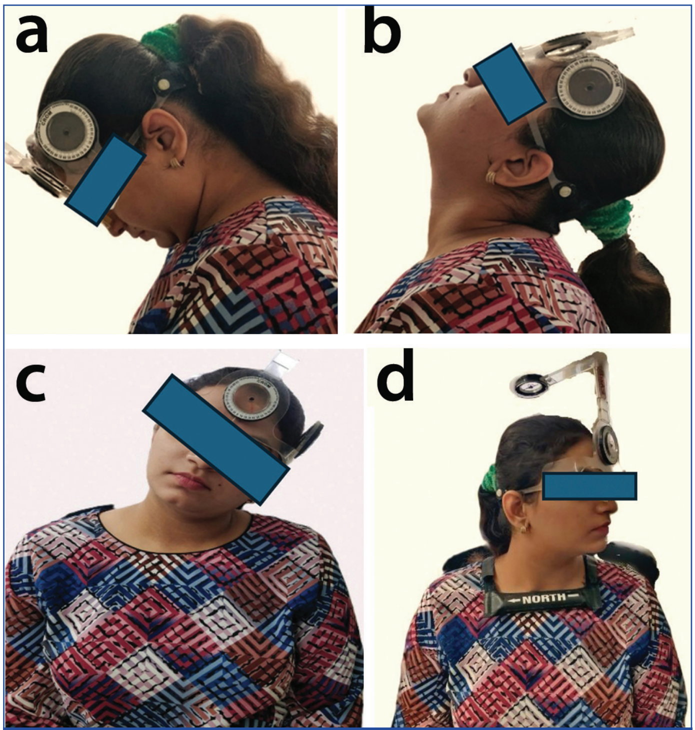
1. **Craniovertebral Angle (CVA) [Table/Fig-1]:** The CVA between 48-50 degrees is considered normal [19]. The CVA was measured using high-quality photography, with participants seated in a neutral, relaxed position. A tripod with a mounted digital camera positioned 0.8 m from the sitting participant was placed perpendicular to the sagittal plane of the participant. The height of the camera was set at the height of each person's seventh cervical vertebra. Adhesive markers were applied to the tragus of the ear and the seventh cervical spinous process to identify them. The angle was calculated using Kinovea software (0.9.5 version) [20]. The CVA measurement is known to be reliable and valid for assessing FHP, with an ICC of 0.98 [21].



[Table/Fig-1]: CVA using Kinovea software.

2. **The Craniocervical Flexion Test (CCFT) [Table/Fig-2]:** CCFT assessed the activation and endurance of the deep neck flexors. Participants performed the test while in a supine position with a pressure biofeedback device (Stabiliser, Chattanooga group) placed under the suboccipital region. The test consists of five progressive pressure levels ranging from 22 to 30 mmHg. The test measured both the activation score (maximum pressure achieved for 10 seconds), for example, if second pressure level was achieved and sustained for 10 seconds than the activation score was recorded as 24 mmHg; and the performance index (repetitions x the highest target pressure that a subject could achieve and hold for 10 seconds, for example, if the participant could achieve the second level of the test (24 mm Hg) and perform six 10-second holds with the correct action of craniocervical flexion, then their performance index was 4 ×6 =24) [22]. The test had high intra-rater and inter-rater reliability, with ICC values of 0.98 and 0.90, respectively [23].
3. **Cervical Range of Motion (CROM) [Table/Fig-3a-d]:** Cervical ROM was measured using the CROM device [24] in all six directions: flexion, extension, right and left lateral flexion, and right and left rotation. The device demonstrated excellent reliability, with test-retest correlations ranging from 0.95 to 0.99 [25,26].

[Table/Fig-2]: Cranio-Cervical Flexion Test (CCFT) with pressure biofeedback unit.



[Table/Fig-3]: a) Cervical flexion range of motion with CROM device; b) Cervical extension range of motion using CROM device; c) Cervical lateral flexion range of motion using CROM device; d) Cervical rotation range of motion using CROM device.

4. **Joint Position Error (JPE):** The patients were given a target range by the therapist (50% of the passive range of motion). The participants were asked to achieve the target range three times, and then the mean value of the three scores was calculated for all six directions of the cervical spine: flexion, extension, right and left lateral flexion, and right and left rotation. It was recorded using the CROM device. An error of less than 4.5° was considered "normal" for cervical proprioception, with reported sensitivities of 86% and specificities of 93% [27]. The test-retest reliability of cervical JPE testing with the CROM has shown moderate to good reliability, with the Intra-Class Correlation Coefficient (ICC) ranging from 0.66 to 0.93 [28].
5. **Motor control tests:** Thirteen cervical movement control tests were performed to evaluate motor control. All the 13 movement control tests were graded for performance as correct/ not correct with a final score of 0, 1, or 2. 0= no performance, 1= first correct + second cross (✓×), 2= first correct+ second correct (✓✓). The first tick was given if the movement was performed with good control and correct dissociated pattern through the benchmark range. The second tick was given if it performed without trick movement, effort, or additional feedback [15]. The total score ranged from a minimum possible score of 0 to a maximum possible score of 26. The kappa values for inter-tester reliability ranged from 0.47 to 1.0 [29].

Intervention

Control group protocol [30]: The conventional corrective exercise protocol included mobility exercises, stretching exercises, postural training, and scapular stabilisation exercises. Mobility exercises consisted of 10 repetitions of movement in each direction. Stretching was administered to the muscles that demonstrated tightness during examination, i.e., trapezius, levator scapulae, pectorals, and suboccipital muscle. Postural training exercises, such as chin tucks, scapular stabilisation exercises (I, Y, T), and scapular retractions, were performed for 10 reps with a 3-second hold time and later progressed to 5-6 seconds. The intervention was administered over six weeks, consisting of three sessions per week, for a total of 18 sessions.

Experimental group protocol [15]: Intervention for the experimental group was also administered for six weeks, consisting of three sessions per week, totalling 18 sessions. The intervention protocol consisted of both conventional and cervical motor control exercises during every session. The motor control exercise selection and progression for each individual were determined based on the findings of pre-intervention motor control testing. Cervical motor control retraining was administered to the affected segment of the cervical spine, with each exercise given for 2 min/<2 mins as per the accuracy of movement control. A detailed description of the progressive training protocol is provided in [Table/Fig-4].

STATISTICAL ANALYSIS

The data of participants were analysed using the SPSS software, version 30.0. The study sample's baseline characteristics were described using descriptive statistics {mean (Standard Deviation {SD}), frequency (%)}, and the normality of the data was assessed using the Shapiro-Wilk test. Intra-group comparison and inter-group comparison of pre-intervention and post-intervention outcomes for CVA, cervical range of motion, CCFT activation score and performance index, JPE, and cervical motor control test were analysed using paired t-tests and independent t-tests.

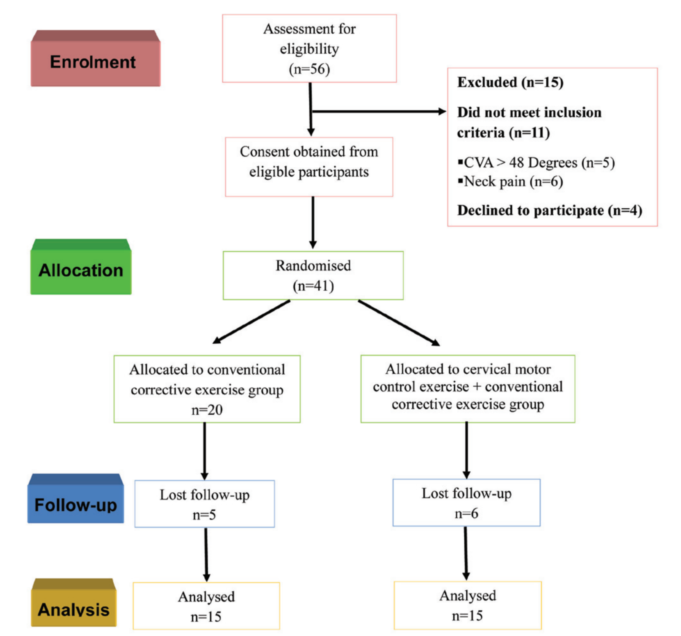
Exercise	Phase 1 (1-2 weeks)	Phase 2 (3-4 weeks)	Phase 3 (5-6 weeks)
For lower cervical flexion UCM			
Occiput lift - nodding	-Standing with wall support -Supine with folded towel	-Hands on wall, head unsupported -Side lying	-Sitting unsupported
Thoracic flexion	-Sitting, with palpation feedback	- 4-point kneeling	-Sitting without palpation feedback
Overhead arm lift	-Standing with wall support	-Forearms wall slide- arms overhead	-Standing unsupported
For upper cervical extension UCM			
Backward head lift	-sitting, backward head lift with therapist palpation/ self-palpation	-hands on wall, head unsupported -recline backwards with chair support	-sitting unsupported
Horizontal retraction	-unilateral horizontal retraction with trunk support on wall	-bilateral horizontal retraction with trunk support on wall prone	-standing unsupported
For upper cervical flexion UCM			
Forward head lean	-standing with wall support 4-point kneeling	-sitting, self-palpation and head unsupported	-sitting unsupported
Arm extension	-unilateral arm extension with back supported	-bilateral arm extension with back supported prone	-standing unsupported
For mid cervical translation UCM			
Head back hinge	-sitting or standing supported with back supported and feedback	-sitting, without back support, feedback with palpation	-sitting unsupported
Chin lift hinge	-head and back supported and self-palpation	-self-palpation, back unsupported	-sitting unsupported

For rotation/ side- bend asymmetry UCM			
Head turn	-supine with head support standing with wall support and shoulder girdle unloaded	-sitting unsupported with active shoulder control and neural loading -4-point kneeling	-sitting
Head tilt	-supine with head support -standing with wall support and shoulder girdle unloaded	-sitting unsupported with active shoulder control and neural loading - 4-point kneeling	-sitting
Upper neck tilt	-standing with wall support and shoulder girdle unloaded	-arms on wall, head supported, hand-position for feedback - 4-point kneeling	-sitting
Lower neck lean	-supine with head support -standing with wall support and shoulder girdle unloaded	-sitting unsupported with active shoulder control and neural loading - 4-point kneeling	-sitting

[Table/Fig-4]: Motor control exercise protocol.

RESULTS

A total of 30 participants completed the study and were included in the final analysis, with 15 participants allocated to each group. [Table/fig-5] shows the flow diagram for the study [31]. The gender distribution in the present study population of 30 was 4:26 (M: F). The percentage of males and females in this study was 13.33% and 86.66% respectively. Within-group analysis of the control group revealed a significant difference in post-intervention outcomes on measures of CVA, cervical range of motion, deep neck flexor strength and endurance, cervical motor control, and cervical joint position sense in all directions, except in cervical extension [Table/Fig-6]. Within-group analysis of the experimental group demonstrated significant post-intervention improvements in CVA, cervical range of motion, deep cervical flexor strength and endurance, cervical motor control, and cervical joint position error across all movement directions [Table/Fig-7].



[Table/Fig-5]: CONSORT flow chart showing method incorporated in study [31].

Before the intervention, there was no significant difference between the control and experimental groups on all outcome measures. Post-intervention, the experimental group had significantly higher scores of CVA, cervical motor control test, and deep cervical strength and endurance compared to the control group. Upon comparing the range of motion, the experimental group showed higher improvement in right and left-side cervical lateral flexion and left-side rotation, with no difference in other directions of range of motion. Lower error on joint position sense assessment in the direction of right and left lateral flexion and left-side rotation compared to the control group, with no difference in other directions of joint position sense [Table/Fig-8].

DISCUSSION

This study aimed to investigate the effect of cervical motor control exercises on the CVA in asymptomatic individuals with FHP. The within-group analysis of the present study demonstrates that both the control and experimental groups experienced significant improvements on all outcome measures, except for JPE in a few directions. Inter-group comparison demonstrated significantly

Conventional group	Pre Mean±SD	Post Mean±SD	Mean difference	t	p-value
CVA	40.28±5.15	44.47±3.91	-4.19	-9.49	<0.001**
Cervical flexion ROM	53.33±4.93	60.53±4.92	-7.20	-10.31	<0.001**
Cervical extension ROM	58.53±5.15	59.73±4.58	-1.20	-2.80	0.014*
Cervical lateral flexion- right ROM	40±3.91	44.8±3.91	-4.80	-5.67	<0.001**
Cervical lateral flexion- left ROM	42±5.18	45.73±5.33	-3.73	-5.32	<0.001**
Cervical rotation- right ROM	55.0±10.33	58.93±8.24	-3.86	-4.09	0.001*
Cervical rotation- left ROM	55.6±10.01	59.2±8.55	-3.60	-4.58	<0.001**
JPE cervical flexion	6±4	4.8±3.36	1.2	2.806	0.014*
JPE cervical extension	4.66±4.18	3.86±4.10	0.800	1.871	0.082
JPE cervical lateral flexion- right	5.33±4.51	2.26±3.52	3.07	2.77	0.015*
JPE cervical lateral flexion- left	4.53±2.40	2.8±3.22	1.73	3.16	0.007*
JPE cervical rotation- right	4.53±3.96	3.06±3.01	1.466	2.44	0.028*
JPE cervical rotation- left	4.26±4.13	2.8±3.18	1.466	2.82	0.036*
CCFT activation score (mmHg)	23.6±1.72	26.26±1.83	-2.66	-10.583	<0.001**
CCFT performance index	23.06±9.25	44.53±15.91	-21.46	-5.961	<0.001**
Cervical motor control test	15.4±5.71	18.8±4.49	-3.40	-5.993	<0.001**

[Table/Fig-6]: Within group analysis of control group.
*p<0.05; **p<0.001, CVA: Craniovertebral angle; ROM: Range of motion; CCFT: Cranial cervical flexion test; JPE: Joint position error.

Experimental group	Pre Mean ± SD	Post Mean ± SD	Mean difference	t	p-value
CVA	40.79±5.02	46.09±5.42	-5.30	-8.03	<0.001**
Cervical flexion ROM	54.4±5.14	59.73±3.69	-5.33	-5.73	<0.001**
Cervical extension ROM	59.06±8.31	60.93±7.28	-1.86	-2.82	0.014*
Cervical lateral flexion- right ROM	40.66±4.38	44.26±3.28	-3.60	-6.08	<0.001**
Cervical lateral flexion- left ROM	44.66±5.05	47.2±4.45	-2.53	-4.21	0.001*
Cervical rotation- right ROM	54.4±6.97	59.86±6.61	-5.46	-6.90	<0.001**
Cervical rotation- left ROM	54.13±6.16	57.86±5.31	-3.73	-4.65	<0.001**
JPE cervical flexion	4.93±4.58	3.2±3.10	1.73	3.873	0.002*
JPE cervical extension	5.06±3.84	3.2±2.90	1.86	3.523	0.003*
JPE cervical lateral flexion- right	3.33±3.90	1.01±3.61	2.32	4.0	0.001*
JPE cervical lateral flexion- left	3.46±3.96	1.10±3.24	2.36	3.09	0.008*
JPE cervical rotation- right	4.8±3.68	2.16±3.17	2.64	3.378	0.005*
JPE cervical rotation- left	2.93±3.53	1.33±2.25	1.6	2.703	0.017*
CCFT activation score (mmHg)	24.66±1.45	27.2±1.65	-2.53	-10.71	<0.001**
CCFT performance index	24.93±9.58	51.2±11.02	-26.26	-8.26	<0.001**
Cervical motor control test	13.4±3.39	23.06±1.38	-9.66	-11.78	<0.001**

[Table/Fig-7]: Within group analysis of experimental group.
*p<0.05; **p<0.001, CVA: Craniovertebral angle, ROM: Range of motion; CCFT: Cranial cervical flexion test; JPE: Joint position error

Outcome measures	Pre/Post	Control group Mean±SD	Experimental group Mean±SD	Mean difference	t-value	p-value
CVA	Pre	40.28±5.15	40.79±5.02	-0.513	-0.276	0.784
	Post	44.47±3.91	46.09±5.42	-1.62	-0.939	0.356
Cervical flexion ROM	Pre	53.33±4.94	54.4±5.14	1.06	0.580	0.567
	Post	60.53±4.92	59.73±3.69	-0.80	-0.503	0.961
Cervical extension ROM	Pre	58.53±5.15	59.06±8.31	-0.53	0.211	0.834
	Post	59.73±4.58	60.93±7.28	-1.20	0.540	0.594
Cervical lateral flexion- right ROM	Pre	40±3.91	40.66±4.38	-0.666	0.454	0.654
	Post	44.8±3.91	44.26±3.28	-0.533	-0.404	0.689
Cervical lateral flexion- left ROM	Pre	42±5.18	44.66±5.05	-2.66	1.427	0.165
	Post	45.73±5.33	47.2±4.45	-1.46	0.817	0.421
Cervical rotation- right ROM	Pre	55.06±10.33	54.4±6.97	0.666	-0.207	0.837
	Post	58.93±8.24	59.86±6.61	-0.933	0.342	0.735
Cervical rotation- left ROM	Pre	55.6±10.01	54.13±6.16	1.46	-0.483	0.633
	Post	59.2±8.55	57.86±5.31	1.33	-0.513	0.612
CCFT activation score (mmHg)	Pre	23.6±1.72	24.66±1.45	1.06	1.835	0.077
	Post	26.26±1.83	27.2±1.65	0.933	1.464	0.154
CCFT performance index	Pre	23.06±9.25	24.93±9.58	1.86	0.543	0.592
	Post	44.53±15.91	51.2±11.02	6.66	1.33	0.194
JPE cervical flexion	Pre	6±4	4.93±4.58	1.07	-0.679	0.50
	Post	4.8±3.6	3.2±3.10	1.58	-1.5	0.140
JPE cervical extension	Pre	4.66±4.18	5.06±3.84	-0.4	0.273	0.787
	Post	3.86±4.10	3.2±2.90	0.6	-0.821	0.418
JPE cervical lateral flexion- right	Pre	5.33±4.51	3.33±3.90	2.00	1.29	0.205
	Post	2.26±3.52	1.01±3.61	1.25	0.716	0.480
JPE cervical lateral flexion- left	Pre	4.53±2.40	3.46±3.96	1.07	0.673	0.506
	Post	2.8±3.22	1.10±3.24	1.7	0.226	0.823
JPE cervical rotation- right	Pre	4.53±3.96	4.8±3.68	-.266	0.191	0.850
	Post	3.06±3.01	2.16±3.17	0.09	-0.354	0.726
JPE cervical rotation- left	Pre	4.26±4.13	2.93±3.53	1.33	-0.950	0.350
	Post	2.8±3.18	1.33±2.25	1.46	-1.46	0.155
Cervical motor control test	Pre	15.4±5.71	13.4±3.39	2.00	-1.16	0.256
	Post	18.8±4.49	23.06±1.38	-4.26	3.51	0.003*

[Table/Fig-8]: Comparison between control group and experimental group.
*p<0.05; CVA: Craniovertebral angle; ROM: Range of motion; CCFT: Cranial cervical flexion test; JPE: Joint position error

greater improvements in cervical motor control test, deep cervical flexor strength, and endurance in the experimental group compared with the control group. No significant between-group difference was observed for CVA. Furthermore, differences in cervical joint position error and cervical range of motion were evident only in selected directions rather than across all movements.

Motor control retraining exercises, which focus on controlled movements and targeting isolated muscle groups [15], may have contributed to improving cervical muscle strength and endurance. This enhances the ability of the deep neck flexor muscles to activate and maintain a sustained contraction. Also, preforming repeated controlled movements targeting isolated muscle groups enhances neuromuscular junction function, including increased presynaptic terminal branching, improved acetylcholine release, and heightened postsynaptic receptor sensitivity, leading to more precise and reliable muscle fibre recruitment [32]. Consistent with these results, a previous study by Hidalgo-Pérez A et al., suggested that the combined effect of motor control and motor imagery leads to improvement in muscle endurance [18]. Additionally, the improvement in cervical deep muscle endurance in the experimental group can be attributed to the additive effect of longer therapy sessions with imposed dynamic demands, which led to improved strength and endurance of the deep cervical muscles required to maintain neutral posture.

The observed improvements in CVA, cervical muscle strength, endurance, and motor control are not isolated outcomes but rather reflect a synergistic and interdependent mechanism. An “improvement in CVA” signifies a correction of FHP and indicates that the head is returning to a more aligned position. Traditional exercise improves CVA by correcting neck muscle imbalances and reducing FHP, as supported by previous studies [12-14]. Traditional exercises alone might address strength and flexibility, but without the motor control aspect, participants may not have the necessary skills to maintain correct posture under functional conditions. As FHP has impaired proprioception that leads to poor cervical motor control [6], the inclusion of motor control exercises may have helped the experimental group improve their awareness of head and neck positioning by improved motor unit activation which enhances the proprioceptive feedback, allowing them to make more precise and controlled adjustments to their posture [18]. The experimental group exhibited a greater numerical improvement in CVA compared with the control group (MD=1.620); however, the between-group difference was not statistically significant (p=0.356). Although the observed mean difference exceeded the reported MCID of 1.400, this finding should be interpreted cautiously, as statistical significance was not achieved. [33]. Additionally, maintaining a neutral posture is emphasised while performing every exercise of motor control retraining in various postures and during imposed movements. The practice of these exercises helps improve motor memory, enabling individuals to retain better movement patterns for long-term improvement [34,35]. This cognitive aspect may have contributed to greater gains in motor control in the experimental group compared to the control group, who may not have received the same level of active learning and motor retraining.

Within-group analysis demonstrated improvements in all directions of cervical ROM among participants of both the control and experimental groups. These findings are consistent with a previous study conducted by Kong YS et al., incorporated similar exercises, such as stretching and strengthening, and demonstrated statistically significant improvements across all cervical movements [36]. Upon comparison of range of motion, no significant between-group differences were observed in cervical flexion, extension, lateral flexion, or rotation. Furthermore, the experimental group showed significantly more improvement in specific directions of JPE (right and left lateral flexion and left-side rotation), which could be attributed to motor learning, as they received an additional motor control retraining intervention. Motor learning can effectively improve sensory function due to the strong connections between the motor cortex and somatosensory areas [15-17]. A study on symptomatic FHP conducted by Lee JD et al., reported that the effect of neuromuscular control exercises is more effective than self-stretching and stabilisation exercises in improving proprioceptive sensation [37]. Improvement following motor control intervention was limited to a few directions, indicating that proprioception deficit in individuals with FHP may be direction-specific. Previous research has demonstrated that rotation respond better to interventions than flexion and extension, possibly due to asymmetrical muscular imbalances and postural adaptations [38]. Furthermore, direction-specific gains in range of motion may reflect corresponding improvements in joint position sense in the same movement direction [39]. This explanation is a tentative suggestion based on the observations; the underlying mechanisms remain unclear and require further research to clarify direction-specific adaptations in FHP. Additionally, these findings must be interpreted with caution because the present study population consisted of asymptomatic individuals, which may have limited the potential for further improvement post-intervention. The effect should also be explored in individuals with a greater range of motion restriction and in those with neck pain. The long-term follow-up of this protocol can be assessed through future research. Furthermore, broadening the participant demographics to include participants across various age groups and those with pre-existing neck pain could aid in determining whether the protocol is effective across these cohorts.

Limitation(s)

The present study did not assess the long-term effects of the intervention. Motor control exercises may be ineffective if not executed properly, and they rely heavily on patient awareness and engagement. Additionally, achieving lasting results requires a long-term commitment, and the current study included only a 6-week intervention. These exercises did not address underlying causes, such as poor posture habits or ergonomic factors that contribute to FHP.

CONCLUSION(S)

The authors conclude that cervical motor control exercises, combined with conventional corrective exercises, are more effective in reducing FHP, improving motor control, and enhancing deep cervical flexor muscle strength and endurance compared to conventional corrective treatment alone. However, when comparing groups for cervical range and cervical JPE, motor control exercise with conventional corrective intervention was more beneficial for mobility and joint proprioception in a few but not all directions, indicating a need for future exploration in this area.

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