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The Effects of Combined Cervical and Scapular Stabilization Exercises on Muscle Tone, Pain, and Cervical Range of Motion in Cervical Extension Type: A Controlled Experimental Study

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Abstract: Background: The prolonged use of smartphones may lead to cervical posture deformities and other associated issues. Among these conditions, cervical extension type is one of the most commonly observed, characterized by increased cervical lordosis, forward head posture, and thoracic kyphosis. These biomechanical changes may lead to neck pain, a restricted range of motion (ROM), and heightened cervical muscle tone. The purpose of this study was to evaluate the impact of combining cervical stabilization exercises with either scapular stabilization or thoracic exercises on the mechanical properties of cervical muscles, the pressure pain threshold (PPT), and the ROM in individuals with cervical extension type. Methods: This study included 32 subjects with cervical extension type who were randomly divided into two groups: 16 subjects were placed in either the cervical and scapular stabilization exercises group (CSG) or the cervical stabilization with thoracic exercises group (CTG). After four weeks of exercise intervention, the following assessments were conducted: measurement of muscle tone, stiffness, and elasticity of the sternocleidomastoid (SCM) and upper trapezius (UT) muscles using Myoton PRO; evaluation of the PPT of the SCM and UT muscles using a pressure pain threshold meter; and assessment of cervical ROM (extension, flexion, and rotation) using motion analysis equipment. Results: Both groups showed significant differences in muscle tone, stiffness, elasticity, PPT, and cervical ROM ($p < 0.05$). The PPT of the UT muscle was significantly improved in the CSG compared to the CTG ($p < 0.05$). Conclusions: There were significant improvements in muscle tone, stiffness, elasticity, pain, and cervical ROM after exercise intervention in both groups of subjects with cervical extension. Cervical stabilization exercises, along with scapular stabilization, have better effects on improving UT muscle pain.

Keywords: cervical extension type; cervical stabilization; muscle tone; muscle elasticity; muscle stiffness

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1. Introduction

The rapid advancement of technology has led to a substantial increase in the use of computers, laptops, and mobile electronic devices such as smartphones and tablets [1]. The prolonged maintenance of such static postures leads to sustained contractions of the head and neck muscles, abnormal postures, and potential cervical posture deformations and associated issues [1–3]. Previous studies have classified various cervical problems,

including cervical extension, cervical flexion, cervical rotation, cervical extension rotation, and cervical flexion rotation [4,5]. Among these conditions, the most common issue is cervical extension type, which is often accompanied by an increased forward curvature of the cervical spine, a forward head posture, posterior spinal curvature, an asymmetrical head posture, asymmetrical oblique muscles in the neck region, and downward rotation of one scapula [4]. These alterations can lead to sustained pressure on the cervical spinal curve, which may result in degenerative changes in the joints, neck pain, and a reduction in the cervical ROM [6,7]. Cervical ROM refers to the ability of the cervical spine to move in directions such as flexion, extension, lateral flexion, and rotation; a reduction in ROM can lead to discomfort, pain, and limitations in daily function [8].

The forward positioning of the head and upper cervical region shifts the gravitational center (the head) in front of the load-bearing axis, thereby lengthening the external moment arm [9], and prolonged exposure to load on the craniovertebral extensor muscles and non-contractile structures disrupts biomechanical movements, resulting in increased stress that may cause musculoskeletal damage and pain [9,10]. To quantify the pain sensitivity associated with these musculoskeletal changes, PPT is often used, referring to the minimum force applied to a muscle that elicits a pain response, serving as an objective indicator of myofascial pain sensitivity [11]. Furthermore, some studies suggest that increased muscle tone and stiffness can lead to neck pain, which can limit the cervical ROM [12,13].

Under static conditions and while sitting, cervical spine loads are significantly greater than those experienced when performing head movements [14]. Consequently, this leads to increased muscle tension and stress in the neck and shoulder regions [15] and heightened tone and stiffness, along with reduced elasticity of the myofascial tissue, in the descending portion of the trapezius muscles [16]. Decreased elasticity induces faster muscle fatigue, thereby limiting movement speed [17].

Research indicates that cervical stabilization exercises strengthen spinal stabilizer muscles, improve their endurance and coordination, alleviate neck pain, and enhance cervical functionality [18]. Cervical stabilization exercises include muscle strengthening exercises and stretching exercises, and the latter in particular have been shown to increase muscle length and elasticity, while reducing stiffness and modifying muscle tone [19,20]. Effective methods to increase cervical ROM include thoracic extension exercises, scapular stabilization exercises, and specific cervical exercises [21]. Cervical stretching exercises can increase muscle length or muscle flexibility and reduce pain symptoms [22]. The scapula, often described as a key connection between the cervical spine and shoulder, is essential for providing both mobility and stability to the neck and shoulder [23]. Scapular stabilization exercises can help alleviate pain and improve posture in individuals with neck pain by enhancing and normalizing muscle function, ultimately contributing to an improved quality of life [24]. Stretching exercises during scapular stabilization exercise can also reduce cervical and shoulder muscle tone and stiffness, improve pain, and increase ROM [25].

One study suggests a biomechanical inter-relationship between the cervical and thoracic regions, with changes in thoracic curvature influencing cervical alignment and function [26]. For instance, increased thoracic kyphosis is associated with cervical flexion, which leads to changes in cervical posture, and individuals with cervical dysfunction often exhibit more pronounced thoracic kyphosis. This increased kyphosis is significantly correlated with neck pain and can impact cervical ROM [6]. The biomechanical interactions between the cervical and thoracic spine also play a crucial role in movement and are significant contributors to neck pain [27]. Studies have found that thoracic spine stretching exercises can improve neck and shoulder pain and thereby increase the ROM of the neck and shoulders [28,29].

Cervical stabilizing, scapular stabilizing, and thoracic exercises have been widely studied to address cervical issues such as forward head posture [29–31], with previous research showing that combining cervical stabilization exercises with either scapular or thoracic stabilization exercises positively impacts neck problems [32,33]. Despite the growing body of research on cervical spine disorders, there is limited understanding of the comparative effectiveness of scapular versus thoracic exercises in treating cervical extension type conditions. This study aims to determine whether combining cervical stabilization exercises with scapular exercises is more effective than combining them with thoracic exercises for improving the muscle's mechanical properties, the PPT, and the cervical ROM in individuals with cervical extension type. By focusing on this specific comparison, this study contributes to a deeper understanding of the effectiveness of these interventions in treating cervical extension type.

2. Materials and Methods

Subjects

This study was conducted with subjects who attended Daegu University in Gyeongsan, South Korea, who had cervical extension. Prior to participation, all subjects were required to read and sign the university-approved consent form for human subjects. The experiment was conducted only after obtaining approval from the Institutional Review Board of Daegu University (IRB number: 1040621-202401-HR-014).

Inclusion criteria: If the test subject met the following criteria, they were classified as having the relevant cervical extension type:

(1) Craniovertebral angle (CVA): Individuals were required to have a CVA $\leq 53^{\circ}$ [1];
(2) Cranial rotation angle (CRA): Individuals were required to have a CRA $\geq 143^{\circ}$;
(3) Individuals were required to have pain during cervical extension or flexion;
(4) Cervical ROM: Individuals were required to have a ROM with extension $\leq 70^{\circ}$ and flexion $\leq 40^{\circ}$;
(5) Weakening of the deep cervical flexor muscle: When the subjects were lying supine, strength testing of the deep cervical flexor (DCF) was performed using a pressure biofeedback unit [34], and failure to maintain this strength for 30 s was considered a weakening of the DCF;
(6) Cervical extension test: In the seated position, the cervical extension test demonstrates posterior translation more prominently than posterior rotation in the sagittal plane.

Exclusion criteria included a history of traumatic cervical spine injuries, inflammatory arthropathy, infectious spondylitis, severe osteoporosis, cervical disc protrusion, cervical spine fractures or dislocations, previous cervical surgery, and intractable migraines.

3. Experimental Procedure

3.1. Study Participants

A preliminary experiment was conducted prior to the main study, and a power analysis was performed using G*Power (Version 3.1, Heinrich Heine University Düsseldorf, Düsseldorf, Germany) to determine the required sample size for detecting a large effect size with a statistical power of 0.80 and an alpha level of 0.05. The power analysis was based on a 2-way repeated measures ANOVA design, which accounts for both between-subject and within-subject factors. Based on the sample size calculation, a minimum of 30 participants (15 per group) was required to achieve an adequate statistical power. However, to account for potential participant dropout or non-compliance, a total of 32 participants (16 per group) were recruited. The participants were assigned to the CSG (n = 16) or CTG (n = 16) group using a randomization procedure.

The randomization was carried out by an administrator who was blinded to the study procedures and not involved in the experiment. The randomization method involved selecting one of two colored ping pong balls (yellow or white) from a sealed opaque container to ensure a 50% chance of assignment to each group. The participants were assessed by the same assessors before and after the intervention. The assessors were blinded to the group allocation during the post-treatment assessment. To maintain blinding, the assessors were not informed of the participants' group until after data collection was completed.

All exercises were supervised by professional physical therapists who had studied physical therapy for many years, with a deep knowledge of the field. The experimental protocols were collaboratively developed and refined by a team of experienced physical therapists to ensure consistency and accuracy in the intervention. An adverse event monitoring protocol was implemented throughout the study. Participants were instructed to immediately report any discomfort, pain, or health issues, at which point the study could be terminated.

3.2. Cervical Stabilization Exercises

The cervical stabilization exercises included three components: muscle stretching, muscle strengthening, and postural correction exercises. The exercise protocol was adapted from various studies [18,32,33]. The program consisted of two phases: Phase 1 (Weeks 1–2) involved moderate-intensity exercises, and Phase 2 (Weeks 3–4) gradually increased the intensity to help participants better adapt to the higher exercise demands. Each session lasted 40 min and was held three times per week, with 3 sets of 15 repetitions per exercise, each held for 30 s, with 3 min of rest between sets (Figure 1).

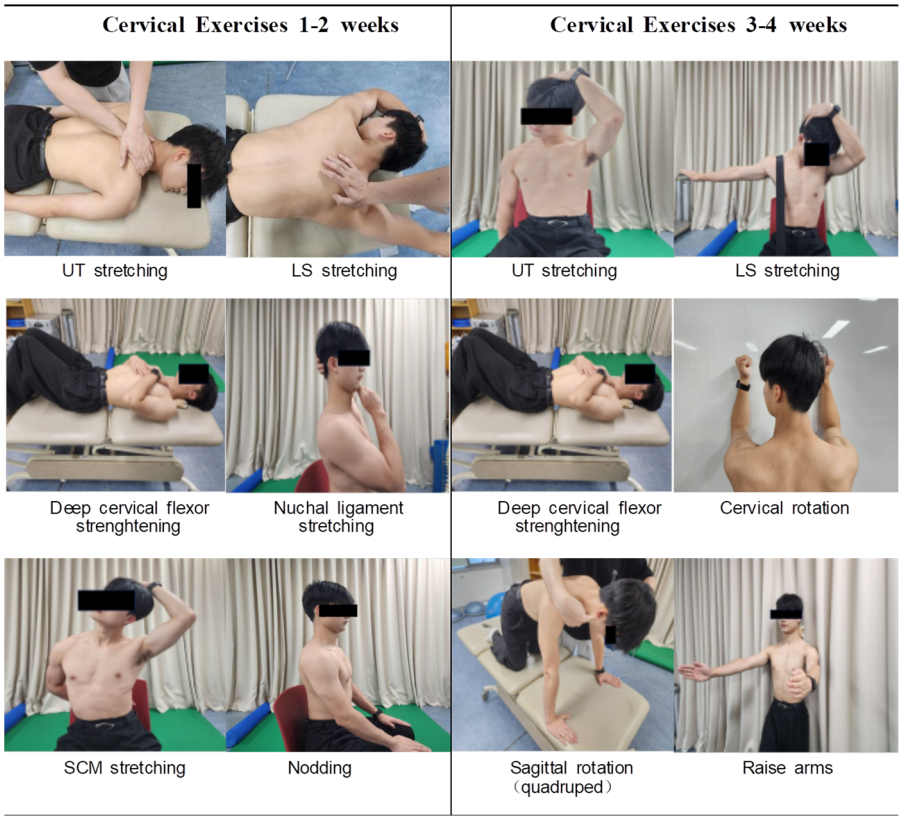


Figure 1. Cervical stabilization exercises: muscle stretching, muscle strengthening, and postural correction exercises.

3.3. Scapular Stabilization Exercises

The scapular stabilization exercises comprised three components: muscle stretching exercises, muscle strengthening exercises, and postural correction exercises. The motion method used in this study was compiled and modified from the motion methods of various studies [4,29,32,35]. The program consisted of two phases: Phase 1 (Weeks 1–2) involved moderate-intensity exercises, and Phase 2 (Weeks 3–4) gradually increased the intensity to help participants better adapt to the higher exercise demands. Each session lasted 40 min and was held three times per week, with 3 sets of 15 repetitions per exercise, each held for 30 s, with 3 min of rest between sets (Figure 2).

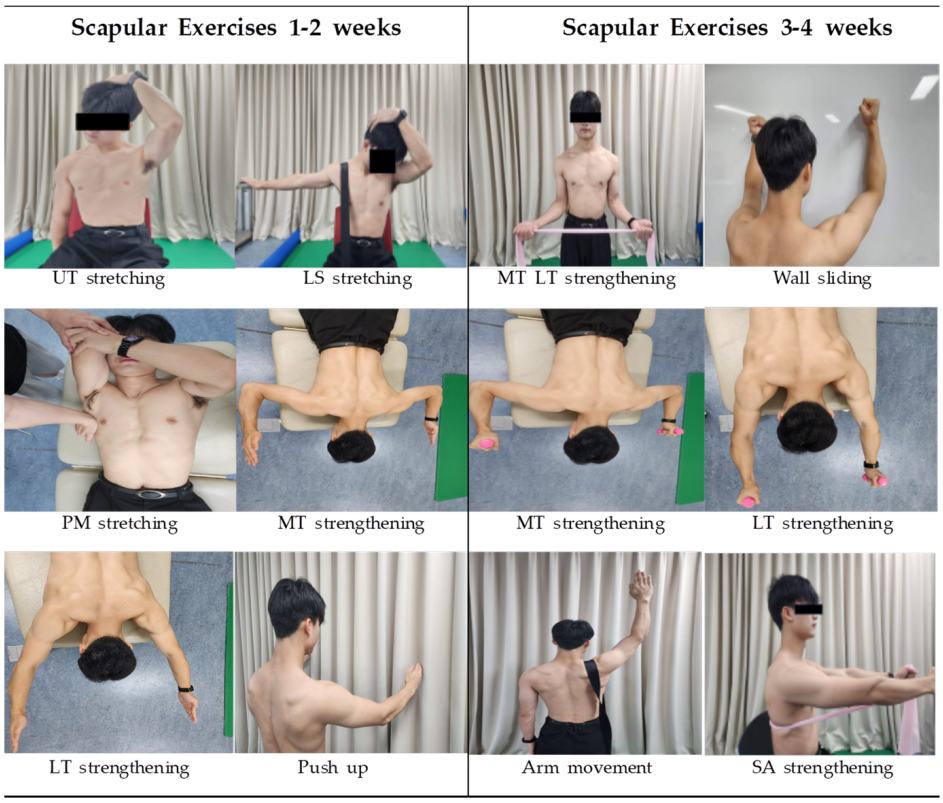


Figure 2. Scapular stabilization exercise: muscle stretching, muscle strengthening, and postural correction exercises.

3.4. Thoracic Exercises

The thoracic exercises comprised three components: muscle stretching, muscle strengthening, and postural correction exercises. The motion method used in this study was compiled and modified from the motion methods of various studies [2,36]. The program consisted of two phases: Phase 1 (Weeks 1–2) involved moderate-intensity exercises, and Phase 2 (Weeks 3–4) gradually increased the intensity to help participants better adapt to the higher exercise demands. Each session lasted 40 min and was held three times per week, with 3 sets of 15 repetitions per exercise, each held for 30 s, with 3 min of rest between sets (Figure 3).

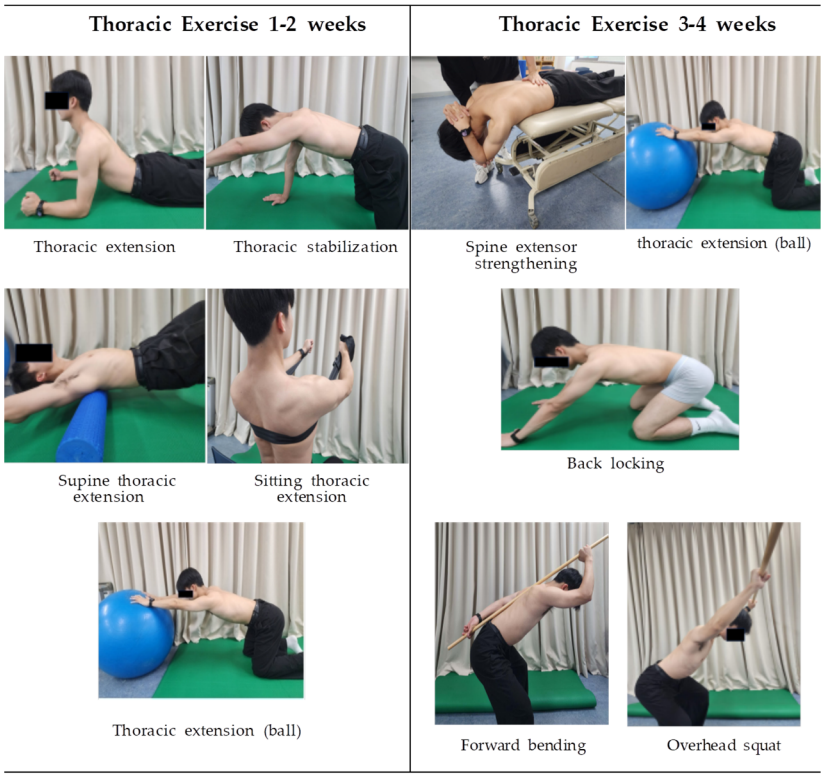


Figure 3. Thoracic exercises: muscle stretching, muscle strengthening, and postural correction exercises.

4. Measuring Methods

4.1. Measurement of Mechanical Properties

The Myoton PRO (Myoton AS, Tallinn, Estonia) was used to assess muscle tone, stiffness, and elasticity, and it has been shown to be effective for evaluating the mechanical properties of muscles such as the SCM and UT, with established reliability and validity in previous studies [37]. The device measures three biomechanical parameters: frequency (F, Hz), representing muscle tone; stiffness (S, N/m), indicating resistance to deformation; and decrement (D), reflecting elasticity. Muscle tone (Hz) is defined as the maximum frequency of oscillation in myofascial tissue, muscle stiffness (N/m) as the resistance of myofascial tissue to external forces causing deformation, and elasticity (D) as the tissue's ability to restore its shape and dissipate mechanical energy, with a lower D value indicating higher elasticity [38,39].

Measurements were conducted by vertically compressing the muscle until the device's indicator light turned green. Each measurement consisted of three taps lasting 15 ms, and the average value was determined [40]. The device was held upright, with hands firmly supported to maintain a perpendicular alignment of the probe to the muscle. Measurements were performed on the UT muscle in a seated position and the SCM muscle in a supine position [37].

4.2. Measurement of Muscle Pressure Pain Threshold

The PPT, defined as the minimum force eliciting a pain response, was measured using pressure algometers designed to assess myofascial pain sensitivity by evaluating deep pressure pain thresholds or tenderness resistance [41,42]. Research has shown that pressure algometers(Commander Algometer, JTECH Medical, Salt Lake City, UT, USA) provide consistent and reproducible measurements, making them valuable for evaluating pain

sensitivity in both healthy individuals and patients with chronic pain conditions, thereby supporting their use in clinical and research settings [42,43].

Using a pressure algometer with a 1 cm^2 probe, gradual pressure was applied to the skin until participants reported the initial perception of pain, at which point the investigator immediately removed the algometer, and the maximum pressure recorded was noted as the PPT value [44]. Measurements were conducted three times per muscle, with 5 min intervals between trials [45]. Measurements for the UT and SCM muscles were performed in a seated position, with the SCM measurement point located at the midpoint of the muscle at the level of C4 [46].

4.3. Measurement of Cervical ROM

Cervical ROM, including extension, flexion, and rotation, was assessed before the treatment program using motion analysis equipment (4D-MT, Busan, Delivery, Republic of Korea) specifically designed for cervical spine mobility evaluation. The device used is reliable for measuring cervical ROM, ensuring accurate and consistent results. All assessments began with participants in a neutral head posture, and instructions were supplemented with a demonstration for consistency [47,48]. All assessments began with participants in a neutral head posture, and instructions were supplemented with a demonstration for consistency.

5. Statistical Analysis

The Kolmogorov–Smirnov test was used to verify the normality of the distribution. Paired *t*-tests were applied to assess within-group differences and pre- to post-intervention changes. A two-way repeated measures ANOVA was used to examine the main effect of time and the effect of the interaction between groups and time on the outcome. When significant main effects or interactions were identified, post hoc pairwise comparisons were conducted. To adjust for multiple comparisons, Bonferroni correction was applied, adjusting the significance threshold ($\alpha = 0.05$) by dividing it by the number of comparisons made. The partial eta squared was considered as the effect size and interpreted as follows: 0.01 (small effect), 0.06 (medium effect), and 0.14 (large effect). Statistical analyses were conducted using SPSS (version 27.0, IBM, Armonk, NY, USA), with a significance threshold set at $p < 0.05$. The analyses were carried out by someone uninformed of the group assignment and not involved in the experimental intervention.

6. Result

A total of 32 subjects were enrolled in this study and were assigned to either the CSG or the CTG. No statistically significant differences were observed between the general characteristics of the two groups (Table 1).

Table 1. Subject characteristics ($n = 32$).

	CSG	CTG	t (*p*)	LCI, UCI
Age (year)	23.25 ± 1.65	23.50 ± 3.18	−0.279 (0.782)	−2.1, 1.6
Sex (female/male)	9/7	8/8	−0.344 (0.733)	−0.4, 0.3
Height (cm)	171.81 ± 7.18	167.75 ± 7.30	1.588 (0.123)	−1.2, 9.3
Weight (kg)	65.50 ± 11.47	62.69 ± 11.23	0.701 (0.489)	−5.4, 11.0
BMI (kg/m^2)	22.10 ± 2.88	22.32 ± 4.03	−0.177 (0.861)	−2.7, 2.3

Values are expressed as means ± SD. CSG: cervical stabilization and scapular stabilization exercises group; CTG: cervical stabilization and thoracic exercises group; BMI: body mass index; LCI and UCI: lower and upper (95%) confidence interval.

All groups showed significant differences in the SCM and UT muscle tone, stiffness, and elasticity; the PPT; and the cervical ROM ($p < 0.001$) (Tables 2–4).

Table 2. Change in muscle mechanical properties in the two groups (unit: F: HZ S: N/m) ($n = 32$).

			Pre	Post	t (p)	Time F (p)	LCI, UCI	Group × Time F (p)
SCM	F	CSG	14.08 ± 1.77	12.89 ± 1.27	4.356 (0.001 *)	43.74 (<0.001 *)	−1.399, −0.739	0.56 (0.460)
		CTG	13.18 ± 1.26	12.24 ± 1.36	5.484 (0.000 *)			
		η^2				0.593		0.018
	S	CSG	224.71 ± 38.09	188.33 ± 27.07	5.886 (0.001 *)	85.13 (<0.001 *)	−40.891, −26.070	0.64 (0.431)
		CTG	233.52 ± 26.24	202.94 ± 22.53	8.039 (0.000 *)			
		η^2				0.739		0.021
	D	CSG	1.26 ± 0.22	1.16 ± 0.18	3.880 (0.001 *)	29.16 (<0.001 *)	0.052, 0.006	1.00 (0.325)
		CTG	1.22 ± 0.12	1.15 ± 0.16	3.890 (0.001 *)			
		η^2				0.493		0.032
UT	F	CSG	17.60 ± 1.57	15.73 ± 1.51	6.157 (0.000 *)	58.18 (<0.001 *)	−1.933, −1.117	2.97 (0.095)
		CTG	17.42 ± 1.81	16.24 ± 1.26	4.537 (0.000 *)			
		η^2				0.660		0.090
	S	CSG	332.92 ± 38.76	292.49 ± 29.15	6.068 (0.000 *)	51.88 (<0.001 *)	−47.163, −26.326	0.52 (0.476)
		CTG	322.86 ± 45.11	289.79 ± 36.05	4.279 (0.000 *)			
		η^2				0.634		0.017
	D	CSG	1.06 ± 0.11	0.90 ± 0.08	5.787 (0.000 *)	75.67 (<0.001 *)	−0.162, −0.100	2.25 (0.144)
		CTG	1.08 ± 0.11	0.97 ± 0.13	7.616 (0.000 *)			
		η^2				0.711		0.077

Values are expressed as means ± SD. CSG: cervical stabilization exercises with scapular stabilization exercise group; CTG: cervical stabilization exercises with thoracic exercise group; SCM: sternocleidomastoid muscle; UT: upper trapezius muscle; LCI and UCI: lower and upper (95%) confidence interval; η^2: effect size; * $p < 0.05$.

Table 3. Change in muscle PPT in the two groups (unit: lb/cm^2) ($n = 32$).

		Pre	Post	t (p)	Time F (p)	LCI, UCI	Group × Time F (p)
SCM	CSG	3.46 ± 1.34	4.50 ± 1.50	−8.759 (0.000 *)	119.57 (<0.001 *)	0.757, 1.105	1.57 (0.222)
	CTG	3.07 ± 0.91	3.89 ± 1.16	−6.470 (0.000 *)			
	η^2				0.799		0.049
UT	CSG	7.86 ± 2.84	11.42 ± 3.75	−8.769 (0.000 *)	136.21 (<0.001 *)	2.726, 3.242	11.50 (0.002 *)
	CTG	7.47 ± 2.35	9.43 ± 2.68	−8.081 (0.000 *)			
	η^2				0.820		0.277

Values are expressed as means ± SD. CSG: cervical stabilization and scapular stabilization exercises group; CTG: cervical stabilization and thoracic exercises group; SCM: sternocleidomastoid muscle; UT: upper trapezius muscle; LCI and UCI: lower and upper (95%) confidence interval; η^2: effect size; * $p < 0.05$.

There were significant time interactions for muscle tone, stiffness, elasticity, and PPT in both the SCM and UT muscles. For the SCM muscle, muscle tone showed a significant reduction ($F = 43.74$, $p < 0.001$, $\eta^2 = 0.593$), stiffness decreased significantly ($F = 85.13$, $p < 0.001$, $\eta^2 = 0.739$), and elasticity improved ($F = 29.16$, $p < 0.001$, $\eta^2 = 0.493$). The PPT also showed a significant increase ($F = 119.57$, $p < 0.001$, $\eta^2 = 0.799$). Similarly, in the UT muscle, muscle tone decreased significantly ($F = 58.18$, $p < 0.001$, $\eta^2 = 0.660$), stiffness reduced ($F = 51.88$, $p < 0.001$, $\eta^2 = 0.634$), and elasticity improved ($F = 75.67$, $p < 0.001$, $\eta^2 = 0.711$). The PPT showed a significant increase ($F = 136.21$, $p < 0.001$, $\eta^2 = 0.820$) (Tables 2 and 3). Additionally, the cervical ROM demonstrated significant improvements in extension ($F = 153.80$, $p < 0.001$, $\eta^2 = 0.836$), flexion ($F = 89.45$, $p < 0.001$, $\eta^2 = 0.749$), right rotation ($F = 127.96$, $p < 0.001$, $\eta^2 = 0.810$), and left rotation ($F = 121.54$, $p <.001$, $\eta^2 = 0.802$)

(Table 4). However, only the PPT in the UT muscle showed a significant group-by-time interaction (F = 11.50, $p < 0.002$, $\eta^2 = 0.277$) (Table 3).

Table 4. Change in cervical ROM in the two groups (unit: °) (n = 32).

		Pre	Post	t (p)	Time F (p)	LCI, UCI	Group × Time F (p)
extension	CSG	56.35 ± 7.32	65.18 ± 6.79	−7.235 (0.000 *)	153.80 (<0.001 *)	7.147, 9.976	0.15 (0.700)
	CTG	53.41 ± 4.89	61.71 ± 4.20	−12.657 (0.000 *)			
	η^2				0.836		0.005
flexion	CSG	30.43 ± 7.69	39.65 ± 5.84	−6.301 (0.000 *)	89.45 (<0.001 *)	6.344, 9.838	1.73 (0.199)
	CTG	33.23 ± 6.07	40.20 ± 7.45	−7.846 (0.000 *)			
	η^2				0.749		0.054
right rotation	CSG	60.29 ± 5.77	68.29 ± 7.64	−7.708 (0.000 *)	127.96 (<0.001 *)	5.830, 8.398	1.96 (0.172)
	CTG	55.82 ± 8.35	62.05 ± 8.60	−8.760 (0.000 *)			
	η^2				0.810		0.061
left rotation	CSG	53.25 ± 6.31	61.77 ± 7.00	−7.789 (0.000 *)	121.54 (<0.001 *)	6.147, 8.942	2.04 (0.164)
	CTG	55.93 ± 7.09	62.49 ± 7.06	−7.985 (0.000 *)			
	η^2				0.802		0.064

Values are expressed as means ± SD. CSG: cervical stabilization and scapular stabilization exercises group; CTG: cervical stabilization and thoracic exercises group; η^2: effect size; * $p < 0.05$.

No participants dropped out during the study, and all participants fully complied with the prescribed exercise regimen.

7. Discussion

This study aimed to compare the effects of combining cervical stabilization exercises with either scapular stabilization exercises or thoracic exercises according to various parameters, including the mechanical properties of the cervical muscle, the PPT, and the cervical ROM. The study specifically targeted individuals exhibiting cervical extension.

The results showed a significant decrease in the muscle tone and stiffness of the SCM and UT muscles in both groups after the intervention. These muscle properties, as well as elasticity, are crucial for joint control and stability [37]. In the intragroup comparison of the elasticity of the SCM and UT muscles, both groups showed a significant increase. Nonetheless, no significant differences were observed between the groups. The elasticity of a muscle describes its ability to return to its original shape after deformation, and increasing muscle elasticity can improve muscle flexibility and reduce muscle stiffness [49,50]. Similarly, others have demonstrated that consistent engagement in stretching exercises and flexibility training can result in an augmentation in muscle elasticity, as the muscle fibers and surrounding connective tissue adapt to the expanded ROM by acquiring enhanced elastic properties [51–53]. In this study, both exercise groups implemented targeted stretching techniques for the nuchal ligament, UT muscle, and SCM muscle, and the UT muscle was subjected to long periods of passive stretching. According to the results, the tone and stiffness of the SCM and UT muscles were effectively reduced and the elasticity of the SCM and UT muscles was effectively increased in both groups of patients after exercise, with no significant differences between the two groups. This may be because both groups performed the same cervical exercises, which affected the SCM muscle, while scapular exercises and thoracic exercises had similar effects on the changes in muscle tone, stiffness, and elasticity of the UT muscle.

Both the CSG and the CTG demonstrated significant improvements in the PPT of the SCM and UT muscles. However, the UT muscle demonstrated greater effectiveness in the CSG. The same incorrect neck and shoulder posture and neck pain are present in both cervical extension and forward head posture [4]. This posture may increase the load on neck structures, potentially resulting in peripheral nociceptive nerve sensitization and a

subsequent reduction in PPT [46]. Previous studies have found that spinal instability can also lead to neck pain and dysfunction. For instance, it has been shown that the DCF plays an important role in spinal stability and movement control, and DCF weakness can cause neck pain and significantly reduce the PPT [46]. The PPT is a substitute for expressing pain. It has also been shown that imbalances in the neck muscles can cause pain, the overactivity of superficial cervical muscles, increased stiffness, and muscle shortening, which can also cause cervical pain [54].

Aiming to alleviate these symptoms, Finocchietti, S. et al. demonstrated that stretching can suppress pain perception in the skin, and pressure pain thresholds were found to increase during and after stretching [55]. Following stretching, the resilience of muscles, tendons, ligaments, and other soft tissues is enhanced, enabling them to better withstand pressure; this may contribute to an increased PPT [56,57]. Similarly, DCF strengthening exercises can improve neck pain and increase the PPT of neck muscles [46]. The application of mechanical stimulation to the muscles, which promotes the realignment of muscle fibers and the relaxation of the muscular structure, has been shown to effectively alleviate pain sensations; furthermore, this form of stimulation has shown an ability to increase the PPT through mechanisms involving the presynaptic inhibition or modulation of pain signals at a conscious level [58]. Mechanical stimulation of the SCM muscle significantly increases its PPT, likely due to pain reduction and presynaptic inhibition, while relaxation of the SCM muscle indirectly contributes to a significant increase in the PPT of the UT muscle [58]. In this study, participants in both groups engaged in cervical stabilization exercises, which included stretching, exercises for strengthening the DCF muscles, and posture correction. Following these exercises, both groups experienced an increase in PPT and a reduction in neck pain. In cervical extension and forward head posture, there is a weakening of LT and SA muscles, which leads to downward rotation of the scapula, an increased load on the cervical spine, and increased neck pain [59,60]. Therefore, both the scapula stabilizing exercises group and the thoracic exercises group performed strengthening exercises for the LT and SA muscles and noted improved neck pain. Only the UT muscle was different between groups. It is speculated that these results may be because both groups performed the same SCM muscle stretching and neck flexor strengthening exercises, but the CSG performed more UT muscle stretching exercises. Stretching exercises can promote muscle relaxation, improve flexibility, and reduce myofascial tightness, which may explain the superior effects observed in the UT muscle. Scapular stabilization exercises have a greater impact on strengthening the LT and SA muscles and reducing the hyperactivity of the UT muscle [24]. These adaptations likely resulted in the greater pain reduction observed in the CSG group.

In this study, the cervical ROM for extension, flexion, right rotation, and left rotation had statistically significant differences in both the CSG and CTG before and after the intervention. However, there was no statistical significance between groups. The ROM of the cervical spine is restricted in cervical extension [4], and previous studies have found that this limited ROM is related to imbalance in the neck muscles, such as a weakening of the DCF and shortening of superficial extensor muscles like the UT and SCM muscles [5,61]. Stretching exercises can contribute to the normalization of muscle length by elongating the shortened muscle, thereby enhancing the ROM [62], and strengthening the weak DCF can improve muscle imbalance and increase the ROM of the cervical spine [63]. According to Rudolfsson, T. et al., neck pain can lead to a reduction in cervical ROM [64]; therefore, strengthening weak DCF muscles and stretching shortened UT and SCM muscles can reduce neck pain and increase the ROM of the cervical spine [61,63]. Both groups performed cervical spine exercises, such as stretching exercises and deep cervical flexor strengthening exercises; thus, the ROM was significantly improved in both

groups. Research has found that, because of the mechanical relationship between the cervical and thoracic spines, improving the thoracic spine can also increase the ROM of the cervical spine [63]. Both scapular exercises and thoracic exercises are muscle strengthening exercises used to improve scapulothoracic dysfunction, thoracic spine alignment, and the ROM of the cervical spine [21]. There was no difference between the two groups. This may be because both scapular stabilization exercises and thoracic exercises improve spinal alignment and thus improve the ROM. Moreover, the ROM limitations experienced by the subjects were not severe, and so they were improved to average levels after exercise. In summary, cervical stabilization exercises, in combination with either scapular stabilization or thoracic exercises, improve the mechanical properties of cervical muscles, reduce pain, and enhance the cervical ROM.

These findings suggest that combining cervical stabilization exercises with scapular or thoracic exercises may be an effective treatment for cervical extension disorders. This noninvasive approach may help reduce pain, improve mobility, and enhance daily functioning, offering a cost-effective alternative to more invasive treatments such as surgery or medications. It offers a valuable option for treating neck pain and improving patients' quality of life.

8. Limitations of the Study

However, the limitations of this study should also be noted. First, the experimental period was short. In this study, a four-week exercise program was carried out; however, exercises should be carried out for more than eight weeks. Second, it is difficult to control for the various daily activities that may affect the dependent variable. Third, the participants were restricted to patients with mild symptoms, with no comparisons made with individuals with severe symptoms; additionally, this study only included younger students, without representation from other age groups. Psychological factors, such as anxiety or stress, were not accounted for and could have influenced participants' pain levels and recovery.

Based on these research limitations, it is recommended that future studies incorporate longer exercise durations and older participants and consider strategies to minimize interference from daily life. Additionally, it would be beneficial to consider psychological factors that may influence recovery.

9. Conclusions

This study evaluated the impact of combining cervical stabilization exercises with either scapular stabilization or thoracic exercises on the mechanical properties of cervical muscles, PPT, and cervical ROM in individuals with cervical extension type. Combining cervical stabilization exercises with scapular stabilization exercises or thoracic exercises had a significant impact on pain, cervical ROM, and the mechanical properties of the cervical muscles in patients with cervical extension who had a similar FHP. Cervical stabilization exercises, combined with scapular stabilization exercises, have a better effect on improving UT muscle pain.

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References

1. Titcomb, D.A.; Melton, B.F.; Miyashita, T.; Bland, H.W. The Effects of Postural Education or Corrective Exercise on the Craniovertebral Angle in Young Adults with Forward Head Posture: A Randomized Controlled Trial. *Int. J. Exerc. Sci.* **2023**, *16*, 954. [PubMed]
2. Kang, N.-Y.; Im, S.-C.; Kim, K. Effects of a combination of scapular stabilization and thoracic extension exercises for office workers with forward head posture on the craniovertebral angle, respiration, pain, and disability: A randomized-controlled trial. *Turk. J. Phys. Med. Rehabil.* **2021**, *67*, 291. [CrossRef]
3. Elvan, A.; Cevik, S.; Vatansever, K.; Erak, I. The Association Between Mobile Phone Usage Duration, Neck Muscle Endurance, and Neck Pain Among University Students: A Cross-Sectional Study. *Sci. Rep.* **2024**, *14*, 20116. [CrossRef] [PubMed]
4. Kwon, O.-Y.; Kang, M.-H.; Kim, M.-H.; Kim, S.-J.; Kim, T.-H.; Park, K.-N.; Oh, J.-S.; Lee, W.-H.; Im, I.-Y.; Jang, J.-H.; et al. *KEMA Approach for Analysis and Management of Motor Impairment 1*; Hakjisa Medical: Seoul, Republic of Korea, 2022.
5. Sahrmann, S.; Azevedo, D.C.; Dillen, L.V. Diagnosis and treatment of movement system impairment syndromes. *Braz. J. Phys. Ther.* **2017**, *21*, 391–399. [CrossRef] [PubMed]
6. Quek, J.; Pua, Y.-H.; Clark, R.A.; Bryant, A.L. Effects of thoracic kyphosis and forward head posture on cervical range of motion in older adults. *Man. Ther.* **2013**, *18*, 65–71. [CrossRef] [PubMed]
7. Fontenele, T.M.d.O.; Rabelo, L.K.S.M.; Medeiros, N.K.F.D.; Sousa, N.R.M.d.; Mont'Alverne, D.G.B.; Abdon, A.P.V. Evaluation of Cervical Posture and Smartphone Use in Young Adults. *Fisioter. Mov.* **2024**, *37*, e37115. [CrossRef]
8. Liao, X.; Chen, H.; Ge, B. The Effect of Mind-Body Exercise on Cervical Spine Mobility of People with Neck Discomfort: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *PLoS ONE* **2022**, *17*, e0262429. [CrossRef]
9. Kim, D.H.; Kim, C.J.; Son, S.M. Neck Pain in Adults with Forward Head Posture: Effects of Craniovertebral Angle and Cervical Range of Motion. *Osong Public Health Res. Perspect.* **2018**, *9*, 309–313. [CrossRef]
10. Cho, J.; Lee, E.; Lee, S. Upper thoracic spine mobilization and mobility exercise versus upper cervical spine mobilization and stabilization exercise in individuals with forward head posture: A randomized clinical trial. *BMC Musculoskelet. Disord.* **2017**, *18*, 525. [CrossRef]
11. Wytrążek, M.; Huber, J.; Lipiec, J.; Kulczyk, A. Evaluation of Palpation, Pressure Algometry, and Electromyography for Monitoring Trigger Points in Young Participants. J. *Manip. Physiol. Ther.* **2015**, *38*, 232–243. [CrossRef] [PubMed]
12. Sbardella, S.; La Russa, C.; Bernetti, A.; Mangone, M.; Guarnera, A.; Pezzi, L.; Paoloni, M.; Agostini, F.; Santilli, V.; Saggini, R.; et al. Muscle Energy Technique in the Rehabilitative Treatment for Acute and Chronic Non-Specific Neck Pain: A Systematic Review. *Healthcare* **2021**, *9*, 746. [CrossRef] [PubMed]
13. Opara, M.; Kozinc, Ž. Which muscles exhibit increased stiffness in people with chronic neck pain? A systematic review with meta-analysis. *Front. Sports Act. Living* **2023**, *5*, 1172514. [CrossRef]
14. Alizadeh, M.; Knapik, G.G.; Mageswaran, P.; Mendel, E.; Bourekas, E.; Marras, W.S. Biomechanical musculoskeletal models of the cervical spine: A systematic literature review. *Clin. Biomech.* **2020**, *71*, 115–124. [CrossRef]
15. Guduru, R.K.R.; Domeika, A.; Domeikienė, A. Effect of rounded and hunched shoulder postures on myotonometric measurements of upper body muscles in sedentary workers. *Appl. Sci.* **2022**, *12*, 3333. [CrossRef]
16. Khan, A.; Khan, Z.; Bhati, P.; Hussain, M.E. Influence of forward head posture on cervicocephalic kinesthesia and electromyographic activity of neck musculature in asymptomatic individuals. *J. Chiropr. Med.* **2020**, *19*, 230–240. [CrossRef]
17. Chuang, L.-L.; Wu, C.-Y.; Lin, K.-C. Reliability, validity, and responsiveness of myotonometric measurement of muscle tone, elasticity, and stiffness in patients with stroke. *Arch. Phys. Med. Rehabil.* **2012**, *93*, 532–540. [CrossRef]
18. Pawaria, S.; SuDhan, D.S.; Kalra, S. Effectiveness of cervical stabilisation exercises on respiratory strength in chronic neck pain patients with forward head posture-a pilot study. *J. Clin. Diagn. Res.* **2019**, *13*, 6–9. [CrossRef]

19. Aura, O.; Komi, P. Effects of prestretch intensity on mechanical efficiency of positive work and on elastic behavior of skeletal muscle in stretch-shortening cycle exercise. *Int. J. Sports Med.* **1986**, *7*, 137–143. [CrossRef] [PubMed]
20. Ali, A.A.; Sheikh, N.; Chughani, V.; Hussain, A.; Rafique, M.; Ismail, M.; Khokhar, H.I. Comparision of effectiveness of isometric and stretching exercise in pain management among the forward head posture patients. *Indian J. Physiother. Occup. Ther.* **2021**, *15*, 84–90.
21. Kang, T.; Kim, B. Cervical and scapula-focused resistance exercise program versus trapezius massage in patients with chronic neck pain: A randomized controlled trial. *Medicine* **2022**, *101*, e30887. [CrossRef] [PubMed]
22. Jaroenrungsup, Y.; Kanchanomai, S.; Khruakhorn, S. Effects of self-posture correction exercise in forward head posture of smartphone users. *Songklanakarin J. Sci. Technol.* **2021**, *43*, 439–447.
23. Yaghoubitajani, Z.; Gheitasi, M.; Bayattork, M.; Andersen, L.L. Corrective Exercises Administered Online vs. at the Workplace for Pain and Function in Office Workers with Upper Crossed Syndrome: A Randomized Controlled Trial. *Int. Arch. Occup. Environ. Health* **2022**, *95*, 1703–1718. [CrossRef] [PubMed]
24. Fathollahnejad, K.; Letafatkar, A.; Hadadnezhad, M. The effect of manual therapy and stabilizing exercises on forward head and rounded shoulder postures: A six-week intervention with a one-month follow-up study. *BMC Musculoskelet. Disord.* **2019**, *20*, 86. [CrossRef] [PubMed]
25. Nitayarak, H.; Charntaraviroj, P. Effects of scapular stabilization exercises on posture and muscle imbalances in women with upper crossed syndrome: A randomized controlled trial. *J. Back Musculoskelet. Rehabil.* **2021**, *34*, 1031–1040. [CrossRef] [PubMed]
26. Moustafa, I.M.; Shousha, T.; Arumugam, A.; Harrison, D.E. Is Thoracic Kyphosis Relevant to Pain, Autonomic Nervous System Function, Disability, and Cervical Sensorimotor Control in Patients with Chronic Nonspecific Neck Pain? *J. Clin. Med.* **2023**, *12*, 3707. [CrossRef]
27. Lau, K.T.; Cheung, K.Y.; Chan, K.B.; Chan, M.H.; Lo, K.Y.; Chiu, T.T. Relationships between sagittal postures of thoracic and cervical spine, presence of neck pain, neck pain severity and disability. *Man. Ther.* **2010**, *15*, 457–462. [CrossRef] [PubMed]
28. Cevik, R.; Pala, O.O. Effects of upper thoracic Mulligan mobilization on pain, range of motion and function in patients with mechanical neck pain: A randomized placebo-controlled trial. *PLoS ONE* **2024**, *19*, e0311206. [CrossRef]
29. Buttagat, V.; Kluayhomthong, S.; Areeudomwong, P. Effects of the combination of traditional Thai massage, scapular stabilization exercise, and chest mobilization in subjects with forward head posture: A single-blinded randomized clinical trial. *Chiropr. Man. Ther.* **2023**, *31*, 31. [CrossRef]
30. Kang, N.-Y.; Kim, K. Effects of a combination of scapular stabilization and thoracic extension exercises on respiration, pain, craniovertebral angle and cervical range of motion in elementary school teachers with a forward head posture: A randomized controlled trial. *J. Korean Soc. Phys. Med.* **2022**, *17*, 29–40. [CrossRef]
31. Ruivo, R.; Carita, A.; Pezarat-Correia, P. The effects of training and detraining after an 8 month resistance and stretching training program on forward head and protracted shoulder postures in adolescents: Randomised controlled study. *Man. Ther.* **2016**, *21*, 76–82. [CrossRef] [PubMed]
32. Abd El-Azeim, A.S.; Mahmoud, A.G.; Mohamed, M.T.; El-Khateeb, Y.S. Impact of adding scapular stabilization to postural correctional exercises on symptomatic forward head posture: A randomized controlled trial. *Eur. J. Phys. Rehabil. Med.* **2022**, *58*, 757. [CrossRef] [PubMed]
33. Choi, Y.-J.; Hwang, R. Effect of Cervical and Thoracic Stretching and Strengthening Exercise Program on Forward Head Posture. *J. Korea Contents Assoc.* **2011**, *11*, 293–300. [CrossRef]
34. Saini, K.; Singh, G.; Kothiyal, S. Normative value of deep neck flexors muscle strength measurement using pressure biofeedback unit and sphygmomanometer: An observational study. *J. Bodyw. Mov. Ther.* **2024**, *39*, 1–3. [CrossRef] [PubMed]
35. Park, S.-H.; Lee, M.-M. Effects of lower trapezius strengthening exercises on pain, dysfunction, posture alignment, muscle thickness and contraction rate in patients with neck pain; randomized controlled trial. *Med. Sci. Monit. Int. Med. J. Exp. Clin. Res.* **2020**, *26*, e920208. [CrossRef]
36. Seidi, F.; Rajabi, R.; Ebrahimi, I.; Alizadeh, M.H.; Minoonejad, H. The efficiency of corrective exercise interventions on thoracic hyper-kyphosis angle. *J. Back Musculoskelet. Rehabil.* **2014**, *27*, 7–16. [CrossRef]
37. Taş, S.; Kaynak, B.A.; Salkin, Y.; Karakoç, Z.B.; Dağ, F. An investigation of the changes in mechanical properties of the orofacial and neck muscles between patients with myogenous and mixed temporomandibular disorders. *CRANIO®* **2024**, *42*, 150–159. [CrossRef]
38. Trybulski, R.; Stanula, A.; Żebrowska, A.; Podleśny, M.; Hall, B. Acute Effects of the Dry Needling Session on Gastrocnemius Muscle Biomechanical Properties, and Perfusion with Latent Trigger Points—A Single-Blind Randomized Controlled Trial in Mixed Martial Arts Athletes. *J. Sports Sci. Med.* **2024**, *23*, 136–146. [CrossRef]

39. Rotllan, C.; Corbi, F.; Viscor, G. Muscle Tone, Stiffness, and Elasticity in Elite Female Cyclists after Consecutive Short Competitions. *Transl. Sports Med.* **2024**, *2024*, 2434494. [CrossRef] [PubMed]
40. Marusiak, J.; Jaskólska, A.; Budrewicz, S.; Koszewicz, M.; Jaskólski, A. Increased muscle belly and tendon stiffness in patients with Parkinson's disease, as measured by myotonometry. *Mov. Disord.* **2011**, *26*, 2119–2122. [CrossRef] [PubMed]
41. Kocur, P.; Wilski, M.; Goliwąs, M.; Lewandowski, J.; Łochyński, D. Influence of forward head posture on myotonometric measurements of superficial neck muscle tone, elasticity, and stiffness in asymptomatic individuals with sedentary jobs. *J. Manip. Physiol. Ther.* **2019**, *42*, 195–202. [CrossRef] [PubMed]
42. Park, G.; Kim, C.W.; Park, S.B.; Kim, M.J.; Jang, S.H. Reliability and usefulness of the pressure pain threshold measurement in patients with myofascial pain. *Ann. Rehabil. Med.* **2011**, *35*, 412–417. [CrossRef] [PubMed]
43. Bae, Y. Change the myofascial pain and range of motion of the temporomandibular joint following kinesio taping of latent myofascial trigger points in the sternocleidomastoid muscle. *J. Phys. Ther. Sci.* **2014**, *26*, 1321–1324. [CrossRef]
44. Barone, M.; Imaz, F.; Converso, G.; Bordachar, D.; Barbero, A.; Trucco, M.; Intelangelo, L. Immediate effects of rhythmic joint mobilization of the temporomandibular joint on pain, mouth opening and electromyographic activity in patients with temporomandibular disorders. *J. Bodyw. Mov. Ther.* **2021**, *28*, 563–569. [CrossRef]
45. Zieliński, G.; Matysik-Woźniak, A.; Baszczowski, M.; Rapa, M.; Ginszt, M.; Pająk, B.; Szkutnik, J.; Rejdak, R.; Gawda, P. Myopia & painful muscle form of temporomandibular disorders: Connections between vision, masticatory and cervical muscles activity and sensitivity and sleep quality. *Sci. Rep.* **2023**, *13*, 20231.
46. Pacheco, J.; Raimundo, J.; Santos, F.; Ferreira, M.; Lopes, T.; Ramos, L.; Silva, A.G. Forward head posture is associated with pressure pain threshold and neck pain duration in university students with subclinical neck pain. *Somatosens. Mot. Res.* **2018**, *35*, 103–108. [CrossRef]
47. Abstracts of the 28th International Meeting of Physical Therapy Science in Korea. *J. Phys. Ther. Sci.* **2019**, *31*, S1_1. [CrossRef]
48. Gugliotti, M.; Tau, J.; Gallo, K.; Sagliocca, N.; Horan, M.; Sussman, N.; Wisnewski, R. Between-week reliability of the cervical range of motion (CROM) device for upper cervical rotation. *J. Man. Manip. Ther.* **2021**, *29*, 176–180. [CrossRef] [PubMed]
49. Aird, L.; Samuel, D.; Stokes, M. Quadriceps muscle tone, elasticity and stiffness in older males: Reliability and symmetry using the MyotonPRO. *Arch. Gerontol. Geriatr.* **2012**, *55*, e31–e39. [CrossRef] [PubMed]
50. Hamilton, R.I.; Garden, C.L.; Brown, S.J. Immediate effect of a spinal mobilisation intervention on muscle stiffness, tone and elasticity in subjects with lower back pain—A randomized cross-over trial. *J. Bodyw. Mov. Ther.* **2022**, *29*, 60–67. [CrossRef]
51. Knudson, D. The biomechanics of stretching. *J. Exerc. Sci. Physiother.* **2006**, *2*, 3–12.
52. Zvetkova, E.; Koytchev, E.; Ivanov, I.; Ranchev, S.; Antonov, A. Biomechanical, healing, and therapeutic effects of stretching: A comprehensive review. *Appl. Sci.* **2023**, *13*, 8596. [CrossRef]
53. Konrad, A.; Tilp, M.; Nakamura, M. A comparison of the effects of foam rolling and stretching on physical performance. A systematic review and meta-analysis. *Front. Physiol.* **2021**, *12*, 720531. [CrossRef] [PubMed]
54. Kocur, P.; Choszczewski, D.; Lewandowski, J.; Goliwąs, M. Assessment of stiffness of the superficial neck muscles in female office workers with impaired endurance of deep neck flexors: A case-control study. *Physiother. Q.* **2023**, *31*, 114–120. [CrossRef]
55. Finocchietti, S.; Mørch, C.D.; Arendt-Nielsen, L.; Graven-Nielsen, T. Effects of adipose thickness and muscle hardness on pressure pain sensitivity: Correction. *Clin. J. Pain* **2011**, *27*, 735–745. [CrossRef]
56. Støve, M.P.; Hansen, L.; Elmbæk, K.K.; Magnusson, S.P.; Thomsen, J.L.; Riis, A. The effect of stretching intensity on pain sensitivity: A randomized crossover study on healthy adults. *Eur. J. Pain* **2025**, *29*, e4750. [CrossRef]
57. Behm, D.G.; Kay, A.D.; Trajano, G.S.; Alizadeh, S.; Blazevich, A.J. Effects of acute and chronic stretching on pain control. *J. Clin. Exerc. Physiol.* **2021**, *10*, 150–159. [CrossRef]
58. Kim, S.J.; Lee, J.H. Effects of sternocleidomastoid muscle and suboccipital muscle soft tissue release on muscle hardness and pressure pain of the sternocleidomastoid muscle and upper trapezius muscle in smartphone users with latent trigger points. *Medicine* **2018**, *97*, e12133. [CrossRef]
59. Kataria, J.; Sindhu, B.; Pawaria, S. Effect of mechanical neck pain with forward head posture on scapula position in primary school teachers. *Al Ameen J. Med. Sci.* **2020**, *13*, 25–30.
60. Sahrmann, S. *Movement System Impairment Syndromes of the Extremities, Cervical and Thoracic Spines*; Elsevier Health Sciences: Amsterdam, The Netherlands, 2010.
61. Cho, J.; Lee, E.; Lee, S. Upper cervical and upper thoracic spine mobilization versus deep cervical flexors exercise in individuals with forward head posture: A randomized clinical trial investigating their effectiveness. *J. Back Musculoskelet. Rehabil.* **2019**, *32*, 595–602. [CrossRef] [PubMed]
62. Oh, S.H.; Yoo, K.T. The effects of stabilization exercises using a sling and stretching on the range of motion and cervical alignment of straight neck patients. *J. Phys. Ther. Sci.* **2016**, *28*, 372–377. [CrossRef] [PubMed]

63. Lee, K.-W.; Kim, W.-H. Effect of thoracic manipulation and deep craniocervical flexor training on pain, mobility, strength, and disability of the neck of patients with chronic nonspecific neck pain: A randomized clinical trial. *J. Phys. Ther. Sci.* **2016**, *28*, 175–180. [CrossRef] [PubMed]
64. Rudolfsson, T.; Björklund, M.; Svedmark, Å.; Srinivasan, D.; Djupsjöbacka, M. Direction-specific impairments in cervical range of motion in women with chronic neck pain: Influence of head posture and gravitationally induced torque. *PLoS ONE* **2017**, *12*, e0170274. [CrossRef]

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