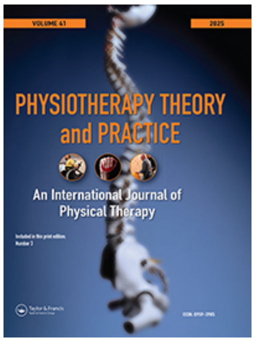

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Immediate Effects of Mobilization With Movement Technique on Cervical Muscle Stiffness, Pain, and Range of Motion in Individuals With Mechanical Neck Pain: A Double-Blind Randomized Controlled Trial

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CASE REPORT

Immediate Effects of Mobilization With Movement Technique on Cervical Muscle Stiffness, Pain, and Range of Motion in Individuals With Mechanical Neck Pain: A Double-Blind Randomized Controlled Trial

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ABSTRACT

Background: Mulligan sustained natural apophyseal glide (SNAG) is a mobilization technique that aims to reduce pain and improve function by correcting positional errors in the facet joint.
Purpose: To investigate the immediate effects of the Mulligan SNAG application on muscle stiffness, pain, pressure pain threshold (PPT) and range of motion (RoM) in patients with chronic mechanical neck pain.
Methods: A randomized, double-blind trial was conducted. Forty individuals with chronic mechanical neck pain (mean age = 39.35 ± 6.68 years) were randomized into two groups: Mobilization with movement group (MWMG), and sham group (SG). Muscle stiffness was measured with MyotonPro, pain intensity with Numerical Pain Rating Scale, cervical RoM with a digital inclinometer, and PPT with an algometer. Measurements were performed pre-and 5 minutes post-intervention in a single session.
Results: Muscle stiffness significantly changed in the MWMG for the left trapezius and right cervical extensors ($p = .003$, effect size (ES) = 0.42; $p = .031$, ES = 0.49, respectively), whereas no significant changes were observed in the SG ($p = .097$, ES = 0.12; $p = .270$, ES = 0.22, respectively). The MWMG showed improvements in pain ($p = .001$, ES = 0.70) and RoM (right: $p = .0001$, ES = 0.89; left: $p = .0001$, ES = 0.99). The SG also showed improvements in pain ($p = .0001$, ES = 0.76) and RoM (right: $p = .0001$, ES = 0.49; left: $p = .0001$, ES = 0.35). PPT improvements were observed in the MWMG for right and left trapezius ($p = .0001$, ES = 1.21; $p = .040$, ES = 0.43, respectively), whereas no significant changes occurred in the SG ($p = .713$, ES = 0.03; $p = .839$, ES = 0.01, respectively).
Conclusion: The mobilization with movement technique leads to significant immediate improvements in muscle stiffness and pain-related parameters in individuals with chronic neck pain.

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Neck pain; manual therapy; muscle stiffness; range of motion

Introduction

Neck pain is a cause of disability that negatively affects the quality of life by causing pain and difficulty in daily life activities, and it imposes a burden on the economy (Safiri et al, 2020). Neck pain is often mechanical in origin. Mechanical neck pain is defined as pain localized in the cervical spine or cervicothoracic junction that originates from non-traumatic causes. The intensity of the pain increases with cervical movement and palpation of the cervical region muscles (Masaracchio et al, 2019). Mechanical neck pain typically has an insidious onset and may result from factors such as poor posture, improper body mechanics, reduced flexibility of the neck region, and strenuous working conditions, while psychological factors may contribute to its chronicity (Dennison and Leal, 2015). The underlying mechanisms of the persistence, recurrence, and progression of neck pain are still not fully understood. However, the role of neck muscles in cervical joint positioning and head motor control, along with reduced proprioception, is thought to be a determining factor in this process (Treleaven, 2008). Additionally, increases in skeletal muscle stiffness may be associated with the severity of neck pain and disability, further contributing to the complexity of its underlying causes (Opara and Kozinc, 2023).

Current and most effective treatment approaches for mechanical neck pain include cervical range of motion (RoM) exercises, scapulothoracic and upper extremity flexibility, strengthening and endurance exercises, as well as manual therapy techniques

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(Blanpied et al, 2017). These approaches provide long-term benefits in reducing pain and improving functionality (Gross et al, 2016). In particular, manual therapy applications such as neck manipulation and mobilization are known to play an important role in the treatment of neck pain (Blanpied et al, 2017).

It is known that small positional errors in the joint can lead to restrictions in physiological movements (Ganesh, Mohanty, Pattnaik, and Mishra, 2015). The Mulligan technique, specifically the sustained natural apophyseal glide (SNAG) application, which is one of the mobilization techniques performed with movement, primarily aims to correct positional errors in the facet joint. Additionally, it is argued that SNAG increases pain-free RoM and positively affects the entire functional spinal unit (Exelby, 2002). The Mulligan SNAG technique applied to the cervical region is a manual therapy technique in which a sustained glide is applied at the symptomatic level of cervical hypomobility while actively maintaining the RoM (Mulligan, 2004). The sliding movement applied with the cervical SNAG intervention separates the facet joint surfaces. This mechanism can be effective in stretching adhesions, thus aiding in the relief of pain and spasms (Hearn and Rivett, 2002).

It is known that a single session of lumbar SNAG application in patients with low back pain leads to a reduction in muscle stiffness in the acute phase, but its effect on cervical region muscle stiffness remains unclear (Çirak et al, 2021). In the literature, the Mulligan SNAG method has been proven to have both immediate and long-term positive effects on pain, RoM, and functionality in patients with neck pain (Andrews et al, 2018; Ganesh, Mohanty, Pattnaik, and Mishra, 2015; Ozlu and Sahin, 2024). However, there is a noticeable lack of studies examining the effects of this technique on muscle stiffness associated with neck pain. Muscle stiffness is considered an important parameter in individuals with chronic mechanical neck pain, as increased stiffness may contribute to pain, restricted movement, and impaired muscle function. Evaluating muscle stiffness provides an objective assessment of soft tissue properties, helping to better understand its relationship with the underlying mechanisms of chronic mechanical neck pain and evaluate the effects of interventions targeting this parameter. Thus, it provides valuable information beyond traditional pain and RoM measures. Therefore, the aim of thestudy was to investigate the immediate effects of the Mulligan SNAG application on muscle stiffness, pain, pressure pain threshold (PPT) and RoM in patients with chronic mechanical neck pain. Our hypothesis was that the Mulligan SNAG technique would have an immediate positive effect on muscle stiffness, pain, PPT, and RoM in patients with chronic mechanical neck pain.

Materials and methods

Study design

This clinical study was designed as a prospective, randomized, double-blind trial. It was conducted in the laboratories of Istanbul University-Cerrahpasa, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation. The research protocol was designed according to CONSORT standards. The study was approved by the Scientific Research and Publication Ethics Committee of Istanbul Kent University Faculty of Health Sciences (ethics committee approval number: E-10420511-050 -29,364). Patients deemed eligible for participation were thoroughly informed about the study, and an informed consent form was signed indicating their voluntary participation. This randomized clinical trial is registered on ClinicalTrials.gov under the code NCT06396104 and was conducted in accordance with the Declaration of Helsinki. All mandatory laboratory health and safety procedures were strictly followed during the experimental work reported in this study.

Participants

The study was conducted between February 2024 and April 2024 at the laboratories of Istanbul University-Cerrahpaşa. All participants were diagnosed with mechanical neck pain by an experienced specialist physician through a comprehensive clinical evaluation to exclude other potential causes of pain and confirm its mechanical origin. Subsequently, all participants underwent a physical examination to assess eligibility criteria, which included joint mobility testing, and neurodynamic examination of the cervical and cervicothoracic regions. To differentiate other cervical pathologies, cervical provocation tests were performed. To identify potential upper cervical mobilization limitations, safety tests for the stability of the cervical segments were performed, including the alar and transverse ligament tests, as well as vertebral artery test. Following this evaluation, they were scheduled for routine physiotherapy sessions, and the study intervention was conducted before the initiation of their standard treatment to assess the immediate effects of the technique without interfering with their planned care.

Individuals aged 20 to 50, who had been experiencing widespread neck pain for more than 3 months, with symptoms of pain aggravated by neck movements or palpation, Neck Disability Index (NDI) score exceeding 10% (Cleland, Childs, and Whitman, 2008), and who volunteered to participate in the study, were included. Once the target number of volunteers with mechanical neck pain was reached, recruitment was closed. Exclusion criteria included individuals with a history of cervical trauma or cervical surgery, congenital torticollis, cancer, pregnancy, cervical radiculopathy, myelopathy or spondylotic changes, facet joint arthritis or any disc pathology, a diagnosis of fibromyalgia syndrome, signs of vertebrobasilar insufficiency, upper cervical spine ligament instability, or those using steroids or muscle relaxants. Individuals who had received exercise, physical modalities, or manual therapy techniques for cervical spine pain management within the past 3 months were also excluded. Additionally, those who declined to participate or did not attend the assessment were excluded from the study.

Forty individuals diagnosed with mechanical neck pain who met the inclusion criteria participated in the study. They were divided into two groups using a simple randomization method (ratio 1:1): The mobilization with movement group (MWMG) ($n = 20$) and the sham group (SG) ($n = 20$). Randomization was carried out using the online randomization web service Research Randomizer (https://www.randomizer.org). Simple randomization procedures (computer-generated random numbers) were performed, and numbered index cards containing the random assignments were sequentially prepared by a researcher (F.B.) who was not involved in the clinical aspects of the study to ensure allocation concealment. The index cards were folded and placed into sealed envelopes, which were given to the physiotherapist (K.B) responsible for performing the interventions. The physiotherapist opened each envelope and assigned participants to the groups according to the selected index card. The interventions were carried out by the same physiotherapist. Assessments were performed by a different physiotherapist (A.E.Ö.), who was blinded to group allocation, both before and immediately after the intervention (blinded assessor). The participants were also blinded to the group they were assigned to.

Outcome measures

The demographic characteristics of all participants, including height, weight, body mass index, age, presence of chronic illnesses, previous surgeries, occupation, and education level were recorded using a medical history form. The NDI is a reliable and valid measure for determining the level of disability in patients with chronic mechanical neck pain. It consists of 10 sections addressing pain severity, personal care, lifting, reading, headaches, concentration, work, driving, sleep, and recreation. Each section is scored from 0 (no disability) to 5 (complete disability) (Telci et al, 2009; Vernon and Mior, 1991). NDI score exceeding 10% was our criterion for inclusion of patients in the study. Therefore, the index was assessed only once before the application.

Muscle stiffness and subjective pain intensity was assessed as the primary evaluation parameters using the MyotonPro device and the Numerical Pain Rating Scale (NPRS). Secondary evaluation parameters included cervical joint rotation RoM assessed with a digital inclinometer, PPT measured with an algometer.

Mechanical oscillations of the soft tissues caused by a mechanical impact in the upper trapezius, sternocleidomastoid, and neck extensors were measured using the portable MyotonPRO device (Muomeetria Ltd., Tallinn, Estonia) (Gavronski, Veraksitš, Vasar, and Maaroos, 2007). A short mechanical impulse was applied to the skin over the muscle and then quickly released. At the end of the measurement, muscle stiffness results were obtained as output. To ensure that measurements could be repeated at the same location, the skin was marked with a pen. In all applications, the MyotonPRO probe was placed perpendicular to the skin, and three measurements were recorded using the 10-pulse multiple scanning mode with a 1-second interval between each measurement. The average of these measurements was used for further analysis. The measurements of stiffness as one of the mechanical properties of the muscle have been reported to show very good to excellent intrarater reliability (ICC: 0.77–0.85) (Taş, Yaşar, and Kaynak, 2021).

Measurement positions for each muscle were carefully standardized to ensure consistency (Figure 1). For the upper trapezius muscle, Participants were placed in a prone position on the examination table, with their arms relaxed at their sides and wrists in pronation. Measurements were taken from the midpoint between the lateral edge of the acromion and the spinous process of C7 (ICC (95% CI): 0.82 (0.62–0.92)) (Taş, Yaşar, and Kaynak, 2021). For the sternocleidomastoid muscle, participants lay in a supine position with a soft pillow placed under their necks. Measurements were taken from the midpoint between the sternum and the mastoid process (ICC (95% CI): 0.85 (0.69–0.93)) (Taş, Yaşar, and Kaynak, 2021). Lastly, for the servical extensor muscles, participants were positioned in a prone position on the examination table, with their arms relaxed at their sides and wrists in pronation.

Figure 1. Muscle stiffness measurements with MyotonPro device and mobilization with movement application. a) sternocleidomastoid muscle, b) cervical extensor muscles, c) upper trapezius muscle, d) mulligan sustained natural apophyseal glide application.

Measurements were taken 2 cm laterally from the spinous process, centered over the fourth cervical vertebra (ICC (95% CI): 0.77 (0.51–0.89)) (Taş, Yaşar, and Kaynak, 2021).

The NPRS, which is reported in the literature as a reliable and valid scale for determining pain intensity, was used to assess the pain severity in patients with neck pain. On the NPRS, 0 indicates no pain, while 10 represents unbearable pain. The NPRS demonstrates a high level of intrarater reliability in patients with mechanical neck pain (ICC (95% CI): 0.76 (0.51, 0.87)) (Cleland, Childs, and Whitman, 2008). The MDC for NPRS was determined to be 2.1 points, and the MCID was 1.3 points (Cleland, Childs, and Whitman, 2008).

For joint RoM, cervical right and left rotation movements were measured. An ACUMAR dual digital inclinometer (ACUMAR Model 002; Lafayette Instrument Company, Lafayette, Indiana) was used, which has excellent intrarater reliability (ICC (95% CI): 0.96 (0.91, 0.98) (Hoving et al, 2005). The RoM measurements displayed on the screen of the digital inclinometer were recorded. The MDC for right and left cervical rotation was determined to be 6.1° and 4.9° (Audette, Dumas, Côté, and Serre, 2010).

To assess the PPT of the participants, a handheld pressure algometer with a 1 cm^2 circular probe surface, capable of measuring pressure forces up to 10 kg (22 lbs × 1/4 lb and 10 kg × 100 g), was used (Baseline Dolorimeter 12–1442 algometry, Enterprises Fabrication, New York, USA) (Griefahn, Oehlmann, Zalpour, and Piekartz, 2017). The PPT measurement was applied approximately 5 to 8 cm superomedial to the upper angle of the scapula on the upper fibers of the trapezius muscle. Standard instructions were provided during the assessment, such as, "I will start applying pressure to your muscle. Please let me know when the sensation changes from a comfortable pressure to a slightly uncomfortable pain." Initially, participants were familiarized with the test by applying pressure to the biceps femoris muscle. The interval between each application at the predetermined points was set to 30–60 seconds, each measurement was repeated three times, and the average value was recorded. The PPT measurement in individuals with neck pain demonstrated excellent intrarater reliability (ICC (95% CI): 0.96 (0.91, 0.98)), and the MDC was 0.48 kg (Walton et al, 2011).

Follow up

All measurements were conducted twice: immediately before the mobilization and sham applications, and again 5 minutes after the interventions. The acute effects of these single-session interventions were evaluated, and patients were not followed up after the study.

Interventions

The participants allocated in the MWMG (Group 1) were treated by a physiotherapist experienced in applying the Mulligan Concept. In this study, participants underwent a standardized Assessment-Treatment-Reassessment (ATR) protocol in a single session to evaluate the immediate effects of Mulligan SNAG (Satpute, Bedekar, and Hall, 2021). The ATR protocol began with pre-intervention assessments, followed by a single session of either real or sham therapy. Immediately afterward, post-intervention assessments were applied. The intervention was conducted in a sitting position using a chair with back support while the patients' feet were on the ground. Initially, the painful or hypomobile spinal segment during cervical rotation joint movements was identified (Gautam, Dhamija, and Puri, 2014). Participants were advised to inform the researcher if they were uncomfortable at any time and describe the painful segment. The physiotherapist placed the medial edge of the distal phalanx of one thumb on the transverse process contralateral to the direction of restriction. The patient was then asked to turn their head toward the painful side at a speed and distance that was comfortable to them, ensuring the movement was pain-free (Satpute, Bedekar, and Hall, 2021). The physiotherapist applied a gentle postero-anterior force toward the patient's eye sockets using the thumb of the other hand to provide support on the transverse process (Jin et al, 2023). The glide provided by the thrust was maintained while the patient actively performed the unilateral cervical rotation movement and held it for a few seconds at the end of the movement (Figure 1). To enhance the effect, the patient applied pressure with their hand on their cheek when pain-free active joint RoM was achieved what is called "overpressure" in Mulligan Concept, and the application was repeated six times. During the application of the procedure, the participant was expected to be entirely symptom-free. If the joint movement was painful, attempts were made on the transverse process of superior or inferior segment. Pain-free joint movement was applied for six repetitions and three sets (Mulligan, 2004). If participants exhibited bilateral rotational restriction and pain, the application was performed in both directions.

Patients in the SG (Group 2) were seated in a chair with back support, and the painful spinal segment during cervical joint movements was identified. No glide movement was performed on the transverse process of this segment. Instead, sensory input was provided only to the transverse process of the relevant segment by placing thumb as in real SNAG, and the patient was instructed to maintain the active rotation movement and hold it for a few seconds at the end of the movement. The application was completed with six repetitions and three sets (Çirak et al, 2021).

Statistical analysis

The researcher conducting the statistical analysis was blinded to the distribution of the groups. The sample size was determined based on the primary evaluation parameters of the study using the G-Power Version 3.1.9.5 program. Since we did not come across a study examining the immediate effects of Mulligan SNAG mobilization on muscle stiffness in mechanical neck pain, the effect size (ES) was estimated based on similar studies. One study using the same methodology on lumbar muscle stiffness reported an ES exceeding 1.0 after a single session (Çirak et al, 2021). Additionally, studies on posterior-anterior mobilization in mechanical neck pain have shown large ES for pain outcomes (Kanlayanaphotporn, Chiradejnant, and Vachalathiti, 2010). Based on these findings, an ES of 0.90 was estimated, with a significance level of 0.05 and 95% power. The required sample size was calculated as 38 (19 per group), with an additional 5% dropout rate, resulting in a total of 40 participants.

Statistical analysis was performed using the "Statistical Package for Social Science for Windows version 22.0." The normality of discrete and continuous quantitative data was assessed using the Shapiro-Wilk test. Demographic data and evaluated parameters were presented as mean and standard deviation for normally distributed variables. As the evaluated parameters were normally distributed, the differences in quantitative data between the independent groups were analyzed using the Independent Samples t-Test, while the differences in pre- and post-intervention quantitative data were analyzed using the Paired Samples t-Test. The ES was calculated using the following formula: absolute difference between measurements/standard deviation of the initial measurement value. An ES of 0.20 to 0.50 was considered small, 0.51 to 0.80 as medium, and 0.81 and above as large (Pallant, 2020). A statistical significance level of $p < .05$ was accepted.

Results

Fifty-one participants with chronic mechanical neck pain were assessed for eligibility; however, seven of them did not wish to volunteer for the study, and four did not meet the inclusion criteria. A total of 40 patients completed the study and were included in the analysis, with 20 patients randomly assigning for each intervention group

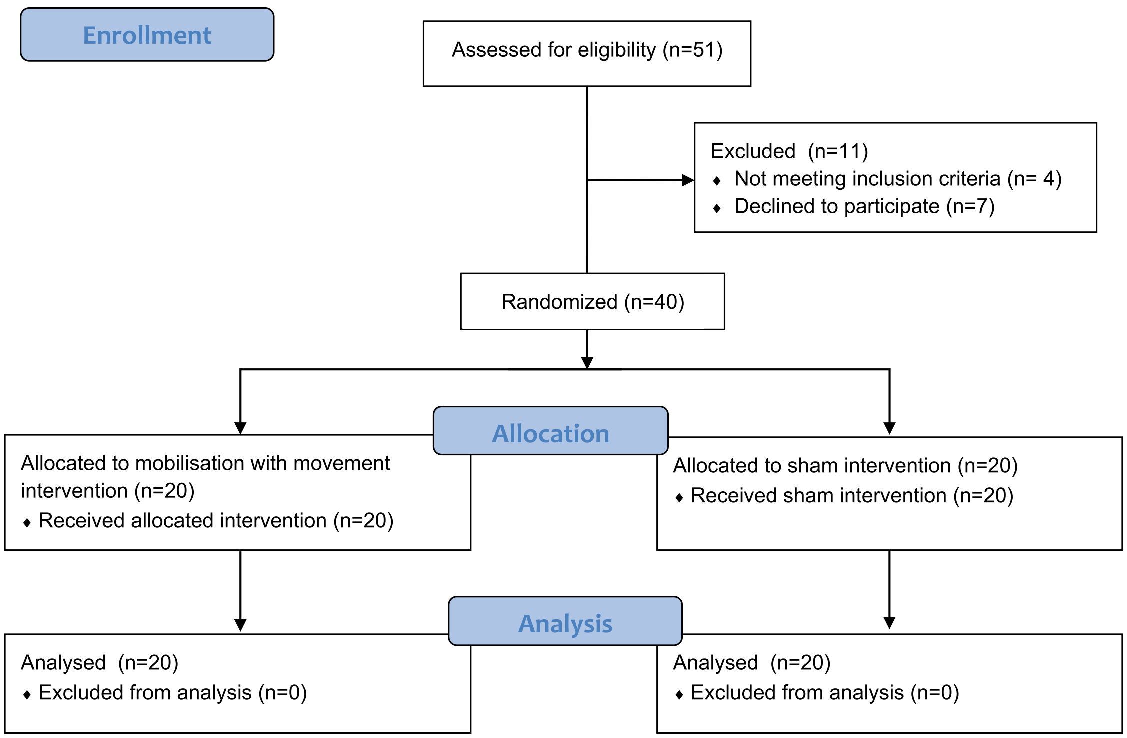

Figure 2. Flow chart of the study.

(Figure 2). Total, 18 right-sided (MWMG = 6), 20 left-sided (MWMG = 12), and 2 bilateral (MWMG = 2) pain cases were observed. The mean pain duration was 7.20 (3.69) months in MWMG and 7.75 (3.83) months in SG. All variables complied with normal distribution within groups and no statistically significant difference was observed between groups in baseline demographic evaluation ($p > .05$) (Table 1).

When examining muscle stiffness measurements, a significant reduction in the trapezius and right cervical extensors was observed only in the MWMG after the intervention ($p < .05$), while no significant difference was observed in the SG ($p > .05$). Except for the right extensor muscle stiffness (ES: 0.49), the ES's were determined as small in all parameters. The actual ES obtained in our study for muscle stiffness variables were lower than the estimated ES. When the mean differences of the groups were compared, no significant difference was observed in the effects of the treatments on muscle stiffness variables ($p > .05$) (Table 2).

When the within-group changes were analyzed; neck pain, right and left cervical rotation RoM showed a statistically significant difference in both groups after the interventions ($p < .05$). The mean differences (MD) in NPRS scores in both groups (MWMG MD: 1.65, SG MD: 1.40) exceeded the

Table 1. Baseline demographics of groups.

		MWMG Mean (sd)	SG Mean (sd)	p[a]
Age (year)		41.30 (6.44)	37.40 (6.50)	0.060
Height (m)		1.67 (0.92)	1.68 (0.89)	0.666
Weight (kg)		63.85 (13.39)	69.75 (14.32)	0.186
BMI (kg/m^2)		24.38 (3.36)	24.38 (3.49)	0.120
NDI		16.45 (7.00)	20.85 (8.10)	0.070
Symptom duration (month)		7.20 (3.69)	7.75 (3.83)	0.647
Gender (n) (F/M)		15/5	12/8	0.311[b]
Painful side	Right	6	12	0.091[b]
	Left	12	8	
	Bilateral	2	0	
Education level	Primary education	2	1	0.882[b]
	Secondary education	6	7	
	Undergraduate	10	9	
	Postgraduate	2	3	

MWMG: Mobilization With Movement Group, SG: Sham Group, sd: Standard deviation, F: Female, M: Male, BMI: Body mass index, NDI: Neck Disability Index, Independent samples t-test[a], Chi-square test[b].

Table 2. Differences between and within groups in muscle stiffness.

Outcome Measure	Group	Pre-intervention Mean (sd)	Post-intervention Mean (sd)	p[a]	ES	Mean difference (95% CI)	p[b]
Right Trapezius Stiffness	MWMG	251.95 (62.54)	236.50 (54.84)	0.104	0.24	−15.45 (−34.41, 3.51)	0.200
	SG	265.35 (91.18)	267.25 (81.95)	0.847	0.02	1.90 (−18.47, 22.27)	
Left Trapezius Stiffness	MWMG	241.65 (44.89)	222.55 (34.07)	**0.003**	0.42	−19.10 (−31.04, −7.15)	0.302
	SG	268.95 (84.78)	258.50 (80.09)	0.097	0.12	−10.45 (−22.96, 2,06)	
Right SCM Stiffness	MWMG	243.70 (49.15)	231.70 (39.60)	0.111	0.24	−12.00 (−27.03, 3.03)	0.355
	SG	240.95 (56.52)	237.45 (43.19)	0.536	0.06	−3.50 (−15.13, 8.13)	
Left SCM Stiffness	MWMG	257.15 (56.07)	251.00 (57.09)	0.335	0.10	−6.15 (−19.17, 6.87)	0.737
	SG	241.35 (47.80)	231.70 (33.87)	0.256	0.20	−9.65 (−26.91, 7.61)	
Right Extensor Stiffness	MWMG	346.30 (40.71)	326.30 (50.14)	**0.031**	0.49	−20.00 (−37.96, −2.03)	0.505
	SG	319.65 (49.66)	308.45 (72.45)	0.270	0.22	−11.20 (−31.83, 9.43)	
Left Extensor Stiffness	MWMG	351.15 (53.73)	335.70 (54.61)	0.069	0.28	−15.45 (−32.24, 1.34)	0.917
	SG	324.00 (51.43)	307.35 (64.13)	0.057	0.32	−16.65 (- 33.84, 0.54)	

MWMG: Mobilization With Movement Group, SG: Sham Group, sd: Standard deviation, SCM: Sternocleidomastoid muscle, ES: Effect Size, CI: Confidence Interval, Paired samples t-test[a], Independent samples t-test[b].

Table 3. Differences between and within groups in pain, range of motion and pressure pain threshold.

Outcome Measure	Group	Pre-intervention Mean (sd)	Post-intervention Mean (sd)	p[a]	ES	Mean difference (95% CI)	p[b]
NPRS	MWMG	6.00 (2.36)	4.35 (2.25)	**0.001**	0.70	−1.65 (−2.49, −0.80)	0.573
	SG	5.75 (1.83)	4.35 (1.56)	**0.0001**	0.76	−1.40 (−1.75, −1.04)	
Right Rotation RoM	MWMG	56.00 (8.90)	64.00 (7.96)	**0.0001**	0.89	8.00 (5.40, 10.59)	0.254
	SG	56.47 (11.84)	62.37 (13.26)	**0.0001**	0.49	5.90 (3.10, 8.68)	
Left Rotation RoM	MWMG	52.70 (9.88)	62.50 (10.34)	**0.0001**	0.99	9.80 (7.15, 12.45)	**0.003**
	SG	57.68 (12.96)	62.21 (13.30)	**0.0001**	0.35	4.55 (2.42, 6.67)	
Right Trapezius PPT	MWMG	3.06 (0.65)	3.85 (0.69)	**0.0001**	1.21	0.78 (0.55, 1.01)	**0.0001**
	SG	3.56 (1.06)	3.52 (1.09)	0.713	0.03	−0.04 (−0.26, 0.18)	
Left Trapezius PPT	MWMG	3.41 (0.86)	3.78 (0.97)	**0.040**	0.43	0.36 (0.01, 0.71)	0.064
	SG	3.63 (1.28)	3.60 (1.48)	0.839	0.01	−0.02 (−0.27, 0.22)	

MWMG: Mobilization With Movement Group, SG: Sham Group, sd: Standard deviation, NPRS: Numeric Pain Rating Scale, RoM: Range of Motion, PPT: Pressure Pain Threshold, ES: Effect Size, CI: Confidence Interval, Paired samples t-test[a], Independent samples t-test[b].

MCID (1.3), while the actual effect size (0.70, 0.76) obtained was moderate and lower than the estimated effect size (0.90). In the MWMG, improvements in cervical rotation exceeded the MDC, with right rotation showing an MD of 8° (MDC: 6.1°) and left rotation showing an MD of 9.8° (MDC: 4.9°). However, in the SG, these improvements did not exceed the MDC, with right rotation showing an MD of 5.9° and left rotation an MD of 4.55°. When the within-group changes for right and left upper trapezius PPT variables were analyzed; a statistically significant difference was seen only after the mobilization interventions ($p < .05$).

When the treatment effects were evaluated between the groups, no statistically significant difference was observed for neck pain, right cervical rotation RoM and left trapezius PPT variables ($p = .57$, $p = .25$, $p = .064$, respectively), while a statistically significant difference was observed for left cervical rotation RoM and right trapezius PPT variables ($p < .05$) (Table 3). This difference was primarily attributed to the MWMG, which showed greater improvements compared to the SG for both of the variables. For left cervical rotation RoM, a high ES was observed for the MWMG (ES: 0.99) compared to the SG (ES: 0.35). Similarly, for right trapezius PPT, a high ES was observed for the MWMG (ES: 1.21), whereas it was small for the SG (ES: 0.03). The PPT of the right trapezius showed an improvement exceeding the MDC, whereas this improvement was not observed on the left side.

Discussion

In this study, the acute effects of the mobilization with movement technique were evaluated in individuals with chronic mechanical neck pain. The technique demonstrated effectiveness in improving muscle stiffness and PPT variables compared to the sham application. While significant improvements were observed in both groups for pain and rotation RoM variables compared to pre-application values, the technique showed superior effectiveness over the sham application specifically in the left cervical rotation RoMand the PPT measured from the right upper trapezius. Additionally, no significant differences were found between the groups in terms of demographic characteristics. In particular, the analysis revealed no significant difference in education level, suggesting that this factor did not influence the observed outcomes. Since the Mulligan technique requires active patient participation during its application, it is considered that there would be no difference in treatment adherence between individuals who has similar education levels, and this factor would not affect the observed outcomes.

In studies conducted with patients suffering from chronic neck pain, it has been found that the stiffness levels of the upper trapezius, levator scapulae, and sternocleidomastoid muscles, measured using shear wave and real-time tissue ultrasound elastography methods, are higher compared to asymptomatic controls (Ishikawa et al, 2017; Taş, Korkusuz, and Erden, 2018). To date, no study has been identified investigating the effects of Mulligan SNAG, a mobilization-with-movement technique, on muscle stiffness in individuals with mechanical neck pain. However, a randomized controlled trial has examined the immediate effects of the Mulligan SNAG technique on erector spinae and multifidus muscle stiffness in individuals with nonspecific chronic low back pain. When a single session of SNAG was compared with sham SNAG, it was found that muscle stiffness, measured via ultrasound shear wave elastography, significantly decreased in the SNAG group (Çirak et al, 2021).

In our study, the mechanical properties of the muscles evaluated as primary variables can be assessed non-invasively using various methods, including myotonometry measurements, shear wave and strain ultrasound elastography, or MRI elastography (Brandenburg et al, 2014; Dresner et al, 2001). However, some of these methods are costly, depend on the skill and experience of the evaluator, and can be time-consuming. MyotonPRO, used for measurements in this study, offers a portable, easy-to-learn, and practical method for performing measurements in different settings, making it easier to integrate into clinical environments compared to other measurement methods (Taş, Korkusuz, and Erden, 2018; Taş, Yaşar, and Kaynak, 2021). Although most studies to date have focused on the lower extremities, a recent review investigating studies on the relationship between shear wave elastography and myotonometry measurements has revealed a generally strong correlation between these two methods (Ličen, Opara, and Kozinc, 2024).

This study, conducted to address the increased muscle stiffness thought to be associated with pain in individuals with mechanical neck pain, concluded that the stiffness of the upper fibers of the left trapezius muscle and the right neck extensor muscles tended to decrease compared to pre-application values. During the SNAG intervention, the glide movement applied in conjunction with motion separates the facet joint surfaces. This glide movement facilitates the release of meniscoid structures trapped between the facet joints or allows meniscoid structures that have protruded outward to return to their intra-articular position, effectively resolving adhesions and stimulating the improvement of spasms (Hearn and Rivett, 2002). We believe that mobilization with movement techniques, through this mechanism, contribute to the reduction of pain and muscle stiffness.

Among the 20 patients in the MWMG, 14 reported restricted left cervical rotation ROM and pain accompanying movement, including 2 patients with bilateral symptoms. The Mulligan mobilization applied with left rotation may have contributed to a reduction in muscle stiffness in the left trapezius by facilitating pain-free joint movement. According to the application procedure, when working in the left rotation direction, the hand contact was placed on the transverse process of the right side. It is known that, the glide applied to the facet joint during mobilization provides sensory input to joint and muscle receptors, potentially leading to proprioceptive improvement (Exelby, 2002). Proprioception is a fundamental component of the somatosensory system, integrating sensory input, central processing, and motor output (Hlaing, Puntumetakul, Khine, and Boucaut, 2021). These proprioceptive changes may have influenced the joints and muscles on the left side, contributing to a reduction in muscle stiffness in the right cervical extensor muscles.

Mobilization with movement techniques are known to be effective in the treatment of neck pain. The placebo effects arising from sham interventions are no longer seen as indicators of an ineffective treatment but rather as a mechanism that explains part of the treatment effects of all pain interventions, including manual therapy (Bialosky, Bishop, George, and Robinson, 2011). This means that while placebo responses may not directly correspond to the physical efficacy of an intervention, they can still explain a portion of the therapeutic benefit. The understanding of these placebo mechanisms encourages practitioners to consider them as part of the treatment process, aiming to maximize their positive influence on pain reduction.

It has been mentioned that the pain inhibition effect of manual therapy arises from a series of systemic neurophysiological responses triggered by temporary mechanical stimuli applied to the tissue (Bialosky et al, 2018). Manual therapy techniques create a sympathetic stimulatory effect through non-opioid analgesic mechanisms, and it has been suggested that touch may play an important role in the formation of this effect (Bowler, Browning, and Lascurain-Aguirrebeña, 2017). A guideline recommends the application of manual therapy techniques for individuals with acute, subacute, or chronic neck pain (Blanpied et al, 2017).

Additionally, systematic reviews on this subject have concluded that cervical mobilization techniques provide a benefit in reducing pain in patients with acute and subacute neck pain in the short term (Furlan et al, 2012; Vernon, Humphreys, and Hagino, 2005). In this study, the mobilization with movement technique applied to individuals with chronic mechanical neck pain demonstrated significant improvement in the pain variable. The MWMG showed a MD of 1.65 points, while the SG had a MD of 1.4 points, both exceeding the MCID threshold for NPRS (1.3 points), indicating clinically meaningful improvements in pain. Although the SG demonstrated a slightly higher effect size (0.76) compared to the MWMG (0.70), the difference between the two groups was minimal. Both ES fall within the moderate ES range (0.50–0.79), indicating that both interventions were effective in reducing pain. It is believed that the reason for the sham intervention being effective in reducing pain, is due to the sensory input provided to the individuals during the sham application.

Brian Mulligan suggested that small positional errors in the joint can lead to limitations in physiological movements (Ganesh, Mohanty, Pattnaik, and Mishra, 2015). The Mulligan SNAG technique applied to the cervical region is a manual therapy technique where a continuous glide is applied to the symptomatic level of cervical hypomobility while actively maintaining the RoM n in the spinal weight-bearing position (Mulligan, 2004). As a result of this therapeutic approach, literature indicates an immediate improvement in the pain-free RoMat the involved joints (Exelby, 2002). It has previously been demonstrated that glide and distraction mobilization techniques applied to the lower cervical region in individuals with chronic neck pain lead to significant improvements in rotation RoM and pain levels (Creighton, Gruca, Marsh, and Murphy, 2014). In a randomized controlled study involving individuals with mechanical neck pain, cervical SNAG technique applied during each session, in addition to a two-week conventional treatment program consisting 10 sessions of electrophysiological agents, RoM, and stretching exercises, was reported to result in greater improvement in right and left rotation, lateral flexion, flexion, extension RoM, pain, and disability after two weeks compared to conventional treatment alone (Ozlu and Sahin, 2024). In light of these informations, mobilization techniques show positive effects on cervical rotation, both in immediate application and when integrated into conventional treatment. However, the key question in this study is whether this effect creates a significant difference when compared to the sham application.

In a study conducted with individuals experiencing mechanical neck pain, the effects of real or sham upper thoracic Mulligan mobilization, combined with conventional physiotherapy over 11 sessions during two weeks, were examined on RoM, pain, and disability. Although significant improvements were observed in all groups, the greatest improvement was noted in the real mobilization group. Additionally, the sham group demonstrated greater improvement in disability and cervical extension RoM compared to conventional physiotherapy alone (Cevik, Pala, and Gunaydin, 2024).

In another randomized controlled study investigating the more acute effects of sham applications, no significant post-application differences in immediate rotational RoM were observed between ipsilateral and contralateral SNAG applications and sham interventions in healthy adults. However, significant improvements were noted in both groups (Bowler, Browning, and Lascurain-Aguirrebeña, 2017). Similarly, in our study, cervical rotational RoM showed a significant increase after the application in both groups, supporting previous findings. Moreover, intergroup comparisons revealed a statistically significant increase in left rotational RoM in the SNAG group. In mobilization with movement techniques, the repetitive active RoM movements performed during the application are also executed in sham applications without the glide component, possibly explaining the significant RoM increase observed in the sham group. However, as previously supported in the literature, it is evident that mobilization techniques combined with treatment are more effective than sham applications.

The literature indicates that mobilization techniques can positively influence PPT in individuals with neck pain, thereby reducing pain. In a randomized controlled trial investigating the effects of adding manipulation and/or mobilization to an exercise program for individuals with chronic neck pain and upper cervical spine dysfunction, participants underwent a home exercise program alongside four 20-minute weekly sessions over four weeks. At 1st, 3rd, and 6th months, increases in PPT measured at the C2–3 zygapophyseal joint and suboccipital muscles, as well as reductions in pain, were observed (Rodríguez-Sanz et al, 2020). In another randomized controlled trial, a single session of upper cervical mobilization applied to individuals with chronic neck pain demonstrated immediate improvements in PPT for the right trapezius and splenius muscles compared to a sham group (Arias-Álvarez et al, 2023).

In this study, although significant improvements in PPT measurements of the right and left upper trapezius were observed only in the mobilization group after both interventions, intergroup comparisons revealed that the improvement in the right upper trapezius PPT was superior to that of the sham group. The mechanical stimuli elicited by joint mobilization trigger neurophysiological responses that suppress pain within the nervous system, leading to positive changes in the PPT of muscles (Bialosky et al, 2018). Thus, it can be concluded that, PPT measurements reflect significant effects in the group receiving the actual intervention, parallel to pain reduction.

Our study is an investigation addressing the lack of research on the application of Mulligan SNAG, a mobilization with movement technique, for improving increased muscle stiffness associated with pain in individuals with mechanical neck pain. In addition to applying mobilization techniques, the inclusion of a sham intervention ensured blinding not only for the evaluators but also for the patients, minimizing bias. The assessment and treatment methods employed in the study are highly integrable into clinical practice due to their cost-effectiveness and ease of application. However, a limitation of the study is that the trapezius muscle was not assessed for trigger points, which are known to be associated with increased pain sensitivity (Geri et al, 2022). In this study, only the immediate effects of the applied techniques were evaluated; therefore, the focus was on short-term variables such as muscle stiffness and pain. Possible effects on disability, quality of life, and activities of daily living were not assessed due to the short follow-up period. This limits the ability to draw conclusions about the long-term therapeutic efficacy of the interventions. Future studies with longer follow-up periods or combined protocols incorporating exercise prescription may yield more pronounced and favorable results, particularly in terms of disability, quality of life, and activities of daily living. Including these measures in future research will provide a more comprehensive evaluation of the long-term effects of interventions for chronic neck pain and offer a complementary perspective to the findings of this study.

Conclusion

The mobilization with movement technique applied to individuals with chronic mechanical neck pain provides a notable immediate improvement in muscle stiffness and pain-related parameters. Additionally, we believe that the sham intervention used in the study produced similar outcomes to the mobilization technique in terms of pain and RoM, likely due to the active joint movement and tactile input involved in its application. However, the inability of the sham intervention to produce the same effects as the actual technique, particularly in muscle stiffness and PPT measurements, underscores the necessity of applying the mobilization with movement technique.

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References

Andrews DP, Odland-Wolf KB, May J, Baker R, Nasypany A, Dinkins EM 2018 Immediate and short-term effects of mulligan concept positional sustained natural apophyseal glides on an athletic young-adult population classified with mechanical neck pain: An exploratory investigation. The Journal of Manual & Manipulative Therapy 26: 203–211. 10.1080/10669817.2018.1460965

Arias-Álvarez G, Bustos MM, Hidalgo-García C, Córdova-León K, Pérez-Bellmunt A, López-de-Celis C, Rodríguez-Sanz J 2023 Are there differences between a real C0-C1 mobilization and a sham technique in function and pressure pain threshold in patients with chronic neck pain and upper cervical restriction? A randomised controlled clinical trial. Journal of Back and Musculoskeletal Rehabilitation 36: 61–70. 10.3233/BMR-220008

Audette I, Dumas JP, Côté JN, Serre SJD 2010 Validity and between-day reliability of the cervical range of motion (CROM) device. Journal of Orthopaedic & Sports Physical Therapy 40: 318–323. 10.2519/jospt.2010.3180

Bialosky JE, Beneciuk JM, Bishop MD, Coronado RA, Penza CW, Simon CB, George SZ 2018 Unraveling the mechanisms of manual therapy: Modeling an approach. Journal of Orthopaedic & Sports Physical Therapy 48: 8–18. 10.2519/jospt.2018.7476

Bialosky JE, Bishop MD, George SZ, Robinson ME 2011 Placebo response to manual therapy: Something out of nothing? The Journal of Manual & Manipulative Therapy 19: 11–19. 10.1179/2042618610Y.0000000001

Blanpied PR, Gross AR, Elliott JM, Devaney LL, Clewley D, Walton DM, Sparks C, Robertson EK 2017 Clinical practice guidelines linked to the International classification of functioning, disability and health from the orthopaedic section of the American physical therapy association. Journal of

Orthopaedic & Sports Physical Therapy 47: A1–83. 10.2519/jospt.2017.0302

Bowler N, Browning P, Lascurain-Aguirrebeña I 2017 The effects of cervical sustained natural apophyseal glides on neck range of movement and sympathetic nervous system activity. International Journal of Osteopathic Medicine 25: 15–20. 10.1016/j.ijosm.2017.02.003

Brandenburg JE, Eby SF, Song P, Zhao H, Brault JS, Chen S, An K-N 2014 Ultrasound elastography: The new frontier in direct measurement of muscle stiffness. Archives of Physical Medicine & Rehabilitation 95: 2207–2219. 10.1016/j.apmr.2014.07.007

Cevik R, Pala OO, Gunaydin G 2024 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 19: e0311206. 10.1371/journal.pone.0311206

Cleland JA, Childs JD, Whitman JM 2008 Psychometric properties of the neck disability index and numeric pain rating scale in patients with mechanical neck pain. Archives of Physical Medicine & Rehabilitation 89: 69–74. 10.1016/j.apmr.2007.08.126

Creighton D, Gruca M, Marsh D, Murphy N 2014 A comparison of two non-thrust mobilization techniques applied to the C7 segment in patients with restricted and painful cervical rotation. The Journal of Manual & Manipulative Therapy 22: 206–212. 10.1179/2042618614Y.0000000077

Çirak YB, Yurdaişik I, Elbaşi ND, Tütüneken YE, Köçe K, Çinar B 2021 Effect of sustained natural apophyseal glides on stiffness of lumbar stabilizer muscles in patients with nonspecific low back pain: Randomized controlled trial. Journal of Manipulative and Physiological Therapeutics 44: 445–454. 10.1016/j.jmpt.2021.06.005

Dennison BS, Leal MH 2015 Mechanical neck pain definition. In: De Las Penas, CF, Cleland J Dommerholt J Eds Manual therapy for musculoskeletal pain syndromes: An evidence- and clinical-informed approach, p. 95. London: Churchill Livingstone.

Dresner MA, Rose GH, Rossman PJ, Muthupillai R, Manduca A, Ehman RL 2001 Magnetic resonance elastography of skeletal muscle. Journal of Magnetic Resonance Imaging 13: 269–276. 10.1002/1522-2586(200102)13:2<269::AID-JMRI1039>3.0.CO;2-1

Exelby L 2002 The mulligan concept: Its application in the management of spinal conditions. Manual Therapy 7: 64–70. 10.1054/math.2001.0435

Furlan AD, Yazdi F, Tsertsvadze A, Gross A, Tulder MV, Santaguida L, Gagnier J, Ammendolia C, Dryden T, Doucette S, et al. 2012 A systematic review and meta-analysis of efficacy, cost-effectiveness, and safety of selected complementary and alternative medicine for neck and low-back pain. Evidence-Based Complementary and Alternative Medicine 2012: 1–61. 10.1155/2012/953139

Ganesh G, Mohanty P, Pattnaik M, Mishra C 2015 Effectiveness of mobilization therapy and exercises in mechanical neck pain. Physiotherapy Theory and Practice 31: 99–106. 10.3109/09593985.2014.963904

Gautam R, Dhamija JK, Puri A 2014 comparison of Maitland and mulligan mobilization in improving neck pain, rom and disability. International Journal of Physiotherapy and Research 2: 482–487.

Gavronski G, Veraksitš A, Vasar E, Maaroos J 2007 Evaluation of viscoelastic parameters of the skeletal muscles in junior triathletes. Physiological Measurement 28: 625–637. 10.1088/0967-3334/28/6/002

Geri T, Botticchio A, Rossettini G, Pournajaf S, Pellicciari L, Di Antonio S, Castaldo M 2022 Pressure pain threshold of the upper trapezius trigger point: A systematic review with meta-analysis of baseline values and their modification after physical therapy. Physical Therapy Journal of Clinical Medicine 11: 7243. 10.3390/jcm11237243

Griefahn A, Oehlmann J, Zalpour C, Piekartz H 2017 Do exercises with the foam roller have a short-term impact on the Thoracolumbar Fascia? – a randomized controlled trial. Journal of Bodywork and Movement Therapies 21: 186–193. 10.1016/j.jbmt.2016.05.011

Gross AR, Paquin JP, Dupont G, Blanchette S, Lalonde P, Cristie T, Graham N, Kay TM, Burnie SJ, Gelley G, et al. 2016 Exercises for mechanical neck disorders: A Cochrane review update. Manual Therapy 24: 25–45. 10.1016/j.math.2016.04.005

Hearn A, Rivett DA 2002 Cervical SNAGs: A biomechanical analysis. Manual Therapy 7: 71–79. 10.1054/math.2002.0440

Hlaing SS, Puntumetakul R, Khine EE, Boucaut R 2021 Effects of core stabilization exercise and strengthening exercise on proprioception, balance, muscle thickness and pain related outcomes in patients with subacute nonspecific low back pain: A randomized controlled trial. BMC Musculoskeletal Disorders 22. 10.1186/s12891-021-04858-6

Hoving JL, Pool JJ, van Mameren H, Devillé WJ, Assendelft WJ, de Vet HC, de Winter AF, Koes BW, Bouter LM 2005 Reproducibility of cervical range of motion in patients with neck pain. BMC Musculoskeletal Disorders 6. 10.1186/1471-2474-6-59

Ishikawa H, Muraki T, Morise S, Sekiguchi Y, Yamamoto N, Itoi E, Izumi S-I 2017 Changes in stiffness of the dorsal scapular muscles before and after computer work: A comparison between individuals with and without neck and shoulder complaints. European Journal of Applied Physiology 117: 179–187. 10.1007/s00421-016-3510-z

Jin X, Du H-G, Kong N, Shen J-L, Chen W-J 2023 Clinical efficacy of the mulligan maneuver for cervicogenic headache: A randomized controlled trial. Scientific Reports 13. 10.1038/s41598-023-48864-1

Kanlayanaphotporn R, Chiradejnant A, Vachalathiti R 2010 Immediate effects of the central posteroanterior mobilization technique on pain and range of motion in patients with mechanical neck pain. Disability and Rehabilitation 32: 622–628. 10.3109/09638280903204716

Ličen U, Opara M, Kozinc Z 2024 The agreement and correlation between shear-wave elastography, myotonometry, and passive joint stiffness measurements: A brief review. SN Comprehensive Clinical Medicine 6. 10.1007/s42399-024-01658-6

Masaracchio M, Kirker K, States R, Hanney WJ, Liu X, Kolber M 2019 Thoracic spine manipulation for the management of mechanical neck pain: A systematic review and meta-analysis. PLOS ONE 14: e0211877. 10.1371/journal.pone.0211877

Mulligan BR 2004 Manual therapy: NAGS, SNAGS, MWMS, etc. Wellington: Plane View Press.

Opara M, Kozinc Z 2023 Which muscles exhibit increased stiffness in people with chronic neck pain? A systematic review with meta-analysis. Frontiers in Sports and Active Living 5: 1–10. 10.3389/fspor.2023.1172514

Ozlu O, Sahin M 2024 The effect of mulligan mobilization technique application in addition to conventional physiotherapy on pain and joint range of motion in people with neck pain. Journal of Bodywork and Movement Therapies 39: 225–230. 10.1016/j.jbmt.2024.02.009

Pallant J 2020 SPSS survival manual: A step by step guide to data analysis using IBM SPSS. London: Routledge: Open University Press.

Rodríguez-Sanz J, Malo-Urriés M, Corral-de-Toro J, López-de -Celis C, Lucha-López MO, Tricás-Moreno JM, Lorente AI, Hidalgo-García C 2020 Does the addition of manual therapy approach to a cervical exercise program improve clinical outcomes for patients with chronic neck pain in short- and mid-term? A randomized controlled trial. International Journal of Environmental Research and Public Health 17: 6601. 10.3390/ijerph17186601

Safiri S, Kolahi AA, Hoy D, Buchbinder R, Mansournia MA, Bettampadi D, Ashrafi-Asgarabad A, Almasi-Hashiani A, Smith E, Sepidarkish M, et al. 2020 Global, regional, and national burden of neck pain in the General population, 1990-2017: Systematic analysis of the global burden of disease study 2017. BMJ 368: 791. 10.1136/bmj.m791

Satpute K, Bedekar N, Hall T 2021 Effectiveness of mulligan manual therapy over exercise on headache frequency, intensity and disability for patients with migraine, tension-type headache and cervicogenic headache – a protocol of a pragmatic randomized controlled trial. BMC Musculoskeletal Disorders 22. 10.1186/s12891-021-04105-y

Taş S, Korkusuz F, Erden Z 2018 Neck muscle stiffness in participants with and without chronic neck pain: A shear-wave elastography study. Journal of Manipulative and Physiological Therapeutics 41: 580–588. 10.1016/j.jmpt.2018.01.007

Taş S, Yaşar Ü, Kaynak BA 2021 Interrater and intrarater reliability of a handheld myotonometer in measuring mechanical properties of the neck and orofacial muscles. Journal of Manipulative and Physiological Therapeutics 44: 42–48. 10.1016/j.jmpt.2020.08.002

Telci EA, Karaduman A, Yakut Y, Aras B, Simsek İE, Yagli N 2009 The cultural adaptation, reliability, and validity of neck disability index in patients with neck pain. Spine 34: 1732–1735. 10.1097/BRS.0b013e3181ac9055

Treleaven J 2008 Sensorimotor disturbances in neck disorders affecting postural stability, head and eye movement control. Manual Therapy 13: 2–11. 10.1016/j.math.2007.06.003

Vernon H, Mior S 1991 The neck disability index: A study of reliability and validity. Journal of Manipulative and Physiological Therapeutics 14: 409–415.

Vernon HT, Humphreys BK, Hagino CA 2005 A systematic review of conservative treatments for acute neck pain not due to whiplash. Journal of Manipulative and Physiological Therapeutics 28: 443–448. 10.1016/j.jmpt.2005.06.011

Walton D, MacDermid J, Nielson W, Teasell R, Chiasson M, Brown L 2011 Reliability, standard error, and minimum detectable change of clinical pressure pain threshold testing in people with and without acute neck pain. Journal of Orthopaedic & Sports Physical Therapy 41: 644–650. 10.2519/jospt.2011.3666