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Comparative Effects of Visual and Pressure Biofeedback on Pain and Range of Motion in Symptomatic Forward Head Posture

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ABSTRACT

Background: *Forward head posture (FHP) is a prevalent sagittal plane postural deviation associated with neck pain, reduced cervical range of motion (ROM), and neuromuscular imbalance, particularly involving deep cervical flexor dysfunction. Biofeedback-guided rehabilitation has been proposed to enhance motor control and optimize therapeutic outcomes, yet direct comparative evidence between pressure and visual biofeedback modalities remains limited.* ***Objective:*** *To compare the effects of pressure biofeedback–guided versus visual biofeedback–guided stabilization exercises on cervical ROM and pain in individuals with symptomatic FHP.* ***Methods:*** *In this assessor-blinded randomized controlled trial, 32 participants aged 20–35 years with FHP (craniovertebral angle <49°; Numeric Pain Rating Scale [NPRS]>3) were allocated equally to pressure biofeedback (n=16) or visual biofeedback (n=16), both combined with standardized stabilization exercises for 4 weeks (3 sessions/week). Cervical flexion, extension, bilateral rotation (goniometry), and pain (NPRS) were assessed at baseline and post-intervention. Within- and between-group analyses were performed using paired and independent t-tests with effect sizes and 95% confidence intervals.* ***Results:*** *Both groups demonstrated significant improvements in ROM and pain (p<0.001). Between-group comparisons favored pressure biofeedback for flexion (mean difference 4.62°, p=0.009), right rotation (5.95°, p=0.02), and left rotation (5.54°, p=0.02), with moderate-to-large effect sizes (d=0.82–0.99). No significant differences were observed for extension (p=0.56) or pain reduction (p=0.10).* ***Conclusion:*** *Both biofeedback modalities effectively improved cervical ROM and pain; however, pressure biofeedback produced superior gains in flexion and rotation, suggesting enhanced neuromuscular specificity in movement restoration.*

Keywords: *Forward head posture, Pressure biofeedback, Visual biofeedback, Cervical range of motion, Neck pain, Randomized controlled trial*

INTRODUCTION

Forward head posture (FHP) is one of the most prevalent sagittal plane postural deviations in young and middle-aged adults and is characterized by anterior translation of the head relative to the trunk, typically quantified by a reduced craniovertebral angle (CVA) (1,2). Biomechanically, FHP reflects lower cervical flexion combined with upper cervical extension, resulting in altered cranial rotation and increased mechanical loading on posterior cervical structures (3,4). A CVA of less than 49° has been frequently operationalized as indicative of FHP in clinical research (5). This maladaptive alignment is not merely cosmetic; it is associated with neck pain, reduced cervical range of motion (ROM), impaired proprioception, and functional limitations that negatively affect quality of life and

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productivity (1,6). Epidemiological data indicate that neck pain affects approximately 27%–48% of adults annually, with a substantial proportion exhibiting postural deviations such as FHP (7). Contemporary lifestyle factors—including prolonged computer use, handheld device engagement, and sustained neck flexion—have been implicated in the increasing prevalence of FHP, particularly among young adults (4,7).

From a pathophysiological perspective, persistent FHP contributes to muscular imbalance and altered neuromuscular control. Shortening of the upper trapezius, levator scapulae, sternocleidomastoid, and suboccipital muscles occurs concurrently with lengthening and reduced activation capacity of the deep cervical flexors (8). These alterations may compromise cervical stability, restrict ROM, and predispose individuals to chronic pain syndromes, including cervicogenic headache and radicular symptoms (3,9). Furthermore, forward displacement of the head increases the lever arm and mechanical load on the cervical spine, amplifying compressive and shear forces that can perpetuate nociceptive input (10). Given these biomechanical and neuromuscular consequences, rehabilitation strategies targeting muscular rebalancing and motor control restoration are central to FHP management.

Therapeutic exercise, particularly isometric stretching and strengthening protocols aimed at correcting muscle imbalance and enhancing cervical stabilization, has demonstrated effectiveness in improving ROM and reducing neck pain in individuals with FHP (11,12). Postural corrective exercise programs implemented over four weeks have shown significant improvements in active cervical ROM and muscular strength (11). Systematic reviews further support exercise-based interventions, highlighting isometric training as beneficial for both pain reduction and functional restoration (12). However, exercise efficacy may be optimized when coupled with feedback mechanisms that enhance motor learning and proprioceptive awareness.

Biofeedback is a therapeutic modality that provides real-time physiological or biomechanical information to facilitate improved motor control (13). In cervical rehabilitation, two principal forms of biofeedback are frequently employed: pressure biofeedback and visual biofeedback. Pressure biofeedback, commonly administered via an inflatable cuff or sphygmomanometer placed beneath the cervical spine, is designed to selectively activate and retrain deep cervical flexor muscles by providing proprioceptive cues related to pressure modulation (14). Visual biofeedback, such as laser-guided head repositioning tasks, offers external visual cues to correct alignment and improve sensorimotor control (15). Both modalities aim to enhance neuromuscular coordination; however, their mechanisms differ. Pressure biofeedback primarily facilitates intrinsic muscular activation and proprioceptive refinement, whereas visual biofeedback emphasizes external focus of attention and alignment correction. Although individual studies have reported beneficial effects of each modality on neck pain and posture (14,15), direct comparative evidence between pressure and visual biofeedback—particularly when integrated with standardized stabilization exercises—remains limited.

Existing literature largely evaluates biofeedback interventions in isolation or compares them with conventional therapy rather than conducting head-to-head randomized comparisons between distinct biofeedback modalities (14,15). Moreover, many studies focus predominantly on pain outcomes or muscle activation parameters without comprehensively assessing changes in multiple cervical ROM components alongside pain intensity. The absence of rigorously designed randomized controlled trials directly comparing pressure versus visual biofeedback within a homogeneous symptomatic FHP population represents a notable knowledge gap. Clarifying whether one modality confers superior improvements in

ROM or pain has important clinical implications for optimizing rehabilitation protocols, resource allocation, and individualized patient management.

Within the PICO framework, the population of interest comprises young adults with symptomatic forward head posture defined by reduced CVA and clinically relevant neck pain. The intervention consists of stabilization exercises combined with pressure biofeedback, while the comparator is stabilization exercises combined with visual biofeedback. The primary outcomes are changes in cervical ROM (flexion, extension, and bilateral rotation), and the secondary outcome is change in pain intensity measured by the Numeric Pain Rating Scale. By systematically comparing these two biofeedback-guided exercise approaches under controlled conditions, the present study seeks to determine whether one modality yields superior clinical outcomes over a four-week intervention period.

Therefore, the objective of this randomized controlled trial is to evaluate and compare the effects of pressure biofeedback–guided stabilization exercises versus visual biofeedback–guided stabilization exercises on cervical range of motion and pain in individuals with symptomatic forward head posture. It is hypothesized that both interventions will produce significant within-group improvements in ROM and pain; however, pressure biofeedback, due to its targeted facilitation of deep cervical flexor activation and proprioceptive control, will result in greater improvements in cervical ROM compared with visual biofeedback.

MATERIALS AND METHODS

This study was designed as a parallel-group, assessor-blinded randomized controlled trial to compare the effects of pressure biofeedback–guided stabilization exercises versus visual biofeedback–guided stabilization exercises on cervical range of motion and pain in individuals with symptomatic forward head posture. A randomized controlled design was selected to minimize selection bias, control for confounding variables, and allow causal inference regarding intervention effects (16). The trial was conducted at the Department of Physical Therapy, Bahawal Victoria Hospital, Bahawalpur, Pakistan, over a 10-month period from January to October 2023. All procedures were standardized prior to trial commencement through investigator training sessions and pilot testing of measurement protocols to ensure procedural consistency.

Participants were screened from patients presenting to the outpatient physiotherapy department with complaints of neck pain and suspected postural deviation. Eligibility criteria were predefined. Individuals aged 20 to 35 years of either sex were included if they demonstrated symptomatic forward head posture defined operationally as a craniovertebral angle (CVA) of less than 49° measured using digital photogrammetry and a Numeric Pain Rating Scale (NPRS) score greater than 3 at baseline (5,17). Participants were required to have neck pain of mechanical origin without neurological deficit. Exclusion criteria included history of vertebrobasilar insufficiency, systemic inflammatory or infectious disease, malignancy, malnutrition, recent fracture of the cervical spine or shoulder region, recent cervical or shoulder surgery, or diagnosed cervical radiculopathy with progressive neurological signs. Screening was performed by a licensed physical therapist with more than five years of musculoskeletal clinical experience.

Participants meeting eligibility criteria were recruited consecutively and provided with a detailed explanation of study objectives, procedures, potential risks, and benefits. Written informed consent was obtained prior to enrollment. Baseline demographic and clinical characteristics were recorded, including age, sex, duration of symptoms, and baseline ROM and pain scores. To minimize selection bias, participants were randomly allocated in a 1:1 ratio to either the pressure biofeedback group (Group A) or the visual biofeedback group

(Group B) using a computer-generated randomization sequence prepared by an independent statistician not involved in recruitment or outcome assessment. Allocation concealment was ensured using sequentially numbered, opaque, sealed envelopes opened only after baseline assessment. Outcome assessment was conducted by a blinded assessor who was unaware of group allocation throughout the study period.

The intervention protocol was standardized across groups with the only difference being the type of biofeedback provided. Both groups received a structured stabilization program consisting of isometric stretching and strengthening exercises targeting deep cervical flexors, cervical extensors, upper trapezius, levator scapulae, and sternocleidomastoid muscles. Each session lasted 25–30 minutes, conducted three times per week for four consecutive weeks, totaling 12 sessions. Exercises included cranio-cervical flexion in supine, cervical isometric flexion, extension, and rotation against manual resistance, and static stretching of shortened musculature. Each strengthening exercise was performed in three sets of 10 repetitions with a 5-second hold and 30-second rest between sets. Stretching was held for 20 seconds and repeated three times per muscle group. Progression was achieved by increasing hold duration to 10 seconds during weeks three and four as tolerated.

In Group A, pressure biofeedback was delivered using an inflatable pressure cuff (sphygmomanometer) placed suboccipitally beneath the cervical lordosis in the supine position. The cuff was inflated to a baseline of 20 mmHg, and participants were instructed to perform graded cranio-cervical flexion to increase pressure incrementally in 2 mmHg steps up to 30 mmHg while maintaining minimal superficial muscle substitution. Each target pressure was maintained for 5–10 seconds with visual monitoring of the pressure gauge to ensure accurate activation of deep cervical flexors (14). In Group B, visual biofeedback was provided using a laser pointer attached to a lightweight headband. Participants performed head repositioning and alignment tasks while focusing the laser beam on a calibrated target grid positioned at eye level approximately 1.5 meters away. Exercises emphasized maintaining neutral alignment and controlled movement within marked boundaries to enhance sensorimotor control and postural correction (15). All sessions were supervised by the same therapist to ensure protocol adherence, and attendance was recorded to monitor compliance.

Outcome measures were assessed at baseline (day 1) and immediately after completion of the 4-week intervention period. The primary outcome was cervical range of motion measured in degrees using a universal goniometer for flexion, extension, and bilateral rotation. Standardized patient positioning and anatomical landmarks were used to ensure measurement reliability. Each movement was measured three times, and the average value was recorded. The goniometric assessment method has demonstrated acceptable intra- and inter-rater reliability for cervical ROM measurement (18). The secondary outcome was pain intensity measured using the 11-point NPRS, where 0 indicates no pain and 10 indicates worst imaginable pain, a tool with established reliability and responsiveness in mechanical neck pain populations (19). All measurements were performed by the blinded assessor at the same time of day to reduce diurnal variation.

The primary independent variable was type of biofeedback intervention (pressure vs visual). Dependent variables included change in cervical flexion, extension, right rotation, left rotation, and NPRS scores from baseline to 4 weeks. Potential confounding variables such as age, sex, and baseline ROM were evaluated for baseline equivalence. To reduce performance bias, both groups received identical exercise dosage and therapist contact time. Measurement bias was minimized through assessor blinding and standardized measurement procedures.

Attrition bias was mitigated by maintaining regular follow-up communication and flexible scheduling to enhance adherence.

Sample size estimation was conducted using G*Power software version 3.1.9.7 based on an independent samples t-test for between-group comparison of mean change in cervical flexion ROM. Assuming an effect size (Cohen's d) of 0.8 derived from previous biofeedback studies in FHP populations (14,15), a two-tailed alpha level of 0.05, and statistical power of 80%, the minimum required sample size was calculated as 28 participants. To account for an anticipated 10% attrition rate, the final target sample was set at 32 participants, with 16 participants allocated to each group.

Statistical analysis was performed using IBM SPSS Statistics version 25.0 (IBM Corp., Armonk, NY, USA). Data normality was assessed using the Shapiro–Wilk test. Continuous variables were summarized as mean ± standard deviation, and categorical variables as frequencies and percentages. Within-group comparisons from baseline to post-intervention were conducted using paired-sample t-tests for normally distributed variables. Between-group differences in post-intervention outcomes were analyzed using independent-sample t-tests, and change scores (post–pre) were additionally compared to confirm robustness of findings. Effect sizes were calculated using Cohen's d with 95% confidence intervals. Missing data were handled using an intention-to-treat approach with last observation carried forward for participants who completed at least one follow-up assessment. A two-tailed p-value of less than 0.05 was considered statistically significant. Exploratory subgroup analyses were performed by sex to assess potential effect modification.

Ethical approval for the study was obtained from the Institutional Review Board of Bahawal Victoria Hospital prior to participant enrollment, and all procedures were conducted in accordance with the Declaration of Helsinki (20). Participant confidentiality was maintained through coded data identifiers, and access to the dataset was restricted to the principal investigator and statistician. All data were double-entered and cross-verified to ensure accuracy. The intervention protocol, measurement procedures, and statistical analysis plan were predefined before data collection to enhance reproducibility and reduce analytical bias.

RESULTS

A total of 32 participants completed the study, with 16 allocated to the pressure biofeedback group and 16 to the visual biofeedback group. As shown in Table 1, baseline demographic and clinical characteristics were comparable between groups. The mean age in the pressure group was 29.25 ± 4.10 years compared to 29.38 ± 2.87 years in the visual group, with a mean difference of −0.13 years (95% CI: −2.66 to 2.40; p = 0.91). Sex distribution was similar, with 56.3% males in the pressure group and 50.0% males in the visual group (p = 0.72). Baseline cervical flexion was 37.01 ± 4.51° in the pressure group and 36.56 ± 3.89° in the visual group (mean difference 0.45°, 95% CI: −2.63 to 3.53; p = 0.77). Baseline extension (38.38 ± 5.08° vs 38.25 ± 4.66°; p = 0.94), right rotation (57.69 ± 7.82° vs 55.31 ± 8.72°; p = 0.42), left rotation (58.50 ± 6.71° vs 56.50 ± 6.68°; p = 0.40), and NPRS scores (5.88 ± 1.25 vs 6.06 ± 1.43; p = 0.69) also did not differ significantly, confirming baseline homogeneity.

Within-group analyses (Table 2) demonstrated statistically significant improvements across all outcomes in both groups after 4 weeks (all p < 0.001). In the pressure biofeedback group, cervical flexion increased from 37.01 ± 4.51° to 46.31 ± 4.86°, yielding a mean improvement of 9.30° (95% CI: 6.91 to 11.69) with a large effect size (Cohen's d = 1.98). In contrast, the visual biofeedback group improved from 36.56 ± 3.89° to 41.69 ± 4.55°, corresponding to a mean change of 5.13° (95% CI: 3.02 to 7.24; d = 1.21). For cervical extension, the pressure group improved by 6.88° (95% CI: 4.09 to 9.67; d = 1.22), while the visual group improved by

5.87° (95% CI: 3.54 to 8.20; d = 1.30). Right rotation increased by 9.32° (95% CI: 6.02 to 12.62; d = 1.33) in the pressure group compared to 5.75° (95% CI: 2.78 to 8.72; d = 0.71) in the visual group. Similarly, left rotation improved by 10.69° (95% CI: 7.66 to 13.72; d = 1.59) in the pressure group and by 7.15° (95% CI: 4.37 to 9.93; d = 1.07) in the visual group. Pain intensity decreased significantly in both groups, with the pressure group demonstrating a reduction of 1.90 points (95% CI: −2.65 to −1.15; d = 1.38) and the visual group a reduction of 1.25 points (95% CI: −1.96 to −0.54; d = 0.88).

Table 1. Baseline demographic and clinical characteristics of participants

Variable	Group A (Pressure) Mean ± SD / n (%)	Group B (Visual) Mean ± SD / n (%)	Mean Difference (95% CI)	p-value
Age (years)	29.25 ± 4.10	29.38 ± 2.87	-0.13 (-2.66 to 2.40)	0.91
Male, n (%)	9 (56.3%)	8 (50.0%)	—	0.72*
Female, n (%)	7 (43.7%)	8 (50.0%)	—	—
Flexion (°)	37.01 ± 4.51	36.56 ± 3.89	0.45 (-2.63 to 3.53)	0.77
Extension (°)	38.38 ± 5.08	38.25 ± 4.66	0.13 (-3.39 to 3.65)	0.94
Rotation Right (°)	57.69 ± 7.82	55.31 ± 8.72	2.38 (-3.54 to 8.30)	0.42
Rotation Left (°)	58.50 ± 6.71	56.50 ± 6.68	2.00 (-2.74 to 6.74)	0.40
NPRS	5.88 ± 1.25	6.06 ± 1.43	-0.18 (-1.17 to 0.81)	0.69

*Chi-square test for categorical variable.

Within-group comparisons demonstrated statistically significant improvements in all cervical ROM components and NPRS scores in both groups after 4 weeks ($p < 0.001$). The magnitude of change and corresponding effect sizes are summarized in Table 2.

Table 2. Within-group pre–post comparisons of cervical ROM and NPRS

Outcome	Group	Pre-test Mean ± SD	Post-test Mean ± SD	Mean Change (95% CI)	Cohen's d	p-value
Flexion (°)	Pressure	37.01 ± 4.51	46.31 ± 4.86	9.30 (6.91 to 11.69)	1.98	<0.001
	Visual	36.56 ± 3.89	41.69 ± 4.55	5.13 (3.02 to 7.24)	1.21	<0.001
Extension (°)	Pressure	38.38 ± 5.08	45.26 ± 6.38	6.88 (4.09 to 9.67)	1.22	<0.001
	Visual	38.25 ± 4.66	44.12 ± 4.24	5.87 (3.54 to 8.20)	1.30	<0.001
Rotation Right (°)	Pressure	57.69 ± 7.82	67.01 ± 6.13	9.32 (6.02 to 12.62)	1.33	<0.001
	Visual	55.31 ± 8.72	61.06 ± 7.91	5.75 (2.78 to 8.72)	0.71	<0.001
Rotation Left (°)	Pressure	58.50 ± 6.71	69.19 ± 6.75	10.69 (7.66 to 13.72)	1.59	<0.001
	Visual	56.50 ± 6.68	63.65 ± 6.65	7.15 (4.37 to 9.93)	1.07	<0.001
NPRS	Pressure	5.88 ± 1.25	3.98 ± 1.52	-1.90 (-2.65 to -1.15)	1.38	<0.001
	Visual	6.06 ± 1.43	4.81 ± 1.42	-1.25 (-1.96 to -0.54)	0.88	<0.001

Between-group comparisons of post-intervention outcomes and change scores are presented in Table 3. Significant differences were observed in favor of the pressure biofeedback group for cervical flexion, right rotation, and left rotation ($p < 0.05$). No statistically significant differences were found between groups for extension or NPRS scores.

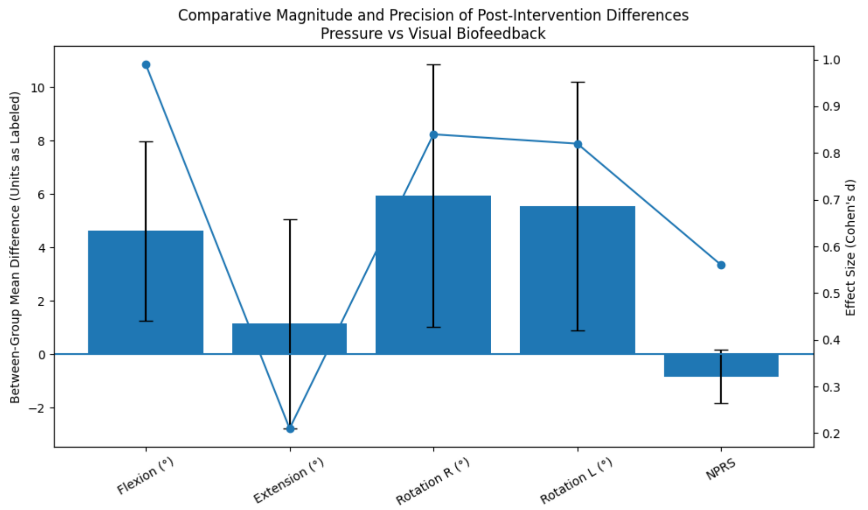
Table 3. Between-group comparisons of post-intervention outcomes and mean change

Outcome	Post-test Mean ± SD (Pressure)	Post-test Mean ± SD (Visual)	Between-group Difference (95% CI)	Cohen's d	p-value
Flexion (°)	46.31 ± 4.86	41.69 ± 4.55	4.62 (1.26 to 7.98)	0.99	0.009
Extension (°)	45.26 ± 6.38	44.12 ± 4.24	1.14 (-2.78 to 5.06)	0.21	0.56
Rotation Right (°)	67.01 ± 6.13	61.06 ± 7.91	5.95 (1.04 to 10.86)	0.84	0.02
Rotation Left (°)	69.19 ± 6.75	63.65 ± 6.65	5.54 (0.88 to 10.20)	0.82	0.02
NPRS	3.98 ± 1.52	4.81 ± 1.42	-0.83 (-1.83 to 0.17)	0.56	0.10

Overall, both interventions resulted in statistically significant improvements in cervical ROM and pain within groups. However, pressure biofeedback combined with stabilization exercises demonstrated significantly greater improvements in cervical flexion and bilateral rotation compared to visual biofeedback, while no significant between-group difference was observed for cervical extension or pain intensity.

Between-group comparisons at post-intervention (Table 3) revealed statistically significant differences favoring the pressure biofeedback group for cervical flexion and bilateral rotation. Post-treatment flexion was 46.31 ± 4.86° in the pressure group compared to 41.69 ± 4.55° in the visual group, with a between-group mean difference of 4.62° (95% CI: 1.26 to 7.98; p = 0.009; d = 0.99). Right rotation demonstrated a mean difference of 5.95° (95% CI: 1.04 to 10.86; p = 0.02; d = 0.84), and left rotation showed a mean difference of 5.54° (95% CI: 0.88 to 10.20; p = 0.02; d = 0.82), both indicating moderate-to-large effect sizes. In contrast, no statistically significant difference was observed for cervical extension, with a mean difference of 1.14° (95% CI: −2.78 to 5.06; p = 0.56; d = 0.21). Pain scores at 4 weeks were 3.98 ± 1.52 in the pressure group and 4.81 ± 1.42 in the visual group, yielding a non-significant between-group difference of −0.83 points (95% CI: −1.83 to 0.17; p = 0.10; d = 0.56).

Collectively, the data indicate that both interventions significantly improved cervical ROM and reduced pain within groups, with the pressure biofeedback group demonstrating greater improvements in cervical flexion and bilateral rotation, while no statistically significant superiority was observed for extension or pain reduction between groups.



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The integrated visualization demonstrates that post-intervention between-group differences consistently favored pressure biofeedback for cervical flexion and bilateral rotation, with mean differences of 4.62° (95% CI: 1.26 to 7.98), 5.95° (95% CI: 1.04 to 10.86), and 5.54° (95%

CI: 0.88 to 10.20), respectively. These effects were accompanied by moderate-to-large standardized effect sizes (Cohen's d = 0.99 for flexion, 0.84 for right rotation, and 0.82 for left rotation), indicating clinically meaningful superiority in sagittal and transverse plane mobility restoration. In contrast, cervical extension showed a small, non-significant mean difference of 1.14° (95% CI: −2.78 to 5.06; d = 0.21), with confidence intervals crossing zero, suggesting limited differential benefit between modalities. Pain reduction demonstrated a mean between-group difference of −0.83 points (95% CI: −1.83 to 0.17; d = 0.56), reflecting a moderate effect size but statistical non-significance due to interval imprecision. The combined depiction of effect magnitude and precision reveals a clear outcome gradient, whereby pressure biofeedback yields its strongest relative advantage in dynamic flexion–rotation control, while extension and pain outcomes exhibit overlapping uncertainty ranges, underscoring domain-specific therapeutic responsiveness rather than uniform superiority across all cervical parameters.

DISCUSSION

The present randomized controlled trial evaluated the comparative effectiveness of pressure biofeedback–guided versus visual biofeedback–guided stabilization exercises on cervical range of motion and pain in individuals with symptomatic forward head posture. Both interventions produced statistically significant within-group improvements across all measured ROM parameters and pain intensity after four weeks. However, between-group analysis demonstrated that pressure biofeedback resulted in significantly greater improvements in cervical flexion and bilateral rotation, whereas no significant superiority was observed for extension or pain reduction. These findings partially support the study hypothesis and suggest that the therapeutic advantage of pressure biofeedback may be movement-specific rather than global across all cervical domains.

The magnitude of improvement observed in the pressure biofeedback group for flexion (mean change 9.30°) and rotations (9.32° right, 10.69° left) exceeded that of the visual biofeedback group (5.13°, 5.75°, and 7.15°, respectively), with moderate-to-large effect sizes favoring pressure biofeedback (d ranging from 0.82 to 0.99 in between-group comparisons). Biomechanically, forward head posture is characterized by impaired deep cervical flexor activation and altered sensorimotor control, particularly affecting sagittal plane stability and axial rotation mechanics (3,8). Pressure biofeedback directly targets deep cervical flexor recruitment through graded cranio-cervical flexion training, thereby restoring segmental control and improving dynamic ROM efficiency (14). The greater gains in flexion and rotation observed in this study are consistent with the premise that enhanced neuromuscular specificity translates into superior mobility restoration, particularly in movements most compromised in FHP (19).

In contrast, cervical extension improvements did not significantly differ between groups despite meaningful within-group gains (6.88° in pressure vs 5.87° in visual). This finding may reflect the multifactorial nature of extension restriction in FHP, which involves both muscular tightness and structural adaptation. Unlike flexion, extension is less directly dependent on deep cervical flexor performance and may respond similarly to general stretching and strengthening protocols regardless of feedback modality (11,12). The small between-group effect size for extension (d = 0.21) and wide confidence interval crossing zero further indicate that the differential impact of biofeedback type is minimal for this movement.

Pain reduction demonstrated significant within-group decreases in both groups (−1.90 in pressure; −1.25 in visual), yet the between-group difference (−0.83; p = 0.10) did not reach statistical significance. Although the effect size for pain (d = 0.56) suggests a moderate magnitude difference, the confidence interval included zero, indicating statistical imprecision. Pain perception in mechanical neck disorders is influenced by multiple factors including central sensitization, psychosocial components, and behavioral adaptations (19). Therefore, while improved motor control may reduce mechanical stress, short-term differences in neuromuscular retraining strategies may not translate into distinctly different pain outcomes within a four-week period. Previous literature similarly reports that biofeedback-guided interventions improve pain, but superiority between modalities has not been consistently established (14,15). These findings reinforce the concept that pain is a multidimensional outcome and may require longer follow-up to detect modality-specific differences.

From a clinical standpoint, the pattern of results suggests that pressure biofeedback may provide greater benefit in restoring dynamic cervical mobility, particularly in flexion and rotation—movements closely associated with deep cervical flexor performance and postural correction (8,14). Visual biofeedback, while effective, may primarily enhance global alignment awareness rather than selective segmental activation. The observed outcome gradient—large effects in flexion and rotation, minimal difference in extension, and moderate but non-significant difference in pain—indicates that intervention selection may be optimized according to specific rehabilitation priorities. For patients with pronounced mobility deficits in sagittal and transverse planes, pressure biofeedback may offer additional benefit; for broader postural retraining objectives, both modalities appear clinically useful.

The study demonstrates methodological strengths including randomized allocation, assessor blinding, standardized intervention dosage, and reporting of effect sizes with confidence intervals, enhancing internal validity. Nevertheless, several limitations must be acknowledged. The sample size, although adequately powered for primary ROM comparisons, may have limited precision for secondary pain outcomes. The intervention duration was restricted to four weeks, precluding assessment of long-term sustainability of gains. Craniovertebral angle was used for inclusion but not reassessed post-intervention, limiting the ability to correlate structural postural correction with functional improvement. Additionally, although assessor blinding was implemented, participant and therapist blinding was not feasible, introducing potential performance bias. Future studies with larger multi-center samples, longer follow-up, and inclusion of objective postural angle reassessment are warranted to confirm durability and mechanistic pathways of observed improvements.

In conclusion, both pressure and visual biofeedback combined with stabilization exercises significantly improved cervical ROM and reduced pain in individuals with symptomatic forward head posture. However, pressure biofeedback demonstrated superior effects in cervical flexion and bilateral rotation, suggesting enhanced neuromuscular specificity in movement restoration. Pain outcomes improved similarly across modalities, indicating that short-term analgesic effects may be comparable. These findings contribute clinically interpretable evidence supporting the integration of targeted biofeedback strategies within rehabilitation programs for forward head posture and provide a foundation for future trials exploring long-term functional and postural outcomes.

CONCLUSION

In individuals with symptomatic forward head posture, both pressure biofeedback–guided and visual biofeedback–guided stabilization exercise programs produced statistically significant improvements in cervical range of motion and pain over a four-week period.

However, pressure biofeedback demonstrated superior gains in cervical flexion and bilateral rotation, with moderate-to-large between-group effect sizes, while no statistically significant superiority was observed for cervical extension or pain reduction. These findings suggest that although both modalities are clinically effective adjuncts to stabilization exercises, pressure biofeedback may offer enhanced neuromuscular specificity and movement restoration in planes most affected by forward head posture. Incorporating targeted biofeedback strategies into rehabilitation protocols may therefore optimize functional cervical mobility outcomes, while longer-term studies are warranted to determine sustainability of benefits and effects on structural postural correction.

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DECLARATIONS

Ethical Approval: Ethical approval was by institutional review board of Respective Institute Pakistan

Informed Consent: Informed Consent was taken from participants.

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Concept: NP; Design: NP, IS; Data Collection: AI, W; Analysis: UE; Drafting: NP, IZA

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