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Neuromuscular Control Exercise Versus Proprioception Training in Patients with Chronic Mechanical Neck Pain

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ABSTRACT

Background: *Neck pain is a common musculoskeletal disorder, impacting a significant percentage of the worldwide population. Chronic mechanical neck pain is commonly associated with impaired neuromuscular control and proprioceptive deficits, leading to reduced functional performance and quality of life. Targeted exercise interventions, such as neuromuscular control exercises and proprioceptive training, have been proposed to address these dysfunctions and improve clinical outcomes*

Purpose: *The objective of this study was to compare between the impacts of neuromuscular control exercises and proprioceptive training on neck pain (change in Pain pressure threshold "PPT" and Neck disability index "NDI") after interventions in adults with chronic mechanical neck pain.*

Setting: Outpatient Clinic of the Faculty of Physical therapy, Cairo University and Kasr El-Ainy Hospitals, Faculty of Medicine, Cairo University.

Methods: *A total of sixty patients (both male and female), between the ages of 30 and 45, diagnosed with chronic mechanical neck pain were divided evenly into three groups at random (n = 20 per group). Study Group I were given neuromuscular control exercises (NMCE), which included rolling exercises utilizing upper limb patterns bilaterally, in addition to a standardized physiotherapy program.Study Group II underwent proprioceptive training, consisting of neck position sense exercises and self-stretching routines, alongside the same standardized physiotherapy program.Control Group were given only the standardized physiotherapy program without additional interventions.All participants underwent evaluations both prior to and following the intervention period. Outcome measures included the Neck Disability Index (NDI) for functional assessment of neck pain and an algometer to assess pain pressure threshold (PPT).*

Results: *Both the neuromuscular control exercise (NMCE) group and the proprioceptive training group demonstrated significant improvements in pain and disability outcomes. However, the NMCE group showed a more pronounced reduction in pain intensity and disability. Specifically, there was a statistically significant decrease in Neck Disability Index (NDI) scores and a significant increase in pain pressure threshold (PPT) in the NMCE group compared to both the proprioceptive training group as well as the control group ($p < 0.05$) following the intervention. Additionally, the proprioceptive training group exhibited a substantial reduction regarding NDI scores as well as a substantial improvement in PPT compared to the control group ($p < 0.05$) post-treatment.*

Conclusion: *Both neuromuscular control exercises and proprioceptive training were effective in reducing pain and disability in individuals with chronic mechanical neck pain. However, neuromuscular control exercises, when combined with conventional physiotherapy, produced superior outcomes, demonstrating greater improvements in pain pressure threshold along with functional disability compared to proprioceptive training and standard physiotherapy alone.*

Keywords: *Mechanical neck pain, Neuromuscular control exercises, Proprioceptive training, Algometer, Neck disability index, Pain pressure threshold*

INTRODUCTION

Neck pain (NP) is primarily characterized as pain occurring between the superior nuchal line, an imaginary transverse line at the apex of the first thoracic spinous process, extended laterally by sagittal planes adjacent to the lateral boundaries of the neck (Shin et al.,2022). Neck pain can be local, referred to the head, or affect one or both upper limbs. NP can also be classified according to its duration (acute, subacute, or chronic) or cause (Guzman J et al., 2008; Blanpied P et al.,2017).

Neck pain is seen as a significant burden on society. The prevalence in the general population may vary from 16.7% to 75.1%. Reports indicate a significant prevalence among women in urban areas and countries with high income. The office workers, particularly those who use computers, have a high incidence rate (Genebra et al., 2017; Hoy et al.,2010; Verma et al.,2021).

Patients with NP are considered to have mechanical or non-specific symptoms since their patho-anatomical causes are not always obvious (Childs et al.,2008). Mechanical NP typically develops gradually and is usually multifactorial in nature. Identified modifiable factors contributing to the beginning of mechanical NP include smoking, incorrect posture, anxiety, depression, neck strain, along with sporting or occupational activity (Heintz M& Hegedus E et al.,2008).

The physiotherapeutic strategy for addressing mechanical NP encompasses several interventions, including manual therapy, therapeutic exercises, modalities, massage, as well as functional training (Heintz and Hegedus,2008). Many physical therapy programs designed for NP focus on implementing treatments aimed at alleviating pain and stiffness. This may include methods such as Transcutaneous Electrical Nerve Stimulation, interferential therapy, and ultrasound therapy. Once sufficient relief is achieved, patients can initiate an exercise regimen that incorporates strengthening and stretching techniques for the neck, utilizing muscle energy techniques, deep neck flexor training, neck mobilization, ROM exercises, and a home program (Cleland et al.,2016).

Most individuals who experience NP have decreased postural stability along with reduced proprioception, which confuses the afferent signals coming from the neck (Cheng et al.,2010). Neck pain and fatigue of the muscles impair the intrinsic proprioception of the cervical region, while posture additionally influences the functionality of the neck's proprioceptive sense (Reddy et al. 2012; Jung et al. 2012).

Proprioceptive training, which includes stretching of the cervical musculature and exercises targeting neck and joint position sense, is commonly employed in clinical practice for the management of cervical dysfunctions. Stretching interventions are believed to activate proprioceptive receptors by elongating muscles and tendons, thereby helping to prevent muscle atrophy, eliminate metabolic waste products, and enhance overall muscle tissue elasticity. (Lee, 2006; Jeong et al.2017).

Neuromuscular training is a form of physical exercise that emphasizes body control, enhances muscle memory to optimize movement, minimizes the risk of injury, and concurrently boosts performance. Additionally, it supports recovery and rehabilitation by improving proper movement patterns and control (Andrew D.,2023). Numerous prior studies have indicated that neuromuscular control exercises (NSEs) improve NP as well as deep muscle activity (Childs et al., 2008; Ferreira et al., 2006). Furthermore, it has been reported that around 80% of neck-related problems arise from weakness and decreased flexibility in the muscles surrounding the neck as well as the shoulders (Jull et al., 2009).

The aim of this study was to compare the effects of neuromuscular control exercises versus proprioceptive training on neck pain, cervical range of motion (ROM), joint position sense, pain pressure threshold (PPT), and Neck Disability Index (NDI) following intervention in adults with chronic mechanical neck pain.

MATERIALS AND METHODS:

Study design:

This randomized controlled trial was carried out at the Outpatient Clinic of the Faculty of Physical Therapy, Cairo University, and Kasr El-Ainy Hospitals, Faculty of Medicine, Cairo University, from August 2023 to May 2025. Before the initial assessment and recruitment, all participants were provided with a comprehensive overview of the study's objectives, procedures, and potential benefits. Approval for ethical considerations

was secured from the Ethics Committee of the Faculty of Physical Therapy at Cairo University (Approval No.: P.T.REC/012/004315).

Participants:

Sixty patients of both sexes suffering from chronic mechanical NP took part in this study. They were diagnosed based on magnetic resonance imaging (MRI) of the cervical spine and referred to by a neurosurgeon. Participants were randomly assigned into three equal groups (n = 20 per group): Study Group I, Study Group II, and the Control Group. Study Group I received neuromuscular control exercises (NMCE), consisting of rolling movements using upper limb patterns bilaterally, in addition to a standardized physiotherapy program. Study Group II received proprioceptive training, which included neck position sense exercises and self-stretching, along with the same standardized physiotherapy program. Control Group received only the standardized physiotherapy program without any additional interventions.

Inclusion criteria:

Participants were considered suitable for this study based on the subsequent criteria for eligibility, 1) aged from 30 to 45years; 2) patients who had NP within seven days prior to this trial, or who had NP for more than three months throughout the previous year; 3) Patient exhibiting active or latent myofascial trigger points (MTrPs) in at least one of the subsequent muscles: upper trapezius, levator scapulae, or splenius capitis; 4) BMI not exceeding 30.

Exclusion criteria:

The patients were excluded, if Patients experience Pain during upper limb pattern rolling exercises 2) Patient with Cervical fracture, arthritis, tumor, muscle disease, osteoporosis, severe neck instability, radiation pain due to compression of nerve tissue.

Randomization:

Participants were assigned randomly into three equal groups—Study Group I, Study Group II, as well as the Control Group—utilizing a straightforward randomization method. A computer-generated random number table was utilized to allocate 20 patients to each group, thereby ensuring balanced group distribution and reducing selection bias.

Outcome measures:

Measurements of neck pain and disabilities:

The Neck Disability Index (NDI) is the most widely utilized self-report measure for assessing neck pain, and it is also employed to evaluate the patient's status and condition. A questionnaire designed for patients to complete, focusing on specific functional status related to their condition. It consists of 10 items addressing pain, personal care, lifting, reading, headaches, concentration, work, driving, sleeping, as well as recreation. This questionnaire has been developed to gather information regarding the impact of NP on the patient's ability to function in daily life.

(Macdermid et al.,2009;Young et al.,2010).

Measurement of pain pressure threshold:

The pain pressure threshold was assessed with the help of an algometer. Algometry has been defined as "the measurement of pain sensitivity or pain intensity". Algometer applies steady pressure to some area, and determines what level of pressure produces a sensation of pain (Mari Kalland et al.,2014).

Interventions:

All training sessions were supervised and conducted by the same physiotherapist to ensure consistency in treatment delivery. Participants in all three groups—Study Group I (neuromuscular control group), Study Group II (proprioception training group), as well as the Control Group—received a conventional physiotherapy program as part of their intervention. Each participant attended a total of 12 treatment sessions, administered on alternate days, with each session lasting approximately 60 minutes.

Conventional Physiotherapy Intervention:

All participants in the three groups received a standardized physiotherapy program comprising the following components: **Thermal therapy:** Application of hot packs for 10 minutes, **Electrotherapy:** Ultrasound therapy for 3–5 minutes, followed by transcutaneous electrical nerve stimulation (TENS) applied in constant mode

for 15 minutes, **Manual therapy:** Myofascial release techniques performed for 5 minutes, **Exercise therapy: Isometric neck exercises** were administered for 5 minutes, consisting of three sets of 10 repetitions each, with resistance applied for 6–8 seconds per movement. **Stretching exercises** targeting tight cervical and shoulder muscles were performed gently for 3–5 minutes. **Strengthening exercises** were conducted for weak neck, shoulder, and upper back muscles over a duration of 3–5 minutes, **Postural education** was also provided to all participants to promote optimal alignment and reduce strain on cervical structures. (Blanpied P et al.,2017; Corp N et al.,2021).

Neuromuscular control exercises (NMCS):

Neuromuscular control exercises aim to enhance the coordinated movement between the neck and shoulder, improve neuromuscular control of the head, neck, along with core musculature, and faN et al.the early activation of stabilizing muscles. This is accomplished by carrying out upper limb pattern rolling exercises as described by Clark et al. (2017). In this study, neuromuscular control was facilitated using upper limb rolling patterns. Based on the intervention protocol outlined by Barbara et al., the rolling exercises were performed in two different positions: prone-to-supine and supine-to-prone. Five minutes on each side followed by a twenty-second rest interval made up the ten-minute exercise.

Proprioceptive exercises:

Self-stretch:

Stretching activates proprioceptive receptors by stretching tendons as well as muscles, preventing muscle degeneration, eliminating fatigue byproducts, along with enhancing the flexibility of muscular tissue, so alleviating neck pain caused by stiffness (Jeong HM et al.,2017). Self-stretching (SS) of the upper trapezius, levator scapulae, as well as sternocleidomastoid muscles was conducted in both sitting and standing positions. Each set of stretches for both left and right muscles was executed for 30 seconds, with a 30-second rest interval between sets, totaling approximately 3-5 minutes.

Neck position sense training:

Cervical joint position sense refers to the body's ability to perceive the spatial orientation of the neck. Impairments in this proprioceptive function can lead to deficits in posture, balance, and coordinated movement. In this study, joint position sense was trained using a laser pointer repositioning test, as described by Peng et al., 2021.)

Participants were seated in a chair and fitted with a headband-mounted laser pointer. The distance between the subject and the target surface was standardized to 90 cm. While facing forward, the subject's head was aligned so that the center of the laser intersected a designated reference point on the target. With eyes open, participants were instructed to align the laser with a new central target point. Once aligned, they were asked to close their eyes and maintain the position for five seconds to internalize the head position. Subsequently, they performed a maximal left cervical rotation and attempted to go back to the original position. This repositioning task was repeated ten times for left cervical rotation, and the identical procedure was then carried out for right cervical rotation.

STATICAL ANALYSIS:

An ANOVA test was performed to compare subject characteristics among groups. A chi-squared test was performed to compare the sex distribution among groups. The Shapiro-Wilk test was employed to assess the normal distribution of the data. Levene's test for homogeneity of variances was performed to assess the homogeneity of variances among groups. A mixed MANOVA was conducted to evaluate the within-group as well as between-group effects on NDI, PPT, CROM, as well JPE. Post-hoc analyses employing the Bonferroni correction were conducted for subsequent multiple comparisons. The significance criterion for all statistical tests was established at $p < 0.05$. All statistical analyses were performed using the Statistical Package for Social Sciences (SPSS) Version 25 for Windows (IBM SPSS, Chicago, IL, USA).

RESULTS:

1-Participant characteristics:

Sixty patients suffering from chronic mechanical NP took part in this study. Table (1) presents the baseline demographic characteristics of the neuromuscular control exercise group (Group A), the proprioceptive training group (Group B), and the control group (Group C). No statistically substantial differences were noted among the groups regarding age, weight, height, BMI, or sex distribution ($p > 0.05$), indicating homogeneity across the study groups at baseline.

Table 1. Demographic data of participants.

	Group A	**Group B**	**Group C**	**p-value**
	mean ± SD	mean ± SD	mean ± SD	
Age (years)	36.85 ± 4.03	38.75 ± 4.62	37.25 ± 4.63	0.93
Weight (kg)	72.10 ± 7.68	70.95 ± 7.39	70.45 ± 10.88	0.73
Height (cm)	166.85 ± 6.30	167.95 ± 7.13	168.15 ± 7.33	0.33
BMI (kg/m²)	25.92 ± 2.55	25.17 ± 2.37	24.81 ± 2.59	0.81
Sex, N (%)				
Females	9 (45%)	11 (55%)	12 (60%)	0.63
Males	11 (55%)	9 (45%)	8 (40%)	

2-Effect of treatment on NDI as well as PPT:(

-Within group comparison:

As presented in Table (2), all three groups demonstrated a statistically significant decrease in Neck Disability Index (NDI) scores and a significant increase in pain pressure threshold (PPT) following the intervention compared to their respective pre-treatment values ($p < 0.001$).

-Between group comparisons:

As shown in Table (2), the neuromuscular control exercise (NMCE) group demonstrated a statistically substantial decrease regarding NDI scores and a significant increase in pain pressure threshold (PPT) compared to both the proprioceptive training group as well as the control group ($p < 0.05$) following the intervention. Additionally, the proprioceptive training group showed a substantial reduction regarding NDI scores as well as a substantial improvement regarding PPT when compared to the control group ($p < 0.05$) post-treatment.

Table.2. Mean NDI and PPT pre and post treatment of group A(NMCS), group B (Proprioception) and group C (control):

	Group A	**Group B**	**Group C**
	mean ± SD	mean ± SD	mean ± SD
NDI			
Pre treatment	17.10 ± 1.59	16.60 ± 1.67	16.30 ± 1.49
Post treatment	9.50 ± 1.70	11.95 ± 1.90	13.75 ± 2.05
MD (95% CI)	7.60 (6.80: 8.40)	4.65 (3.85: 5.45)	2.55 (1.75: 3.35)
	p = 0.001	p = 0.001	p = 0.001
PPT (kg/cm²)			
Pre treatment	2.19 ± 0.27	2.28 ± 0.29	2.22 ± 0.37
Post treatment	2.94 ± 0.30	2.65 ± 0.35	2.38 ± 0.36
MD (95% CI)	-0.75 (-0.80: -0.69)	-0.37 (-0.43: -0.32)	-0.16 (-0.21: -0.10)
	p = 0.001	p = 0.001	p = 0.001

DISCUSSION:

The present study was carried out to investigate and analyze the effect of neuromuscular control exercise

versus proprioception training among patients having chronic mechanical NP, in addition to determine the best effective approach to improve neck pain in patients having mechanical NP. The findings of the current study demonstrated that, traditional physical therapy program solely may be not sufficient to improve neck pain in chronic mechanical neck pain patients. Neuromuscular control exercises, when combined with a traditional physiotherapy program, led to in substantial improvements in NP as well appeared to be a more effective approach for managing symptoms among patients having chronic mechanical NP. The findings of the current study demonstrated a substantial reduction in NDI scores across all three groups following the intervention. However, the neuromuscular control exercise (NMCE) group showed superior improvement compared to both the proprioception (self-stretching) group and the control group.

These findings are consistent with those of Jae-Doo Lee and Won-Seob Shin (2020), who reported a significant effect of neuromuscular control exercises (NMCE) on NDI scores across all comparison groups ($p < 0.01$). Similarly, Amrutha S. et al. (2024) found that NMCE led to significant reductions in both NDI scores and pain levels in patients with nonspecific neck pain. Additionally, the results align with the study by Yu-Yun Huang et al. (2021), which demonstrated that a 6-week NMCE program significantly improved NDI scores and pain among patients having chronic NP when contrasted with to other exercise interventions.

These findings are in line with the findings of Hwang et al. (2012), who emphasized that stretching is one of the most essential and effective approaches for managing joint contractures and pain. In the present study, all three groups demonstrated substantial enhancements regarding pain pressure threshold (PPT) following the intervention. However, the neuromuscular control exercise (NMCE) group exhibited greater improvement compared to both the proprioception (self-stretching) group and the control group.

This finding is further supported by E. Kosek et al. (2013), who suggested that neuromuscular control exercises can positively influence PPT by increasing it, thereby indicating a reduction in pain sensitivity.

Previous studies have shown that neuromuscular exercises, particularly those aimed at enhancing dynamic stability and motor control, can lead to an increase in pain pressure threshold (PPT). This indicates that after such procedures, a greater amount of pressure is necessary to provoke a pain response, signifying a decrease in pain sensitivity. The findings of the present study are also partially in agreement with Samuel et al. (2023), who reported that proprioceptive exercises may contribute to improved PPT by enhancing the body's ability to sense joint position and movement, thereby modulating pain perception.

Furthermore, stretching exercises have also been found to influence pain pressure thresholds. Research suggests that static stretching, in particular, can lead to a temporary elevation in PPT, increasing an individual's tolerance to pain. This supports the notion that all three interventions—neuromuscular control, proprioceptive training, and stretching—have the potential to positively affect pain sensitivity, with neuromuscular control exercises demonstrating the most pronounced effect in the present study.

However, the findings of the current study are not universally supported in the literature. For instance, Ylinen et al. (2010) reported that strength and endurance training, rather than neuromuscular control exercises, had a more substantial effect on reducing neck pain and disability in patients with chronic neck pain. Their findings indicated that motor control exercises, when used alone, did not demonstrate a significant advantage over conventional physiotherapy in enhancing clinical outcomes. Similarly, Kay et al. (2012), in a systematic review, concluded that while various exercise approaches can be beneficial, there was insufficient evidence to support the superiority of neuromuscular control exercises over other forms of therapeutic exercise, including stretching or proprioceptive training, in improving neck pain or disability scores.

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