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Effect of Eye- Cervical Proprioceptive Training Program on Cervical Sensorimotor Control Dysfunction

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ABSTRACT
Objective: Objectives: *Proprioceptive training is extensively employed as a therapeutic exercise method. However, its impact on pain reduction and improvement in range of motion (ROM) wasn't been widely investigated. This study was done to examine the effectiveness of combining Eye-Cervical proprioceptive training program with multimodal physiotherapy treatment to alleviate pain and enhance joint mobility in individuals with cervical sensorimotor control dysfunction.* ***Material and Methods****:* ***Design:*** *A randomized, controlled clinical trial.* ***Setting:*** *physical therapy Department, Egypt Air hospital.* ***Participants:*** *Fifty subjects were randomized into two groups of equivalent number.* ***Interventions:*** *All participants received a multimodal physiotherapy treatment. In addition, the experimental group performed a specialized exercise program incorporating eye-cervical proprioceptive training (ECPTP).* ***Outcomes:*** *Pain intensity was evaluated using the McGill Pain Questionnaire (MPQ), while cervical mobility was assessed using the Cervical Range of Motion (CROM 3) device.* ***Results:*** *The results indicated significant improvement in cervical (ROM) and neck pain scores in both groups, with the experimental group demonstrating more improvements in cervical (ROM) compared to the control group, this included significant gains in flexion ($p < 0.001$), extension ($p < 0.003$), left side bending ($p < 0.001$), right lateral bending ($p < 0.004$), left and right rotation ($p < 0.009$). Moreover, the experimental group showed greater reduction in (MPQ) scores than the control group ($p < 0.001$).*
Conclusions: *The Eye-Cervical proprioceptive training program has been shown to effectively improve cervical (ROM) such as flexion, extension, lateral bending, as well as rotation, while also reducing pain levels.*
Keywords: *Proprioceptive training, Chronic neck pain, Cervical sensorimotor control dysfunction, Cervical Range of Motion.*

1. INTRODUCTION

Neck pain (NP) ranks among the most frequently reported musculoskeletal conditions, with a standardized prevalence of 27 per 1,000 individuals as of 2019.[1] In about one-third of cases, symptoms persist for over a year, potentially resulting in chronic pain and increased healthcare costs.[2] Issues such as reduced cervical range of motion (ROM) and muscle weakness may significantly lead to both the development and persistence of neck pain.[3]

The upper cervical spine is the most flexible region of the vertebral column, but this increased mobility reduces its mechanical stability. To maintain proper function, it relies on an advanced proprioceptive system that offers neuromuscular control. This system, through specialized links with the vestibular and visual systems, supports the effective coordination and use of essential head structures.[4]

Cervical proprioception plays a vital role in spatial orientation by providing awareness of head position and movement relative to the trunk. This sensory input is essential for the precise integration of visual and vestibular signals. It enables the detection of head to body alignment and supports the execution of coordinated, goal-directed, and corrective intersegmental movements.[5-6]

The cervical spine plays a key role in delivering proprioceptive input, as evidenced by the high concentration of mechanoreceptors in the region and their extensive connections with the vestibular, visual, and central nervous systems.[7] Impaired proprioception may contribute to an increased risk of pain and injury by disrupting effective motor control.[8]

A decreased range of motion (ROM) in the neck is a commonly observed and extensively studied feature in chronic neck pain (CNP) cases.[9,10] It can be suggested that proper cervical muscle function is closely linked to ROM, as alterations in muscle activation patterns may change stiffness distribution, thereby impacting both the passive stability of the cervical spine and its passive and active ROM.[11]

Individuals with neck pain have been found to exhibit impairments in oculomotor control, including reduced smooth pursuit velocity gain, changes in the speed and timing of saccadic eye movements, and an elevated gain in the cervico-ocular reflex.[12]

Prolonged visual demands, often caused by factors such as inadequate lighting, improper or uncorrected vision correction, poor workstation design, and insufficient breaks, can lead not only to eye discomfort but also to increased musculoskeletal strain and symptoms. This is likely due to hardwired sensorimotor reflexes and the strong functional connections between the eyes, neck, and scapular muscles.[13]

Visual impairments have been linked to musculoskeletal discomfort in the neck and shoulder regions.[14] While these conditions are often examined separately; research suggests a possible physiological connection between them.[15]

The Eye-Cervical Proprioception Training Program (ECPTP) refers to targeted proprioceptive rehabilitation approach that incorporates exercises such as head repositioning, gaze stabilization, eye tracking, and coordinated movements of the eyes and head.[7]

Up to the author's knowledge, the impact of combined Eye-Cervical Proprioception Training Program (ECPTP) and multimodal physiotherapy intervention (MPI) wasn't investigated. Therefore, this study was done to verify their combined impact in increasing ROM in the cervical area and reducing pain.

To verify this effectiveness, we used objective and reliable assessment tools to measure ROM in the cervical area by CROM 3 and pain by McGill Pain Questionnaire.

2. MATERIALS AND METHODS:

Study design: The randomized controlled study (RCT) took place at Egypt Air Hospital's physical therapy department from August 2023 to May 2025. All participants gave their written informed consent before the study began, outlining their rights to withdraw at any time and providing a thorough explanation of the study's goals, methods, risks, and benefits. This consent was given before the initial evaluation and recruiting. A protocol for this study was approved by the Faculty of Physical Therapy's Ethics Committee at Cairo University (P.T.REC/012/003939).

Participants:

Fifty Participants with chronic neck pain were participated and recruited from the outpatient clinic of Egypt Air Hospital. Participants were considered suitable for this study based on the subsequent criteria for eligibility, 1) Both sexes, 2) Age ranged from 25 to 40 years, 3) Had experienced neck pain of varying intensity for 6 to 18 months, 4) Demonstrated limitation in one or more cervical movements, 5) BMI ≤ 30. Participants were excluded if they had any of the following conditions: existing vestibular or inner ear disorders, cervical fractures or dislocations, neurologically related cervical pain, cervical infections, a history of traumatic head injury, systemic diseases, cranial nerve injuries, previously diagnosed central nervous system (CNS) disorders, a history of ear or eye surgery, deafness, or dizziness caused by vascular issues.

Sample Size and Randomization:

Utilizing G*power (version 3.1.9.6, Dusseldorf, Germany) and a 0.80 effect size, 20% beta error, and a two-sided 0.05 alpha error, we estimated the sample size to determine if there had been any clinically significant changes among the groups of 450 for cervical (right rotation) ROM and 35 points according to the McGill pain questionnaire (MPQ). A total of five volunteers from each group participated in the pilot study to establish the impact size. Based on the calculation, the sample number should be 42 participants. The original estimated sample size was 40 participants; to accommodate for dropouts, the size was increased by 19% to 50 participants. The subjects were divided into two equivalent groups "Study" or "Control" at random using a simple randomization method. A computer-generated random number was used to assign 25 patients to each group, ensuring equal group distribution and minimizing selection bias. Study group was given MPI and Eye-Cervical proprioceptive training Program (ECPTP). While control group was given only the Multimodal Physiotherapy Intervention (MPI).

Outcome Measures:

1- The McGill Pain Questionnaire (MPQ)

The McGill Pain Questionnaire (MPQ) is considered as a self-reported tool commonly used to assess pain in individuals with various diagnoses. It evaluates both the quality and intensity of pain as experienced subjectively by the patient. The questionnaire consists of 78 descriptive words, from which respondents select those that best characterize their pain experience.

2- Cervical Range of Motion (CROM):

The Cervical Range of Motion (CROM 3) device is used to assess cervical spine mobility, including rotation, flexion, extension, and lateral flexion. Its reliability and validity in measuring cervical range of motion have been well-established, with favorable outcomes reported.[16] The CROM 3, a more advanced version, utilizes three individual inclinometers mounted on a spectacle-like frame to accurately measure movements in all primary cervical planes.

Interventions:

All training sessions were supervised and conducted by the same physiotherapist to ensure consistency in treatment delivery. Participants in groups. Study Group received MPI and ECPTP, and the Control Group received MPI only. Each participant attended a total of 12 treatment sessions, administered on alternate days, with each session lasting approximately 60 minutes.

1- Multimodal Physiotherapy Intervention (MPI):

All participants in both groups received a standardized physiotherapy program comprising the following components: Interferential Current. (Phyaction Guidance E device by Uniphy). Using quadrupoles dynamic vector with 6×8 cm rubber electrodes, were placed two poles perpendicular to the other two poles on trapezius muscles with frequency from 50- 100 Hz; for 20 Min, Hot packs for 15 Min, Myofascial release for 10 min, and stretching exercises for neck muscles for 5 min.[17]

2- Eye-Cervical proprioceptive training Program (ECPTP):

This program consists of 10 proprioceptive exercises targeting the cervical region, structured into three progressive phases.[7]

Phase A: Ocular Mobility Without Cervical Movement Position:

The patient lies in a supine position while the physiotherapist is seated at the level of the patient's head.

Exercise 1: Ocular Muscle Activation

The patient performs maximal eye movements in four directions right, left, upward (toward the front), and downward (toward the feet) without moving the head. Each movement is repeated three times with eyes open, followed by three times while closing eyes.

Exercise 2: Passive Cervical Mobilization with Visual Fixation

At the same time that the patient is focusing on a set point in the vertical direction, the physical therapist produces passive rotation and flexion-extension in the cervical spine. The same exercise is repeated with eyes closed after memorizing the visual target.

Phase B: Cervical Mobility with Restricted Eye Movement

The patient was positioned on a rotating stool. Opaque glasses limit eye movement and provide only foveal vision.

Exercise 3: Analytical Cervical Mobility

The patient actively performs cervical movements (flexion, extension, rotation, lateral flexion), aiming to maintain gaze on a distant visual target in each direction. Each movement is repeated three times.

Exercise 4: Visual Tracking with Cervical Movement

The patient's eyes track a detailed geometric pattern or image projected onto the wall, promoting coordinated eye and head movement.

Exercise 5: Trunk Instability with Visual Fixation

While the patient fixates on a wall-mounted target, the physiotherapist applies multidirectional destabilizing forces to the trunk to challenge cervical control.

Exercise 6: Head Repositioning – Level 1

The patient, positioned correctly in front of a mirror, memorizes the head position, then performs various neck movements with eyes closed (flexion, extension, rotation, side bending). The next step is for the patient to try to go back into the starting position without using any visual cues. 10

repetitions were done.

Exercise 7: Head Repositioning – Level 2

This is a progression of Exercise 6, with the physiotherapist applying destabilizing inputs while the patient performs the task.

Phase C: Eye and Neck Movement Coordination

Position: With their opaque spectacles removed, patients maintained their seated position on the stool.

Exercise 8: Free Coordination with Moving Object

A physiotherapist stands facing the patient and uses a multi-directional item to demonstrate movement. With the goal of achieving full cervical ROM, the patient keeps their eyes on the item. The duration of this exercise is one minute, and it is done twice. The range of motion is adapted to the patient's capacity.

Exercise 9: Manual Resistance Coordination

The physical therapist stands behind the patient, who is instructed to move in specific directions while the therapist applies manual resistance. Intensity and movement range are tailored to the patient's physical condition. Each session lasts two minutes.

Exercise 10: Oculo-Cervical Coordination with Multidirectional Stimuli

This exercise builds on Exercise 9. Instead of resistance, the physiotherapist applies gentle, multidirectional perturbations to the patient's head. Duration is two minutes.

Statistical Analysis

SPSS version 25 for Windows was utilized to carry out the statistical analyses. Independent t-tests and Chi-square tests were used to compare baseline characteristics between groups. Data normality was assessed using the Shapiro–Wilk test, while Levene's test was applied to verify the equality of variances. The effects of the intervention on outcome variables were analyzed using a mixed-design multivariate analysis of variance (MANOVA). When significant results were found, Bonferroni-adjusted post-hoc tests were conducted. Statistical significance was defined as a p-value below 0.05.

3. RESULTS

Subject Characteristics:

Groups did not differ significantly with respect to age, BMI, or gender distribution ($p > 0.05$). (Table 1).

Table 1. Subject characteristics.

	Study group	Control group	MD	t- value	p-value
	Mean ± SD	Mean ± SD			
Age (years)	32.44 ± 4.20	33.76 ± 3.90	-1.32	-1.15	0.26
Weight (kg)	69.64 ± 4.77	71.88 ± 6.16	-2.24	-1.44	0.16
Height (cm)	158.20 ± 5.32	158.72 ± 3.95	-0.52	-0.39	0.69
BMI (kg/m²)	27.93 ± 2.89	28.57 ± 2.76	-0.64	-0.79	0.43
Sex distribution, N (%)					
Female	16 (64%)	18 (72%)	χ^2 = 0.37		0.54
Male	9 (36%)	7 (28%)			

SD, standard deviation; MD, mean difference; χ^2, Chi squared value; P value, probability value

Impact of treatment on MPQ and CROM:

Treatment and time were found to interact significantly in a mixed MANOVA ($F = 67.93$, $p < 0.001$, $\eta p^2 = 0.98$). The main impact of time was statistically significant ($F = 1031.05$, $p < 0.001$, $\eta p^2 = 0.99$). A significant main impact of group was observed ($F = 30.32$, $p < 0.001$, $\eta p^2 = 0.92$).

Within group comparison:

In both the study and control groups, there was a significant decline in MPQ and a significant improvement in CROM after treatment compared to before ($P < 0.001$) (Tables 2-3).

Between group comparison:

The MPQ showed a significant decline in the study group after treatment when compared to the control group ($p < 0.05$). (Table 4). Also, post-treatment assessments showed significant improvement in CROM (flexion, extension, side bending, and rotation) in the study group compared with the control group ($p < 0.01$). (Table 5)

Table 2. Comparison of MPQ and CROM between pre-treatment and post-treatment for study group.

Outcome	Pre-treatment vs post-treatment		
	MD	95% CI	p-value
MPQ	29.2	27.85: 30.55	0.001
CROM (degrees)			
Flexion	-27.16	-29.36: -24.96	0.001
Extension	-24.92	-28.57: -21.27	0.001
Right bending	-8.92	-10.06: -7.78	0.001
Left bending	-11.04	-12.70: -9.38	0.001
Right rotation	-16.28	-18.60: -13.96	0.001
Left rotation	-21.84	-24.15: -19.53	0.001

MD, mean difference; CI, confidence interval; p-value, probability value

Table 3. Comparison of MPQ and CROM between pre-treatment and post-treatment for control group.

Outcome	Pre-treatment vs post-treatment		
	MD	95% CI	p-value
MPQ	27.04	25.69: 28.39	0.001
CROM (degrees)			
Flexion	-14.24	-16.44: -12.04	0.001
Extension	-16.88	-20.53: -13.23	0.001
Right bending	-6.68	-7.82: -5.54	0.001
Left bending	-6.96	-8.62: -5.30	0.001
Right rotation	-9.68	-12.00: -7.36	0.001
Left rotation	-13.28	-15.59: -10.97	0.001

MD, mean difference; CI, confidence interval; p-value, probability value

Table 4. Comparison of MPQ between groups.

Outcomes		Study group	Control group	MD	95% CI	p-value	ηp^2
		Mean ± SD	Mean ± SD				
MPQ	**Pre-treatment**	35.56 ± 3.16	36.08 ± 3.09	-0.52	-2.30: 1.26	0.56	0.007
	Post-treatment	6.36 ± 1.55	9.04 ± 1.17	-2.68	-3.46: -1.90	0.001	0.49

SD, standard deviation; MD, mean difference; CI, confidence interval; p-value, probability value; MPQ, The McGill Pain Questionnaire; ηp^2, Partial Eta Squared.

Table 5. Comparison of Cervical Range of Motion (CROM) between groups.

CROM (degrees)		Study group	Control group	MD	95% CI	p-value	ηp^2
		Mean ± SD	Mean ± SD				
Flexion	**Pre-treatment**	36.84 ± 3.52	37.96 ± 4.28	-1.12	-3.35: 1.11	0.32	0.009
	Post-treatment	64.00 ± 5.71	52.20 ± 5.62	11.8	8.58: 15.02	0.001	0.12
Extension	**Pre-treatment**	27.12 ± 6.71	26.24 ± 6.98	0.88	-3.01: 4.77	0.65	0.003
	Post-treatment	52.04 ± 10.46	43.12 ± 9.57	8.92	3.22: 14.62	0.003	0.29
Right bending	**Pre-treatment**	31.20 ± 3.95	30.68 ± 4.48	0.52	-1.88: 2.92	0.66	0.004
	Post-treatment	40.12 ± 3.24	37.36 ± 3.25	2.76	0.91: 4.61	0.004	0.10
Left bending	**Pre-treatment**	30.72 ± 4.19	31.20 ± 3.06	-0.48	-2.56: 1.60	0.65	0.01
	Post-treatment	41.76 ± 3.38	38.16 ± 3.22	3.6	1.72: 5.48	0.001	0.09
Right rotation	**Pre-treatment**	47.00 ± 8.84	46.12 ± 9.14	0.88	-4.23: 5.99	0.73	0.001
	Post-treatment	63.28 ± 8.94	55.80 ± 10.49	7.48	1.94: 13.02	0.009	0.24
Left	**Pre-treatment**	45.56 ± 7.18	46.16 ± 9.38	-0.6	-5.35: 4.15	0.80	0.002

rotation	**Post-treatment**	67.40 ± 9.88	59.44 ± 10.82	7.96	2.07: 13.85	0.009	0.11

SD, standard deviation; MD, mean difference; CI, confidence interval; p-value, probability value; CROM, Cervical Range of Motion; ηp^2, Partial Eta Squared.

4. DISCUSSION:

The current study was done to examine and analyze the impact of ECPTP in combination with MPI versus multimodal physiotherapy intervention alone in patients with cervical sensorimotor control dysfunction. The findings of the current study demonstrated a significant improvement in Cervical Range of Motion (CROM) values and reduction in McGill Pain Questionnaire (MPQ) scores across the two groups following the intervention. The group that underwent the eye-cervical proprioceptive training program (ECPTP) exhibited significantly greater improvement than the control group in terms of pain intensity and cervical range of motion (ROM).

The proposed mechanism by which the eye-cervical proprioceptive training program reduces pain sensation in the cranio-cervical muscles involves enhancing muscle spindle function and improving eye-head coordination, which in turn enhances proprioception [18]. The improvement in cervical proprioception can be attributed to eye-cervical proprioceptive training program's facilitation of proprioceptive inputs, which aids in the autonomic control of cervical muscle posture and tone [19].

The eye-cervical proprioceptive training approach contributes to decreasing cervical disability through the enhancement of the contractile capability of the cervical deep flexor muscles [20]. The highest density of motor receptors is seen in these muscles. Additionally, it is known that these muscles play a special role in reflex and central connections to the ocular, vestibular, and postural control systems 21. As a result, these muscles play a key role in maintaining head posture and coordinating specific movements of the cervical spine, thereby enhancing overall neck function [22].

Moreover, the eye-cervical proprioceptive training program improves the transmission of sensory information from the cervical region to the central nervous system. This is achieved through specific contractions of cranio-cervical muscles, which are rich in muscle spindles, ultimately leading to an increase in cervical range of motion [23].

The results of the current study come in agreement with Canli et al.[24] who conducted a study to compare the effects of tactile discrimination training (TDT) and oculomotor exercises (OEs) on pain outcomes in individuals with chronic neck pain, aiming to determine which intervention was more effective. Their results showed that OEs were the most beneficial in reducing pain intensity, followed by TDT, when compared to a control group. The difference in effectiveness may be due to the distinct mechanisms of each intervention: TDT primarily targets the sensory dimension of pain, while OEs influence both sensory and motor components.

Moreover, Abdel-Aal et al.[25] examined the impact of integrating eye-cervical re-education exercises (ECRE) and motor imagery therapy (MIT) with standard physical therapy (CPT) in patients suffering from chronic neck pain (CNP). The findings indicated that ECRE was superior to both MIT and conventional therapy alone in decreasing pain intensity and improving cervical range of motion in all directions.

According to Izquierdo et al.[18] the pain-reducing effects of the ECRE program on cranio-cervical muscles may be linked to its ability to enhance muscle spindle activity and optimize eye-head coordination, thereby improving proprioception. Additionally, Jull et al.[19] suggest that the enhancement of cervical proprioception is likely due to the program's role in stimulating proprioceptive input, which supports the autonomic regulation of cervical muscle tone and posture.

Additionally, Reddy et al.[26] compared the effectiveness of eye-head coordination exercises and isometric strengthening exercises in individuals with chronic neck pain (CNP). The group performing eye-head coordination exercises showed significantly greater reductions in cervical disability and pain intensity than the control group. However, the study was limited by the implementation of the ECRE as an unsupervised home-based program, and adherence to the exercise protocol was not monitored.

Also, the findings of the current study align with those of Pérez-Cabezas et al.[7] who conducted a randomized controlled trial involving 44 patients with chronic neck pain (CNP) undergoing nine sessions of intervention. Their results demonstrated that the group receiving ECRE combined with traditional physical therapy showed a more significant decrease in pain intensity and improvement in cervical range of motion across all directions compared to those receiving only conventional physical therapy.

Perez-Cabezas et al.[27] evaluated the impact of an Eye-Reeducation Program on individuals with chronic neck pain. The results demonstrated that the program was effective in significantly decreasing pain levels and enhancing cervical range of motion across all directions.

In a study conducted by Balbaa and Ayad[28] the effectiveness of an eye-head coordination rehabilitation program was assessed in individuals with chronic neck pain (CNP). The results indicated a statistically significant reduction in neck pain and disability scores in both the experimental and control groups, with the experimental group demonstrating more substantial improvements. However, the study's conclusions were limited by a small sample size of 40 participants.

Humphreys & Irgens[29] revealed a positive effect of eye-head coordination exercises on reducing pain intensity and enhancing the disability of cervical muscles in CNP patients, which agreed with our study results.

Also, these results align with an earlier study by Revel et al.[30] which compared an oculomotor exercise program to conventional treatment and found the oculomotor exercises to be more effective in lowering pain intensity.

Moreover, Hürer and Erden[31] conducted a study to evaluate the impact of combining oculomotor exercises with a traditional physiotherapy program on pain intensity and range of motion (ROM). Their findings indicated that both the oculomotor exercises and the conventional physiotherapy methods produced similar effects on reducing pain. This may be attributed to the use of the Numeric Pain Rating Scale, which is unidimensional and highly subjective, unlike the McGill Pain Questionnaire used in our study, which is multidimensional and offers a more comprehensive assessment by integrating both subjective and objective components.

However, while both groups showed significant improvements in intra-group ROM, the greatest enhancement was seen in the group that performed oculomotor exercises. Notably, improvements in rotational movements were more pronounced in the oculomotor exercise group compared to the group receiving only classical physiotherapy. This may be due to the use of a Bubble Inclinometer, which measures cervical flexion-extension and lateral bending in a seated position, while assessing left and right rotation in a supine, more relaxed posture. In contrast, our study used the CROM3 device, which evaluates all cervical movements from a seated position.

In contrast to the present study's findings, previous research by Lluch et al. and Bobos et al.[32,33] reported no significant benefits of cervical re-education programs on neck pain. Lluch et al.[32] found no meaningful reduction in cervical pain, which may be attributed to their single-group design, a limited sample size of 30 participants, and the absence of eye-focused rehabilitation exercises in their intervention. Additionally, their results were based solely on within-group comparisons, lacking a control group for reference.

Similarly, Bobos et al.[33] observed no effect of cervical re-education exercises on muscular neck pain in individuals with chronic neck pain (CNP). The discrepancies between their findings and those of the current study may be due to methodological differences and the exclusion of eye rehabilitation from the intervention.

LIMITATIONS

There is a lack of long-term follow-up to evaluate how long the achieved outcomes last. Assessing results over these extended periods can offer clinicians and researchers a more comprehensive understanding of the sustained effectiveness of treatment. Additionally, Conditions like whiplash could be considered for prospective inclusion, because affected patients frequently have more severe disturbances in eye-cervical proprioception. Additional clinical tests regarding cervical proprioception, like the cranio-cervical flexion test or joint position error, could be interesting for inclusion as well.

CLINICAL IMPLICATION

Eye-cervical proprioceptive training program along with multimodal physiotherapy should be incorporated in cervical sensorimotor control dysfunction subjects. When utilized daily in clinical practice, ECPTP may significantly reduce the severity of pain with minimal effort, cost, and require less time and improve cervical mobility in cervical sensorimotor control dysfunction subjects.

Additionally, it can be utilized to enhance the quality of life for those suffering from cervical sensorimotor control dysfunction.

5. CONCLUSION:

The combination of Eye-Cervical proprioceptive training Program (ECPTP) with multimodal physiotherapy appears to be a superior intervention for enhancing CROM and reducing neck pain in patients with sensorimotor dysfunction. These results underscore the necessity of incorporating proprioceptive and sensorimotor strategies into clinical rehabilitation protocols for cervical sensorimotor control dysfunction.

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