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THE ACUTE EFFECT OF PROPRIOCEPTIVE NEUROMUSCULAR FACILITATION ON CERVICAL RANGE OF MOTION, STRENGTH, AND PROPRIOCEPTION

ORIGINAL ARTICLE

ABSTRACT

Purpose: This double-blind randomized controlled study aimed to investigate the acute influence of two different proprioceptive neuromuscular facilitation (PNF) exercise, targeting stretching and strengthening, on cervical proprioception, range of motion (ROM) and strength among healthy university students.

Methods: Healthy subjects were randomly divided into three groups as PNF stretching (PNFS) (n=36), resistive PNF pattern (PNFP) (n=35), and control group (CG) (n=33) which received only passive range of motion (ROM) exercises without causing any stretch. All participants were assessed in terms of cervical proprioception, ROM and muscle strength before and after one intervention session.

Results: Within-group analysis of the PNFS group showed a significant difference only in extension proprioception and right rotation ROM ($p \le 0.05$) while the PNFP group showed a significant difference in extension, right rotation, right and left lateral flexion proprioception; extension and right rotation ROM, and right and left rotation muscle strength ($p \le 0.05$). For the CG, the within-group analysis showed a significant difference in flexion, extension, right rotation and right lateral flexion proprioception, extension, and left and right lateral flexion ROM ($p \le 0.05$). Between-group analysis showed a significant difference only in cervical flexion proprioception ($p=0.023$) for PNFP over the CG.

Conclusion: Although a lack of significant difference found in the between-group analysis, the within-group analysis showed that PNF patterns applied with resistance may be a promising technique to improve cervical proprioception, muscle strength and ROM.

Keywords: Cervical spine, Proprioception, Proprioceptive neuromuscular facilitation, Range of motion, Strength.

PROPRİOSEPTİF NÖROMUSKÜLER FASİLİTASYONUN SERVİKAL EKLEM HAREKET AÇIKLIĞI, KUVVET VE PROPRİYOSEPSİYON ÜZERİNE AKUT ETKİSİ

ARAŞTIRMA MAKALESİ

ÖZ

Amaç: Bu randomize kontrollü çift kör çalışmada, sağlıklı üniversite öğrencilerinde uygulanan, germe ve güçlendirmeyi hedefleyen iki farklı propriyoseptif nöromüsküler fasilitasyon (PNF) egzersizinin servikal propriyosepsiyon, eklem hareket açıklığı (EHA) ve kas kuvveti üzerindeki akut etkisinin araştırılması amaçlanmıştır.

Yöntem: Sağlıklı denekler rastgele olarak PNF germe (PNFG) (n=36), dirençli PNF paterni (PNFP) (n=35), ve herhangi bir gerilmeye neden olmadan sadece pasif EHA egzersizleri uygulanan kontrol grubu (KG) (n=33) olmak üzere üç gruba ayrıldı. Tüm katılımcılar bir müdahale seansından önce ve sonra servikal propriyosepsiyon, EHA ve kas gücü açısından değerlendirildi.

Sonuçlar: PNFS grubu sadece ekstansiyon propriyosepsiyonu ve sağ rotasyon EHA'sında anlamlı bir fark gösterirken ($p \le 0,05$), PNFP grubunun grup içi analizi ekstansiyon, sağ rotasyon, sağ ve sol lateral fleksiyon propriyosepsiyonu; ekstansiyon ve sağ rotasyon EHA'sı ile sağ ve sol rotasyon kas kuvveti açısından anlamlı bir fark gösterdi ($p \le 0,05$). KG için, grup içi analizde fleksiyon, ekstansiyon, sağ rotasyon ve sağ lateral fleksiyon propriyosepsiyonu ile ekstansiyon ve sol ve sağ lateral fleksiyon EHA'sında anlamlı bir fark bulundu ($p \le 0,05$). Gruplar arası analizde ise yalnızca PNFP grubu KG'ye göre servikal fleksiyon propriosepsiyonunda anlamlı bir fark gösterdi ($p=0,023$).

Tartışma: Gruplararası karşılaştırmada anlamlı fark bulunamamış olsa da, yapılan grup içi değerlendirmeler dirençle uygulanan PNF paternlerinin servikal propriyosepsiyon, kas gücü ve ROM'u iyileştirmek için umut verici bir teknik olabileceğini göstermiştir.

Anahtar Kelimeler: Servikal omurga, Propriyosepsiyon, Propriyoseptif nöromusküler fasilitasyon, Eklem hareket açıklığı, Kuvvet.

INTRODUCTION

The cervical spine is responsible for providing enough stability for the head (1). Because it is the most mobile region of the spine with the ability to move in all plans of motion, the cervical spine is vulnerable to injury among all populations (2,3). Its sensorimotor control includes the integration and processing of all the visual, vestibular, and proprioceptive information (1). If there is an alteration in one of these systems, especially in the proprioceptive system, it results in many problems linked to the musculoskeletal system such as pain and functional disability (4,5).

Proprioception is the ability to sense the information raised from the musculoskeletal system regarding the movement and position of body parts in space (6). Disturbed proprioceptors have a negative influence on feedback and feedforward motor control. Moreover, they cause a decrease in alpha motor neuron drives and balance, and an increase in visual movement error when their functioning is improper (7). Because the cervical spine has a very delicate proprioceptive system to control posture and balance (1), it is extremely important to be sure that this system is functioning perfectly. In this way, future injuries and pain syndromes may be prevented and functional movement may be maximized.

Proprioceptive neuromuscular facilitation (PNF) is a treatment approach that develops and restores the proper functioning of joints and related structures by using neurological reflexes (8). It can also be defined as a method that influences neuromuscular processes by stimulating proprioceptors (9). PNF is concerned with motor unit activation and firing rate by using neural mechanisms that contribute to neural adaptation (10). Literature supports that because the PNF patterns are performed as large dynamic movements, they help to contract the muscles functionally. Thus, in addition to proprioception, they may increase strength, motor control, coordination and ROM (11).

Several studies are searching for the effectiveness of various PNF applications on different regions and health conditions. These studies have mainly compared the effectiveness of PNF stretching with other stretching methods (12–14). Also, some studies use PNF patterns for strengthening the muscles or increasing motor control (11,15). As far as we know, there is no study in the literature comparing the effectiveness of PNF stretching and PNF strengthening on cervical proprioception.

The primary aim of this study is to investigate the differences between one session PNF stretching and one session PNF strengthening applied to the cervical region on cervical proprioception (CP). Secondly, because of the potential effectiveness of the PNF on increased ROM and muscle strength, PNF stretching and strengthening were aimed to be compared in terms of cervical range of motion (ROM) and cervical muscle strength (MS). We hypothesized that even one session of PNF applications may be effective in increasing the CP, ROM and MS among university students.

METHOD

This double-blinded randomized controlled trial with a parallel design was conducted in Bahçeşehir University Physiotherapy and Rehabilitation Laboratories between June 2019 and July 2019. It was conducted in accordance with the ethical principles of the Declaration of Helsinki and was approved by the Medical Ethics Committee of Medical, Surgical and Drug Researches of Yeditepe University Medical Faculty (Decision no: 1028). It was also registered in the ClinicalTrials.gov (NCT04045106).

The inclusion criteria were (1) having a score of 5 or less on the Neck Disability Index, (2) having no history of cervical trauma, diseases or syndrome, (3) having no history of surgeries to the neck, face, shoulders, (4) having no history of cancer or systemic diseases, (5) being 18 or older, (6) being able to understand and follow the instructions.

All the students in the university were invited to the study. 158 students accepted to be assessed and 54 of them were excluded from the study because of the mismatch in the inclusion criteria (Figure 1). 104 participants were randomly divided into three groups as PNF Stretching (PNFS) (n=35), PNF Pattern (PNFP) (n=36) and Control (CG) (n=33). Randomization was done by a person external to the study, by using a computer-based randomizer to generate a simple randomized list. This list was

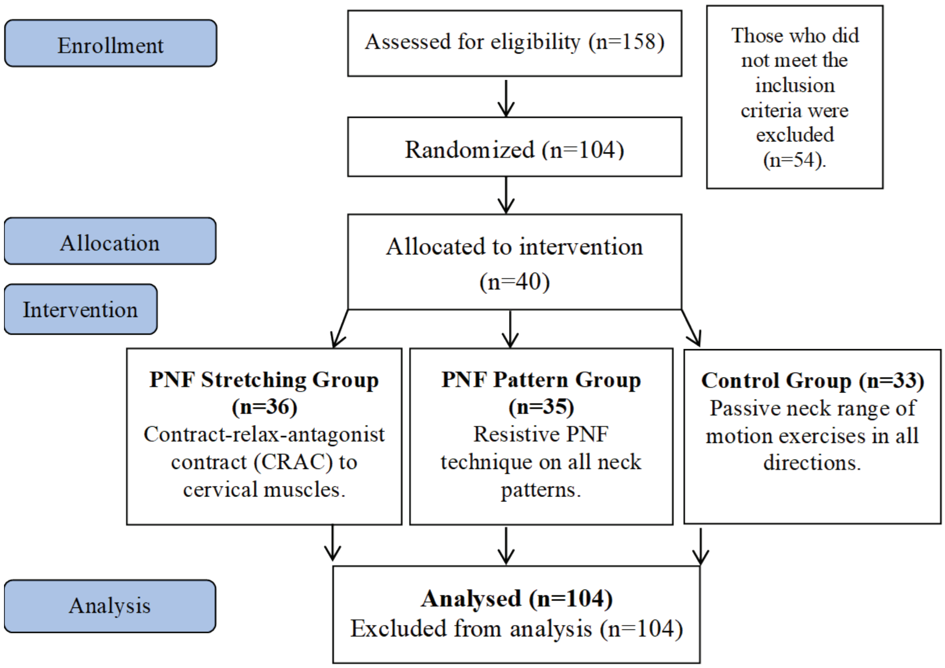

Figure 1. Flow Chart of Participants Allocation and Randomization

kept in a password-protected tablet, only the therapist who performed the intervention had access to the list. All the participants and the assessor therapist were blind to the groups. The informed consent was taken from all participants who met the inclusion criteria. They were assessed at the beginning by the blind assessor. Then the intervention was applied by another therapist according to the group in which the patient was involved. The intervention was performed in a separate room and the participants were not allowed to see each other. After the application, the second assessment was performed by the same, blind assessor.

Assessments

The demographic data were collected face-to-face with a structured questionnaire prepared by the researcher. The questionnaire included the age, weight, height and gender of the participants.

CP was assessed by using the Cervical Range of Motion Instrument (CROM, Performance Attainment Associates, Lindstrom, MN, USA) which was reliable and valid to assess CP (16–18). CP was assessed in flexion, extension, right and left lateral flexion, and right and left rotation. Participants were asked to sit and put on the CROM on the head. They were instructed to start moving their head to one of the directions. The assessor stopped them at the target angle which is 30 degrees and told them to feel the amount of movement and muscle tension. This was repeated 3 times as a reference, then they were asked to do the same procedure 3 times without the guidance of the therapist with the eyes closed until they reached the target angle. Deviation from the target angle was recorded as the test result.

Active range of motion (AROM) was measured by using the CROM instrument. AROM was taken for flexion, extension, right and left lateral flexion, and right and left rotation. The validity and reliability of CROM to assess ROM is well documented in the literature. Subjects were asked to sit on a chair during the measurement and they were first asked to look straight ahead, then to move the head as far as they can in the direction to be tested. For flexion and extension sagittal plane inclinometer was used; for lateral flexions frontal plane inclinometer was used and for rotations, a transverse plane inclinometer was used. Each measurement was repeated three times and the final position was recorded for each trial (19,20).

MS was taken by a myometer device (MicroFET2™ Hoggan Health Industries, Inc, West Jordan, Utah).

Subjects were positioned sitting on a chair. Cervical strength tested in 6 different positions isometrically. Resistance was applied (1) to the forehead for forward flexion (2) to occiput for extension (3) above the ear for right and left lateral flexion and (4) along the jaw near the chin for right and left rotation (21).

Interventions

Contract-relax-antagonist contract (CRAC) technique was applied to cervical flexors, extensors, right and left lateral flexors and right and left rotators to the participants in the PNFS group. For the application, the starting position was the neutral head position for all target muscle groups. According to the target muscle group, the head was moved to the stretching position of that muscle and at the end of the range, maximal voluntary isometric contraction was asked for 6 seconds. After the relaxation, the head was moved to the new range. The technique was applied 6 times for each muscle group with 1-2-minute rest was given before changing the target muscle group (22,23).

PNF strengthening was applied by using the resistive PNF patterns to the participants in the PNFP group. The participants were asked to sit on a chair. The therapist showed all of the 4 neck patterns (8). Then all the patterns were performed resistively as 3 sets of 10 repetitions with 1-2-minute rest between sets. The level of resistance was set as “optimal” to let the participant complete the pattern without any cessation of the movement or any pain. Participants were told to keep breathing normally and to report any discomfort and/or pain.

Participants allocated to the CG received passive ROM (PROM) to keep the participants blinded to group allocation. Flexion, extension, right and left lateral flexion, and right and left rotation were performed passively for 10 repetitions. It was done from a neutral position to the limit of motion without causing any stretch to the muscle.

Statistical Analysis

Statistical analysis was done by Statistical Package Analyze for Social Sciences (SPSS) version 26.0 for Windows (Armonk, NY: IBM Corp). The level of significance was accepted as p≤0.05. The variables were analyzed using probability plots and Kolmogorov-Smirnov Test to test the normality of the distribution. Descriptive analysis was presented with median, minimum, maximum, mean and standard deviation (SD), and frequency tables for the nominal variable. The Kruskal-Wallis test was used to compare the groups and significant results were analyzed by Mann-Whitney-U Test with Bonferroni correction to observe the pairwise differences. Nominal variables were analyzed by Chi-Squared Test and within-group analysis was done by Wilcoxon Signed Rank Test.

Table 1. Characteristics of Groups (n=104)

		PNFS (n=36)	PNFP (n=35)	CG (n=33)	p
Age (Years)	Median (Min-Max)	21.50 (19-28)	22 (20-28)	21 (19-26)	0.115
	Mean±SD	22.472.56±	22.372.13±	21.362.64±	
Height (m)	Median (Min-Max)	1.70 (1.50-2.05)	1.70 (1.55-1.87)	1.70 (1.57-1.93)	0.850
	Mean±SD	1.72± 0.10	1.710.08±	1.710.10±	
Weight (kg)	Median (Min-Max)	66 (46-107)	66 (50-117)	65 (40-120)	0.721
	Mean±SD	68.8317.33±	68.9114.38±	66.7017.49±	
BMI (kg/m²)	Median (Min-Max)	22.31 (15.92-35.83)	23.12 (18.47-33.82)	21.72 (16.02-35.06)	0.700
	Mean±SD	23.154.50±	23.393.63±	22.664.41±	
		PNFS (n=36)	**PNFP (n=35)**	**CG (n=33)**	**p***
Gender	Female n (%)	20 (55.6)	22 (62.9)	23 (69.7)	0.479
	Male n (%)	16 (44.4)	13 (37.1)	10 (30.3)	

p: Kruskal Wallis-H Test, p*: Chi-Squared Test, BMI: Body Mass Index; CG: Control Group; kg: kilogram; m: meter; Min-Max: Minimum-Maximum; n: Number; PNFS: Proprioceptive Neuromuscular Facilitation Stretching Group; PNFP: Proprioceptive Neuromuscular Facilitation Pattern Group; SD: Standard Deviation, %: Percentage.

Table 2. Cervical Proprioception Before and After Intervention Within Each Group and Between Groups

	Base	PNFS (n= 36)				PNFP (n= 35)				CG (n= 33)				Diff
	p*		Median (Min – Max)	Δ	p**		Median (Min – Max)	Δ	p**		Median (Min – Max)	Δ	p**	p*
Flexion	0.059	pre	2 (0 – 8)	-0.612.98±	0.270	pre	2 (0 – 10)	0.11±2.83	0.648	pre	4 (0 – 10)	-2.003.46±	**0.004***	**0.020***
		post	1 (0 – 4)			post	2 (0 – 10)			post	0 (0 – 4)			
Extension	0.653	pre	2 (0 – 12)	-1.503.26±	**0.010***	pre	2 (0 – 6)	-0.972.24±	**0.018***	pre	2 (0 – 12)	-1.33±2.81	**0.014***	0.899
		post	0 (0 – 10)			post	0 (0 – 6)			post	2 (0 – 6)			
Right LF	0.699	pre	2 (0 – 8)	-0.893.22±	0.065	pre	4 (0 – 10)	-1.43±2.73	**0.005***	pre	4 (0 – 8)	-1.45±2.93	**0.010***	0.846
		post	2 (0 – 10)			post	2 (0 – 6)			post	2 (0 – 6)			
Left LF	0.399	pre	2 (0 – 6)	0.173.00±	0.728	pre	2 (0 – 8)	-1.312.17±	**0.001***	pre	2 (0 – 9)	-0.762.61±	0.104	0.058
		post	2 (0 – 6)			post	0 (0 – 6)			post	2 (0 – 6)			
Right Rotation	0.732	pre	2 (0 – 16)	-0.674.51±	0.465	pre	2 (0 – 10)	-1.60±3.28	**0.011***	pre	2 (0 – 10)	-1.883.16±	**0.002***	0.420
		post	2 (0 – 18)			post	2 (0 – 6)			post	0 (0 – 6)			
Left Rotation	0.149	pre	2 (0 – 12)	-0.943.50±	0.189	pre	2 (0 – 8)	-0.512.58±	0.295	pre	2 (0 – 10)	-0.853.08±	0.132	0.944
		post	2 (0 – 12)			post	2 (0 – 8)			post	2 (0 – 10)			

p*: Kruskal Wallis-H Test, p**: Wilcoxon Signed Rank Test, Base: Baseline Comparison, CG: Control Group; Diff: Between Group Difference; LF: Lateral Flexion; PNFS: Proprioceptive Neuromuscular Facilitation Stretching Group; PNFP: Proprioceptive Neuromuscular Facilitation Pattern Group; post: After the study; pre: Before the study; SD: Standard Deviation, Δ: Within-group difference.

RESULTS

This study included 104 healthy participants (65 female, 39 male; 36 PNFS, 35 PNFP, and 33 CG). No adverse effect was reported in any group. The study ended when completing all assessment parameters of all voluntary subjects. The power of the study was calculated by using G*Power 3.1.7 for Windows (G*Power©, University of Dusseldorf, Germany). Analysis results of cervical flexion proprioception were used to calculate the power. The calculated effect size (eta square) was 0.113 and the power of the study was calculated as 0.90. There was no significant difference between the groups according to the demographical characteristics of the groups ($p>0.05$) as shown in Table 1. Before the intervention, there was no significant difference between groups in CP, ROM and MS in all movement directions ($p>0.05$).

The deviation from the target angle before and after the intervention for each movement direction was compared within and between groups (Table 2). There is a significant improvement in proprioception during only extension in the PNFS group ($p=0.010$) while it improved in most of the directions in the PNFP group and CG significantly ($p<0.05$). There was a significant difference in flexion proprioception sense between groups ($p=0.020$). A pairwise comparison done with Bon-

Table 3. Cervical ROM Before and After Intervention Within Each Group and Between Groups

	Base	PNFS (n= 36)				PNFP (n= 35)				CG (n= 33)				Diff
	p*		Median (Min – Max)	Δ	p**		Median (Min – Max)	Δ	p**		Median (Min – Max)	Δ	p**	p*
Flexion	0.643	pre	62 (40 – 80)	2.33±7.91	0.130	pre	58 (38 – 84)	1.777.06±	0.245	pre	60 (48 – 80)	0.736.70±	0.473	0.871
		post	66 (46 – 80)			post	60 (40 – 82)			post	60 (46 – 80)			
Extension	0.638	pre	66 (50 – 82)	1.147.79±	0.498	pre	70 (40 – 80)	3.717.36±	**0.009***	pre	66 (42 – 90)	1.945.78±	**0.037***	0.579
		post	70 (48 – 84)			post	70 (46 – 88)			post	68 (50 – 82)			
Right LF	0.497	pre	46 (32 – 64)	0.535.68±	0.407	pre	44 (32 – 60)	-0.294.95±	0.771	pre	44 (32 – 70)	1.885.02±	**0.020***	0.197
		post	47 (34 – 60)			post	44 (34 – 58)			post	46 (34 – 60)			
Left LF	0.447	pre	47 (34 – 58)	0.864.63±	0.295	pre	46 (34 – 56)	0.914.48±	0.093	pre	44 (32 – 64)	2.365.11±	**0.014***	0.283
		post	46 (34 – 60)			post	44 (36 – 56)			post	46 (38 – 68)			
Right Rotation	0.739	pre	70 (52 – 84)	2.926.72±	**0.022***	pre	70 (54 – 84)	3.606.32±	**0.003***	pre	70 (60 – 80)	1.886.08±	0.118	0.413
		post	70 (60 – 84)			post	72 (60 – 84)			post	72 (54 – 82)			
Left Rotation	0.872	pre	70 (50 – 80)	1.836.68±	0.089	pre	70 (54 – 82)	0.945.46±	0.405	pre	70 (60 – 80)	1.395.76±	0.150	0.710
		post	70 (60 – 84)			post	70 (50 – 82)			post	70 (60 – 80)			

p*: Kruskal Wallis-H Test, p**: Wilcoxon Signed Rank Test, Base: Baseline Comparison, Base: Baseline Comparison, CG: Control Group; Diff: Between Group Difference; LF: Lateral Flexion; PNFS: Proprioceptive Neuromuscular Facilitation Stretching Group; PNFP: Proprioceptive Neuromuscular Facilitation Pattern Group; post: After the study; pre: Before the study; SD: Standard Deviation; Δ: Within-group difference.

Table 4. Cervical Muscle Strength Before and After Intervention Within Group and Between Groups

	Base	PNFS (n= 36)				PNFP (n= 35)				CG (n= 33)				Diff
	p*		Median (Min – Max)	Δ	p**		Median (Min – Max)	Δ	p**		Median (Min – Max)	Δ	p**	p*
Flexion	0.951	pre	12.90 (6.2 – 26.9)	0.142.93±	0.918	pre	11.30 (6.1 – 22.3)	0.072.22±	0.881	pre	11.10 (4.7 – 21.2)	0.612.03±	0.070	0.467
		post	12.25 (6.1 – 31.5)			post	13.10 (7.1 – 24.5)			post	12.50 (6.8 – 24.5)			
Extension	0.939	pre	18.95 (7.8 – 34.2)	-0.053.64±	0.869	pre	18.40 (9.1 – 44.8)	0.673.60±	0.151	pre	18.50 (8 – 31.4)	0.653.32±	0.304	0.541
		post	19.10 (10.1 – 26.2)			post	19.5 (10.1 – 34.4)			post	19.80 (10.5 – 30)			
Right LF	0.800	pre	17.80 (7 – 29.1)	0.333.25±	0.372	pre	17.80 (8.1 – 33.3)	0.423.32±	0.426	pre	16.40 (7.6 – 28.4)	0.522.48±	0.131	0.907
		post	17.05 (9.9 – 31.9)			post	18.3 (10.1 – 31.5)			post	17.20 (9.7 – 32.3)			
Left LF	0.576	pre	17.05 (7.1 – 30.9)	0.253.63±	0.718	pre	17.60 (7 – 32.6)	0.393.86±	0.694	pre	15.30 (7 – 30.4)	0.722.98±	0.114	0.681
		post	16.50 (8.8 – 32.9)			post	17.60 (8.3 – 32.1)			post	16 (9.7 – 27.3)			
Right Rotation	0.197	pre	12.30 (7.6 – 20.2)	0.003.09±	0.795	pre	11.70 (7 – 19.9)	1.212.28±	**0.005***	pre	11.40 (6 – 19)	0.53±1.79	0.126	0.052
		post	12.45 (9.6 – 25.1)			post	12.60 (8.3 – 20.1)			post	11.70 (6.8 – 18.2)			
Left Rotation	0.758	pre	12 (7.3 – 21.1)	0.372.76±	0.514	pre	11.5 (7.4 – 37.6)	0.545.19±	**0.005***	pre	11.50 (5.5 – 22.4)	0.15±1.88	0.242	0.112
		post	12.5 (8.1 – 28.5)			post	12.40 (7.3 – 19.1)			post	11.40 (6.8 – 21.6)			

p*: Kruskal Wallis-H Test, p**: Wilcoxon Signed Rank Test, Base: Baseline Comparison, CG: Control Group; Diff: Between Group Difference; LF: Lateral Flexion; PNFS: Proprioceptive Neuromuscular Facilitation Stretching Group; PNFP: Proprioceptive Neuromuscular Facilitation Pattern Group; post: After the study; pre: Before the study; SD: Standard Deviation; Δ: Within-group difference.

ferroni correction showed a significant difference between PNFP-CG (p=0.017) but not between PNFS-CG (p=0.269) and PNFS-PNFP (p=0.799).

Within-group and between group analysis of ROM improvement showed in Table 3. In PNFS group, only right rotation was improved significantly (p=0.022). In PNFP group, both the extension (p=0.09) and right rotation (p=0.003) were improved significantly. CP group showed significant improvements in extension (p=0.037), right lateral flexion (p=0.020) and left lateral flexion (p=0.014). According to between-group analysis, there was no significant difference between groups in ROM in all movement directions (p>0.005).

The comparison of the improvement in MS within and between groups is shown in Table 4. When the MS analysis results were examined, there was no significant improvement in both CG and PNFS groups in any movement directions (p>0.005). The PNFP group showed a significant difference in right (p=0.005) and left rotation (p=0.005), whereas the rest of the movement directions showed no significant difference (p>0.005). The between-group analysis showed no significant difference (p>0.005).

DISCUSSION

The aim of the study was to compare the acute effects of PNF stretching and PNF strengthening on CP, ROM and MS among healthy university students. According to the results, PNF strengthening applied with resistive PNFP may improve CP and MS in most of the planes assessed in this study while these improvements are similar when compared to PNFS. To the best of our knowledge, this is the first study comparing the effectiveness of PNFS and PNF strengthening on the cervical region.

Proprioception

There are some studies in the literature done to reveal the effectiveness of PNFS on proprioception. In a study done by Younis et al. on the lower extremity, the PNFS hold-relax technique was performed on hip flexors and it did not influence the knee proprioception (13). Another study revealed that the PNFS CRAC technique performed on the hamstring muscle did not change the knee proprioception in both short and long terms (12). The current study supports the literature on this aspect by not showing a significant influence of PNFS on most of the directions for proprioception. Proprioception is regulated by the reflexive activity of muscle spindles, Golgi Tendon Organs and joint receptors (24). After stretching, nerves are expected to become less excitable and it causes a reflex inhibition (25). However, PNFS includes the isometric and concentric contraction of the target muscle in addition to static stretching. This may prevent negative changes in proprioception following PNFS, contrary to other stretching types.

On the other hand, the literature supports that both resistive training (26) and passive ROM exercises (27) may improve joint proprioception. In the current study, both the PNFP and CG showed significant improvement in proprioception in most directions after the intervention in accordance with the literature. The possible cause might be related to the warming-up effect of motion. Warming-up may increase the sensitivity of the proprioceptors and may help to detect the changes in the position (28). Moreover, passive motion may stimulate brain activity and help to increase the processing of proprioception (27).

In the comparison of the groups in the current study, there was a difference only in cervical flexion proprioception sense in favor of CG. A previous study revealed that the cervical flexors have a smaller activity than the cervical extensors in a neutral position among healthy subjects (29). This might be the reason why the difference between the groups can be seen only in the cervical flexion proprioception in the current study. If the flexor muscles' activity was lower than the other muscles in our participants, passive motion might cause a larger warming-up effect in these muscles and it might cause a greater increase in the sensitivity of the muscular proprioceptors. However, future studies comparing the activity level of all cervical muscles before and after such interventions will be required for detailed interpretation.

Range of Motion

Previous studies supported that PNFS has evidence to increase the ROM (30). However, in the current study, the PNFS group could not be improved significantly in terms of ROM. It was known that ROM improvements may not have lasted 6 minutes after PNFS (31). In this study, the duration till the second assessment was not noted and it could be a possible cause of not observing the improvements statistically in ROM.

A recent meta-analysis showed that resistance training done with external load might improve the range of motion. Even the exact reason is not understood well, it might be because of the stress on musculotendinous and connective tissue, and the changes in fascicle length (32). Similarly, our study revealed that there was a significant improvement in extension and right rotation ROM. Improvement seen in rotation might be because the rotational components of the PNF patterns are the key to maximum muscular activity (33). Additionally, just mentioned in the proprioception title, if the cervical extensors have a wider activity in our population, it might be the reason for the significant improvement seen in cervical extension ROM.

Within-group analysis showed that the CG has improved in more directions when compared to other groups. (14). Also, as stated before, passive motion has a warm-up effect on the muscles (27,28) This may help the musculoskeletal system to perform in wider ranges.

Muscle Strength

Literature supports that PNFS might cause a reduction in MS (30,34). After stretching, muscle's cross-bridge forming capacity could be reduced and it could take time to recover (35). Another possible cause might be that PNF may cause fatigue (14). The current study revealed that PNFS did not change MS significantly. The reason might be the duration between repetitions was long to prevent any kind of muscle fatigue. However, future studies comparing different resting durations between each PNFS application should be done to determine the effectiveness of resting duration on MS.

Most of the studies support at least a 6-week strengthening program for any gain in MS (36). However, a previous EMG study showed high muscle activations in almost all tested upper extremity muscles with PNFP, which indicates a higher ability to gain strength (15). Even if one session is not enough to improve strength, the PNFP group showed an acute improvement in rotational MS. The authors believed that this might be the potential effect of the PNF patterns which emphasize the rotational components (8). Improvements in MS of CG were not statistically significant as expected. This is because the CG underwent only PROM without causing any stretching, fatigue or active muscle contraction.

The current study has some limitations: (1) chronic adaptations or follow-up changes were not compared, (2) the effectiveness of PNFS and PNFP is analyzed only in healthy populations, not in case of pain and (3) the effectiveness of the techniques was not compared in different age groups. Future studies may focus on different populations, PNF techniques and protocols in terms of duration, number of repetitions to draw more conclusive results.

In conclusion, the current study showed that PNFP is promising to improve CP, ROM and MS at the same time. There is a lack of studies in the literature regarding the use of different PNF techniques applied to the cervical region on CP and the data in this study suggest the need for further investigation for the use of PNF on the cervical region and also the neurophysiological mechanisms behind the use of PNF techniques.

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Explanations: This study has been never presented or published on a scientific platform.

Ethical Approval: The study protocol was accepted by Medical Ethics Committee of Medical, Surgical and Drug Researches of Yeditepe University Medical Faculty (Decision no: 1028).

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