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Comparison and Correlation of Cervical Proprioception, Muscle Strength and Posture among Participants with Neck Pain- Randomized Controlled Trial

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Abstract

Cervical proprioception, the ability of neck muscles and joints tosense position and movement,is crucial for head and neck stability. Deficits in cervical proprioception can lead to impairedmotor control, neck pain, and dysfunction. This study investigates the effectiveness ofproprioceptive training for deep cervical flexors in reducing pain, enhancing proprioception, andimproving muscular endurance in patients with neck pain. The study involved 40 patients aged20-45, divided into two groups of 20. Group A (control) received conventional therapy, whileGroup B (experimental) participated in deep flexor training with pressure biofeedback andcervical proprioceptive training using a laser feedback unit. The intervention spanned 4-8 weekswith three sessions per week. Assessments included the Visual Analog Scale (VAS), NeckDisability Index (NDI), Deep Cervical Flexors (DCF) endurance test, and Joint Position Error (JPE) test and the Data were analyzed. Post-treatment assessments revealed significantimprovements in pain (VAS: pre- treatment mean = 6.00 ± 1.08, post-treatment mean = 3.00 ±0.30), disability (NDI: pre-treatment mean = 13.2 ± 6.89, post-treatment mean = 11.2 ± 5.38), craniovertebral alignment (CVA: pre-treatment mean = 4.35 ± 2.98, post-treatment mean = 4.01 ± 0.32), and muscular endurance (DCF endurance: pre-treatment mean = 26 ± 1.32, post-treatment mean = 29 ± 2.23), with the experimental group showing superior outcomes. Deep flexor training with pressurebiofeedback and cervical proprioceptive training proved more effective than conventionaltherapy, resulting in significant improvements in pain, disability, craniovertebral alignment,muscular endurance, and overall quality of life. This highlights the importance of targetedproprioceptiveinterventions in optimizing rehabilitation forneck painpatients. Future researchesare needed to explore long-term outcomes of these interventions to determine their sustainedbenefits.

Keywords: Neck pain; Proprioception; Visual Analog Scale (VAS); Neck Disability Index(NDI); Craniovertebral Angle (CVA); Deep Cervical Flexors (DCF); Joint Position Error (JPE)

1. Introduction

Neck pain is one of the most common musculoskeletal conditions, characterized by symptoms in the cervical spine lasting three months or more without a specific cause. Common contributors to cervical discomfort include injuries, poor long-term posture or cervical spine movement, nerve root compression, muscle sprains, and whiplash-related issues (Kazeminasab *et al*., 2022). Cervical spondylosis, a widespread degenerative condition of the cervical spine, predominantly affects individuals in their 40s and 50s. It is a frequent cause of neck pain, which not only diminishes quality of life but also incurs significant financial costs, such as medical expenses. Additionally, it significantly contributes to poor balance and dizziness associated with spinal degeneration (Jitin, 2021). It predominantly affects the C5-C6 and C6-C7 levels of the cervical spine, but it can also lead to high cervical spine lesions in some cases. The severity of symptoms varies depending on the location and extent of spinal damage (Reddy *et al*., 2019). The incidence rate of neck pain is broad, ranging from 0.4% to 86.8% (Miao *et al*., 2018), and it is more prevalent among individuals at higher risk of developing this condition. Currently, it is estimated that around 349 million people worldwide suffer from neck pain and related conditions (Zhao *et al*., 2018).

Studies indicate that proprioception differs in patients with cervical spondylosis which is attributed to altered input from cervical afferents, especially muscle spindles, linked to neck pain. Muscle spindles, along with cutaneous and joint receptors, are considered primary cervical receptors for position sensing (Wrisley *et al*., 2000; Rix and Bagust, 2001; Boyd-Clark et al., 2002; Reddy *et al*., 2019). Hence, improved muscle spindle function enhances cervical proprioception. Regarding cervical muscles, deeper cervical muscles possess a high density of muscle spindles (Reddy *et al*., 2019). An imbalance between the Deep Cervical Flexors (DCFs) and posterior neck stabilizers disrupts proper alignment and posture, aggravating cervical dysfunction and neck pain (Jull *et al*., 2009). Consequently, specific proprioceptive training programs are often designed to target the deep suboccipital muscles to regulate neck posture, alleviate pain, and improve proprioception. These programs may incorporate gaze stability exercises, eye-head coordination exercises, or head-on-trunk movements (Falla *et al*., 2008; Iqbal et al., 2021).

Moreover, DCF training is recommended for addressing poor neuromuscular control of the cervical flexors, aiming to enhance DCF activation and restore coordination between deep and superficial cervical flexors (Falla *et al*., 2013). Research on the effectiveness of this exercise regimen has shown promising outcomes, including reduced neck pain and disability, improved sitting posture, increased neuromuscular control over cervical flexors in patients with persistent neck pain, and enhanced neck proprioceptive acuity, suggesting that proprioception can be improved with targeted exercise (Aydoğmuş et al., 2022; Rahnama *et al*., 2023). This study explores the efficacy of proprioceptive training, focusing on the deep cervical flexors, in reducing neck pain and disability while enhancing proprioception and muscular endurance in patients with neck pain.

2. Materials and Methods

Research Approach and Design

This study utilized a randomized controlled trial design to assess the effectiveness of deep cervical flexor training with pressure biofeedback and cervical proprioceptive training using laser feedback in comparison to conventional therapy (Figure.1). Forty participants were randomly assigned to either the control group (Group A) receiving conventional therapy or the experimental group (Group B) receiving specialized training.

Description of Variables

o Independent Variable: Type of therapy (conventional therapy vs. deep cervical flexor training with biofeedback and proprioceptive training).

o Dependent Variables: Pain intensity, Neck disability, Craniovertebral angle, Deep cervical flexor endurance, and Joint position error.

Setting, Population, and Sample Size

The study was conducted in a clinical setting with a sample of 40 participants aged 20-45, all of whom experienced neck pain lasting three months or more. Participants were divided into two groups of 20 each.

Criteria for Sample Selection

Inclusion Criteria: Adults aged 20-45; Neck pain lasting three months or more

Exclusion Criteria: Chronic neck pain; Recent traumatic injuries; History of cervical spine surgery; Neurological disorders; Systemic musculoskeletal diseases; Pregnancy; Concurrent treatments for neck pain; Inability to comply with the study protocol; Contraindications to the proposed treatments

Sampling and Method of Data Collection

Participants were selected using a randomized sampling method. Data were collected through various standardized assessment tools, including the Visual Analog Scale (VAS) for pain, the Neck Disability Index (NDI) for disability, the Deep Cervical Flexors (DCF) muscle endurance test, and the Joint Position Error (JPE) test for cervical proprioception.

Development and Description of Tools

Evaluation of Neck Pain

The Visual Analogue Scale (VAS) was used to measure the intensity of neck pain. Participants marked their pain level on a 10-centimeter line, with 0 indicating no pain and 10 indicating unbearable pain (Langley and Sheppeard, 1985).

Evaluation of Neck Disability

The Neck Disability Index (NDI) assessed disability due to neck pain. This scale, created by Vernon and Mion (1991), evaluates how pain affects daily activities across 10 topics: pain intensity, personal care, lifting, reading, headache, concentration, work life, driving, sleep, and rest. Scores range from 0 (no disability) to 50 (maximum disability), with higher scores indicating greater disability. The Turkish version of this index has been validated and found reliable (Vernon and Mior, 1991).

Measurement of Craniovertebral Angle

The craniovertebral angle (CVA) was measured to determine forward head posture using photogrammetry. A photograph was taken from the lateral side with a digital camera. The angle was calculated by drawing a line from the C7 vertebra to the tragus of the ear and a horizontal line from C7. The 7th cervical vertebra was identified by asking the subject to flex and extend their neck. Two researchers confirmed the landmark of the spinous process of the 7th vertebra (Kang *et al*., 2012).

Deep Training of the Cervical Flexors

The strength of the Deep Cervical Flexors was measured using a Pressure Biofeedback Unit. With the neck in a neutral position, the unit was placed below the occiput and inflated to 20 mmHg. Subjects performed gentle head nodding actions at pressures of 22, 24, 26, 28, and 30 mmHg, maintaining each level for 10 seconds with 30-second rest intervals between levels. The test concluded when the subject could not maintain the pressure for 10 seconds or reached 30 mmHg (Nezamuddin *et al*., 2013). Training followed the Jull et al. methodology (2008), aiming to minimize superficial cervical flexor activation while targeting DCFs. Patients performed the exercise with a biofeedback unit positioned behind the neck, progressively increasing pressure from 20 mmHg to 30 mmHg. Each level was maintained for 10 seconds, with 10 repetitions per level and brief rest intervals. The exercise progressed to the next level after completing a set of 10 repetitions.

JPE Evaluation

In this study, a laser beam and colored target were utilized to measure the Joint Position Error (JPE) of the cervical spine. The laser method, which has been validated for its strong test-retest reliability, correlates well with ultrasound techniques for measuring JPE. A laser pointer was secured to a lightweight headband worn on the participant's head. The distance from the starting point of the laser, projected from the forehead, to the center of the target was set at 90 cm using a measuring tape. The key variable measured was the difference between the initial and return positions of the laser beam on the target, recorded in degrees using the formula: angle = $\tan^{-1}$ (error distance / 90 cm) (Roren *et al*., 2009). For the cervical joint position error test, yellow and red circles representing 4.5 and 6 degrees, respectively, were used, along with three green circles indicating 1, 2, and 3 degrees. Revel et al. initially reported that patients with neck pain had a reduced ability (6.11°) to return to the original head position after maximal rotation compared to healthy individuals (3.50°).

Validity of Tool

The tools used in the study have been validated in previous research. The VAS and NDI are widely accepted and validated measures for assessing pain intensity and neck disability, respectively. The DCF endurance test and JPE test have also been validated for assessing muscle endurance and proprioception.

Reliability of Tool

The reliability of the tools was ensured through standardized administration procedures. The VAS, NDI, DCF endurance test, and JPE test have demonstrated high test-retest reliability in previous studies, indicating consistent results across different testing occasions.

Methods of Data Collection and Statistical Analysis

Data collection involved pre- and post-intervention assessments using the aforementioned tools. Participants were assessed at baseline and after the intervention period, which lasted between 4 to 8 weeks with three sessions per week. Statistical analysis was performed using SPSS version 23.0 to determine the effectiveness of the interventions in reducing pain, improving function, and enhancing proprioceptive accuracy.

3. Results

Demographic Characteristics

The descriptive statistics of demographic variables (age, weight, height, BMI, and gender distribution) between Group 1 (N=20) and Group 2 (N=20) are presented in Table.1. The study included participants with a mean age of 42.9 ± 4.78 years. Group 1 consisted of 6 males and 14 females, while Group 2 included 8 males and 12 females. No significant differences in BMI, height, or weight were observed between the groups, ensuring comparability of baseline characteristics. Only age showed a statistically significant difference between the groups ($p = 0.02$), while there were no significant differences in weight, height, BMI, and gender distribution.

Comparison of Pre-Treatment and Post-Treatment Measurements with Associated P-Values

Table.2 compares the mean values of Visual Analogue Scale (VAS), Neck Disability Index (NDI), Craniovertebral Angle (CVA), and Deep Cervical Flexors Endurance (DCF-Endurance) before and after treatment for both groups. Significant improvements in post-treatment were observed in all variables ($p < 0.005$), indicating efficacy of the intervention.

Distribution of Joint Proprioception Error (JPE)

Table.3 presents the mean, standard error of measurement (SEM), 95% confidence intervals (CI), minimal detectable change (MDC), and p-values for Joint Position Error (JPE) measurements in cervical flexion, extension, and rotational movements between Group 1 and Group 2. Significant improvements in JPE were observed across various cervical movements in Group 2 compared to Group 1 ($p < 0.005$). For Group 2, the mean JPE values were 1.78 ± 1.23 for cervical flexion, 2.47 ± 1.03 for cervical extension, 1.15 ± 0.98 for right rotation, and 1.37 ± 1.00 for left rotation. These values were lower than those reported in the referenced study, indicating better proprioceptive function in our cohort.

Comparison of Pre-Treatment and Post-Treatment of JPE with VAS, NDI, CVA, DCF Endurance

Table.4 compares the pre-treatment and post-treatment mean values of JPE with VAS, NDI, CVA, and DCF Endurance scores. Significant improvements were noted after the treatment in all variables ($p < 0.005$), indicating that the intervention led to reductions in pain, improvements in neck disability, craniovertebral alignment, and muscular endurance, with Group 2 demonstrating superior outcomes.

4. Discussion

This experimental study demonstrates that proprioception deficits are prevalent in patients with neck pain, extending to those with cervical pain. Previous research has rarely examined the commonality of proprioception impairment in patients with cervical pain. This study stands out by evaluating how proprioceptive deficits impact cervical flexion, extension, and rotational movements on both sides and how these pathologies respond to proprioceptive training. An important aspect of this protocol is that, in addition to gaze stabilization and coordination exercises, it proposes a treatment plan that targets the deep sub-occipital muscles and reflex connections to enhance proprioceptive acuity in neck pain patients.

When comparing the demographic characteristics of our study with those reported by Reddy *et al*. (2012) and Nagai *et al*. (2014), notable differences are observed. Our study cohort had a mean age of 42.9 ± 4.78, differing from Reddy *et al*.'s cohort (21.7 ± 1.8) and Nagai *et al*.'s cohort (34.5 ± 6.4). These differences may be attributed to factors such as geographic location, sample selection criteria, or study design nuances. The gender distribution in our study also differs from that reported by Saleh *et al*. (2018). While Saleh et al. had 7 males and 13 females, our study had 6 males and 14 females in Group 1 and 8 males and 12 females in Group 2. These variations might result from different recruitment methods or demographic characteristics, emphasizing the need to consider population diversity in research interpretations. No significant differences were observed in BMI, height, or weight between the two groups in our study, suggesting that baseline characteristics were comparable and reducing potential confounding effects, thus enhancing the validity of the results.

The Visual Analog Scale (VAS) is a widely used tool for assessing pain intensity, and cervical proprioception refers to the body's ability to sense the position and movement of the neck. In our study, pre-treatment VAS scores averaged 6 ± 1.08 and significantly decreased to 3 ± 0.3 post-treatment (p = 0.001*), demonstrating a substantial reduction in pain intensity following the intervention. This finding is consistent with Saleh et al.'s control group, where the VAS scores were 6 ± 1.13 on average, indicating similar initial pain levels across studies.

Our study highlights documented proprioceptive deficits in neck pain patients and their implications for functional disability. It underscores the importance of exploring the relationship between Neck Disability Index (NDI) scores and cervical proprioception to enhance understanding and inform rehabilitation strategies. Comparing our study's pre- and post-treatment mean values for NDI with those reported by Saleh *et al*. (2018) (47.9 ± 2.77 and 48.65 ± 2.73, respectively) shows a marginal difference. This suggests that while our intervention may lead to measurable improvements in neck disability, the extent of change may vary compared to Saleh et al.'s findings. Subtle differences in treatment modalities, duration, or participant characteristics could account for these variations. Further exploration, including meta-analysis or subgroup analysis, may provide deeper insights into these discrepancies, enhancing our understanding of treatment efficacy and its clinical implications.

In patients with cervical pain, disruption of afferent input from the neck's proprioceptors causes a sensory mismatch between vestibular, visual, and cervical inputs to the sensorimotor control system, leading to objective proprioceptive abnormalities (Revel *et al*., 1994, Kristjansson et al., 2009). This study focused on improving proprioception as a potential key to a positive treatment effect (Boyd-Clark et al., 2002), given the high-density concentrations of muscle spindles found in the suboccipital and deep cervical muscles (Reddy *et al*., 2022). Patients with neck discomfort exhibited decreased head-neck coordination, altered proprioception (measured by cervical joint position), altered balance, and altered cervical muscle postural activity in relation to the postural control system (Sremakaew *et al*., 2018).

Patients with neck pain also demonstrated abnormal joint position error (JPE) when tested on their ability to actively change a position within a movement plane or return to the natural head posture after an active movement. Changes in input from cervical afferents to higher centers may contribute to these disruptions in postural control (Mugdha *et al*., 2015). Compared to the referenced study's JPE measurements for Group 2, our study observed lower mean JPE values in cervical flexion (1.78 ± 1.23) and cervical extension (2.47 ± 1.03). Specifically, our study recorded mean JPE values of 1.15 ± 0.98 in right rotation and 1.37 ± 1.00 in left rotation for Group 2. These values contrast with the referenced study's findings, which reported higher mean JPE values of 1.97 ± 1.71 in cervical flexion, 2.29 ± 1.32 in cervical extension, 1.14 ± 1.12

in left rotation, and 1.97 ± 1.04 in right rotation for Group 2. These discrepancies suggest potential variations in proprioceptive function or measurement techniques between studies, highlighting the need for further investigation to understand the factors contributing to differences in JPE assessments across various research contexts.

The study highlights significant improvements in pain levels and disability as evidenced by reduced VAS scores (p = 0.003) and NDI scores (p = 0.002) post-treatment. Positive trends in cervical alignment (CVA, p = 0.002) and enhanced muscular endurance (DCF-Endurance, p = 0.001) were also observed. Group 2 showed greater improvements in VAS, NDI, DCF endurance (all p < 0.001), and JPE measurements (p < 0.005) compared to Group 1, underscoring the effectiveness of the intervention. The study's rigorous assessment and targeted intervention support its clinical relevance and validity.

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5. Conclusion

This study underscores the efficacy of proprioceptive training, specifically targeting the deep cervical flexors, in enhancing pain relief and functional outcomes for individuals with neck pain. By comparing conventional physiotherapy with proprioceptive and deep cervical flexor training, the study illuminates the critical role of proprioception in managing neck pain and identifies effective therapeutic approaches. The superior results observed in the group receiving combined treatment emphasize the integration of proprioceptive interventions in clinical settings to improve patient care and overall well-being. These findings highlight the necessity for future research and broader adoption of proprioceptive strategies to advance neck pain management and enhance patient outcomes.

Conflict of Interest: None

Reference:

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Figures and Tables

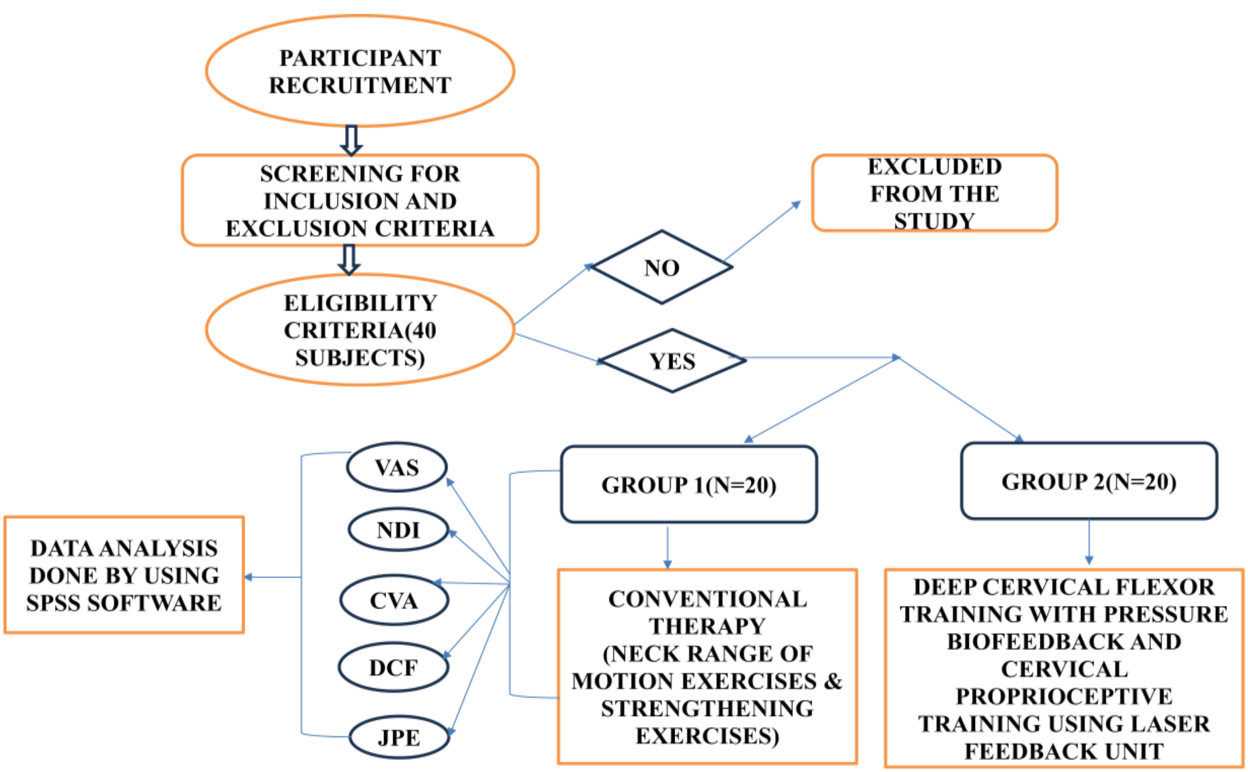

Figure: 1 Flow Chart for overall study design

Table 1: Descriptive Statistics

Variables	Mean ±SD		P Value
	GROUP 1 (N=20)	**GROUP-2 (N=20)**	
Age	42.6±5.3	43.2±4.6	0.02
Weight	72.01±7.82	76.2±8.93	0.18
Height	154.8±8.32	156±8.96	0.35
BMI(Kg/M^2)	26.32±4.12	27.02±3.16	0.16
Male/Female	6/14	8/12	0.89

(Aside from age, there are no statistically significant differences between the groups in weight, height, BMI, and gender distribution)

Table 2: Comparison of Pre-Treatment and Post-Treatment Measurements with associated P-Values

Variables	Pre-Treatment	Post-Treatment	P-Value
	Mean ±SD	**Mean ±SD**	
VAS	6±1.08	3±0.3	0.001*
NDI	13.2±6.89	11.2±5.38	0.002*
CVA	4.35±2.98	4.01±0.32	0.005*
DCF-ENDURANCE	26±1.32	29±2.23	0.001*

*P VALUE less than 0.005 shows statistically significant. VAS-visual analogue scale, NDI-Neck Disability Index, CVA-Craniovertebral Angle, DCF-Deep Cervical Flexors Endurance

Table 3: Distribution of Joint Proprioception Error.

JPE	Mean ±SD		SEM	95%Cl		MDC	P Value
	Group-1	Group-2		Upper	Lower		
Cervical Flexion	1.82±1.32	1.78±1.23	0.762	3.316	0.324	1.774	0.002*
Cervical Extension	2.53±1.93	2.47±1.03	1.93	3.24	1.26	4.47	
Right Rotation	1.25±1.03	1.15±0.98	1.03	6.32	0.74	2.40	
Left Rotation	1.68±1.21	1.37±1.00	1.21	3.49	0.13	2.86	

*-p value shows less than 0.005 statisticallysignificant.SD-standard deviation JPE-joint position error, SEM-Standard error of measurement, MDC-Minimal detectable change.

Table 4: Comparison of Pre-Treatment and Post-Treatment of JPE with VAS, NDI, CVA, DCF Endurance

	JPE(Joint Position Error)		P value
	Pre-Treatment	Post-Treatment	
	Mean ±SD	Mean ±SD	
VAS	6.00±1.08	3.00±0.30	0.003*
NDI	13.2±6.89	11.2±5.38	0.002*
CVA	4.35±2.98	4.01±0.32	0.002*
DCF-ENDURANCE	26±1.32	29±2.23	0.001*

*-Pvalue shows less than 0.005 statistically significant**.**

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