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Immediate effect of craniocervical flexion exercise and Mulligan mobilisation in patients with mechanical neck pain — A randomised clinical trial

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Background: Mechanical neck pain (MNP) is one of the most prevalent musculoskeletal pathologies in the present time. Physiotherapy management strategies comprising manual therapy and exercise therapy are routinely administered in patients with MNP.
Objective: To compare the immediate effect of craniocervical flexion (CCF) exercise and Mulligan mobilisation on pain, active cervical range of motion (CROM) and CCF test performance in patients with MNP.
Methods: This prospective, randomised, single-blinded study involved 26 patients with MNP (16 females; mean age; 31.12 ± 8.40 years) randomised to a single session of active CCF exercise (3 sets of 10 repetitions) or Mulligan mobilisation (3 sets of 6–10 repetitions). Pain intensity was measured on a numerical pain rating scale (NPRS), active CROM was measured using CROM device, and CCF test performance with surface electromyography (EMG) from bilateral sternocleidomastoid (SCM) and anterior scalene (AS) muscles recorded pre- and immediately post-intervention by an assessor blinded to the treatment groups. Mann–Whitney *U* test was used to analyse between groups and Wilcoxon signed rank test was used to analyse within-group significance for pain and CROM, Cochran–Mantel–Haenszel correlation test was used to analyse the CCF test performance on EMG from the bilateral SCM and AS muscles.

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Results: Comparison between pre- and post-intervention readings revealed statistically significant within-group ($p < 0.05$) and no between-group significant difference for pain, ROM, and CCF test performance, indicating both interventions were equally effective.
Conclusion: Patients with MNP who received active CCF exercise or Mulligan mobilisation exhibited similar reduction in pain intensity and increased CROM and CCF test performance post-intervention. Surprisingly, AS surface EMG amplitudes were increased post-intervention in both groups warranting further exploration of its role in neck pain.

Keywords: Manual therapy; mobilisation; motor control; neck muscles.

Introduction

Among musculoskeletal disorders, mechanical neck pain (MNP) is quite frequent, leading to disability, it is characteristically aggravated by neck movements and activity. The course is variable, marked by periods of exacerbation and remission with subsequently high economic costs.[1] Almost 70% of individuals are affected by MNP at some time in their lives.[2] Physical and psychological factors at the workplace can contribute to the development of neck pain.[3] Physiotherapy is routinely the first line of contact for non-specific neck pain with substantial evidence supporting the use of exercise therapy, manual therapy, or its combination.[4–7]

Manual therapy approach is defined as "the use of hands to apply a force with a therapeutic intent".[8] It encompasses a wide range of techniques aimed at alleviating pain and improving joint mobility. Mulligan concept constitutes an integral component of manual therapy, it involves the application of joint glide to a motion segment which is sustained while the patient performs the impaired action.[9] Performing the technique in a weight-bearing position when indicated enables the affected joint to move freely without pain or impediment.[10] Mulligan mobilisation techniques are commonly used by physiotherapists to treat neck pain. Cervical sustained natural apophyseal glides (SNAGs) is a Mulligan mobilisation technique that can be applied over the spinous process or articular pillar of the superior vertebra of the implicated functional spinal unit. Plausible mechanisms for the ameliorative effects of Mulligan mobilisation include restoration of positional faults, centrally mediated hypoalgesia, neurophysiological effects, and sympathoexcitation.[11]

Exercises play a crucial role in the effective management of patients with MNP. With neck musculature being significant contributors of cervical stability,[12] a reduction in endurance and strength of cervical muscles could lead to dysfunctions subsequently affecting their performance.[13] Altered motor control could perpetuate patient symptoms thereby causing greater excitability of the motor neuronal pool which might modify the electromyography (EMG) amplitude.[14] Literature advocates an emphasis on motor control for effective rehabilitation of patients with neck disorders rather than muscle strength.[15] Craniocervical flexion (CCF) test (CCFT) was developed by Jull *et al.* to explore the action of the deep cervical flexors (DCF).[16] This clinical test uses a biofeedback system to assess an individual's ability to perform and hold a precise capital flexion action. Impaired performance on the CCFT reflects a deficit in the motor control of craniocervical flexors with a greater difference at higher levels of test, suggesting different movement strategies adapted to compensate for the impairment.[17] This test can be used to train and monitor the progress of patient performance in successive treatment sessions. It is proposed to improve endurance, neuro-motor control, structural adaptations, and coordination between deep and superficial cervical flexors.[18] CCF exercise has shown to be effective in immediate as well as long-term pain relief and the possible mechanism for pain alleviation is attributed to various mechanisms like exercise-induced hypoalgesia and altered pain perception.[2,19,20]

Accordingly, rehabilitation programmes utilising manual therapy and exercise therapy are accepted practices in the clinical management of MNP. Given the potential importance of these interventions in the management of neck pain with their combination providing beneficial effects,[5,21,22] a greater understanding of their individual effects is needed. Furthermore, a review conducted by Fredin and Loras (2017) has identified a lack of literature on comparing the effect of individual physical therapy approaches in the management of adult neck pain.[23] Determining the most appropriate physiotherapy intervention is integral for the management of patients with MNP. Although both interventions are effective, the mechanisms of action of these two interventions are different. This could potentially provide important aid for clinicians in their clinical decision-making process. Thus, the objective of this study was to compare the effectiveness of Mulligan mobilisation to that of active CCF exercise in individuals with MNP, using pain response, cervical range of motion (CROM), and CCFT performance measures.

Methods

Study design

This prospective, randomised, single-blinded, clinical trial was performed to compare the immediate effect of active CCF exercise to Mulligan mobilisation in patients with MNP. The outcome assessments were performed at baseline and immediately after the intervention. Randomisation of participants to exercise or mobilisation group was performed by block randomisation using a computer-generated randomised table of numbers before the recruitment process. Individually and sequentially numbered cards were placed in opaque sealed envelopes. The randomisation and list maintenance were handled by a researcher who was not involved in the evaluation or care of the individuals. The outcome assessor was blinded to the allocation of participants to the intervention groups. The participants were requested not to disclose their intervention to the assessor. The trial was prospectively registered through the clinical trial registry with the following registration number: CTRI/2017/03/007990.

Participants

Participants were patients with a complaint of non-specific MNP as per the defined criteria, referred to the physiotherapy clinic with the duration of the present episode of neck pain less than three weeks, age between 18 and 50 years, either gender, numerical pain rating scale (NPRS) score ≥ 3. The participants were excluded if they had cervical radiculopathy, vertebrobasilar insufficiency, metabolic bone disease, any severe neurological disorder, pregnancy, previous cervical surgery, a recent history of fall/trauma to the cervical spine or shoulder, participation in any exercise program for neck pain in the past 6 months. All the participants provided written informed consent to participate and the study was approved by the institutional ethics (IEC 18/2017) and research committee. Protocols were followed in accordance with the Helsinki Declaration.

Twenty-six participants were randomised into two groups: The CCF exercise group performed deep cervical activation exercise ($n = 13$), and the Mulligan mobilisation group received cervical SNAGs ($n = 13$).

Sample size calculation

Considering pain as the primary outcome of interest, the sample size was calculated based on the minimal clinically important difference of 2 points for neck pain on NPRS with a standard deviation of 1.8 points.[24] At a 95% confidence interval and power of 80%, the total sample size calculated was 26 participants with 13 participants in each group.

Outcome measurements

The primary outcome measure was neck pain intensity on NPRS, with CROM and CCFT performance as secondary outcomes. Demographic information was collected at baseline and all outcomes were assessed by an investigator blinded to the randomisation.

Numerical pain rating scale

The patient reported pain on NPRS, an 11-point scale ranging from 0 “no pain” to 10 “worst pain imaginable”. The psychometric properties of NPRS are acceptable for neck pain with MCID as 2.[24]

CCFT performance

Participants performed the CCFT as per the description of Gwendolen Jull and the performance level was assessed via the patient’s ability to progress through the stages of the test.[25] The examiner monitored for any substitution or trick movements. Activation of DCF from the baseline of 20 mmHg over five different levels of sequentially increasing pressure of 2 mmHg attempting upto 30 mmHg. Isometric contraction of 10 s duration of

10 repetitions at each level was noted to record the target level.

Cervical range of motion

The CROM device comprises a hard-plastic frame attached to the patient's head to measure cervical spine ROM. The device consists of three inclinometers, one for rotation in the transverse plane, one for lateral flexion in coronal plane, and one to measure extension and flexion in the sagittal plane. The inclinometer in the transverse plane with a magnetic needle and a magnetic collar is worn by the participant. This produces the required magnetic field to move the needle when the head is rotated. The patient was comfortably seated on a chair, with feet flat on the ground, with 90° of hip and knee flexion, back against the chair, and hands resting on the lap. The patient was asked to move his head actively within the pain-free range as far as possible, in all six directions of movement. All measurements were performed by a single therapist with standard instructions in the same setting. The intratester reliability of 0.87 and 0.96 was exhibited in subjects with neck pain using the CROM device.[26]

Surface EMG

Surface EMG (sEMG) is a widely used non-invasive method to analyse muscle function in musculoskeletal conditions.[27] sEMG amplitude was recorded bilaterally from sternocleidomastoid (SCM) and anterior scalene (AS) muscles using Delsys Trigno wireless EMG System (USA). The sensors were attached to the skin using the Delsys adhesive sensor placed with the participant in a sitting position for SCM, and supine lying for AS. EMG signals were captured at 0–500 Hz, preamplified (0–1.5 mV). Optimal electrode placement is essential for the accurate estimation of sEMG signals. The electrodes were placed after appropriate skin preparation and standard guidelines for electrode placement according to the innervation zone were followed with the sensor placed on the lower portion of the muscle belly.[28] Average muscle activation was recorded for each 10-s isometric contraction at the highest level of pressure maintained by the participant. The recording of sEMG was begun at the initiation of each contraction and stopped when the participant maintained the 10-s contraction at that level of the CCFT until he/she returned to the starting position. Wireless EMG signals were amplified ($\times 1000$), band-pass filtered (30–1000 Hz), and sampled at 4 kHz by LabChart 8 Software. Normalization of raw data (% Maximum Voluntary Isometric Contraction (MVIC)) was calculated. These data were used for plotting muscle activation. The test was terminated if there was an increase in the pain intensity or if trick movements were observed by the tester in superficial cervical muscles.

Interventions

CCF exercise

To perform the exercise, the participant was positioned in a crook lying with neck in neutral position. An air-filled pressure sensor (Stabilizer™, Chattanooga Group Inc., USA) was inflated to 20 mmHg and placed below the occiput. Participants were instructed to remain relaxed and perform a gentle, nodding head movement. The investigator observed any substitution movement during the performance of the technique and corrected it to ensure that all participants could perform the exercise appropriately. Verbal feedback was used to prevent the use of superficial neck flexor muscles or neck retraction movement. A low-load CCF exercise was performed at the established target level which was determined from the CCFT.[25] Target levels were determined as the highest-pressure levels at which the participants were comfortably able to maintain contractions for $10\,\text{s} \times 10$ repetitions. To exercise, the participant had to perform three sets of 10 repetitions (10 s hold) of the exercise at the target level with a 10-s rest pause provided between each set. Emphasis was provided on the performance of correct movement without the use of superficial muscles throughout the procedure.

Mulligan mobilisation

The participant randomised to the Mulligan mobilisation group received cervical SNAGs which combine mobilisation with active movements. The intervention was applied by one of the authors (A.S.), a certified Mulligan practitioner. The participant's position was sitting upright on a chair with the therapist standing behind the patient in a stride stance. The level of mobilisation was selected based on a thorough physical examination and patient description. The therapist performed the technique with one thumb reinforced on the other at the level of articular pillar or the spinous process of the superior vertebra of the functional spinal unit. The therapist applied a sustained passive accessory movement along the zygapophyseal joint plane (45°) with the participant simultaneously performing the physiological movement (comparable sign). The therapist sustained the glide throughout the movement and released it upon the return of the patient to the starting position. The dosage was decided pragmatically depending upon the symptom of the patient with three sets of 6–10 repetitions with a 1-min break in between each set.

Statistical analysis

Data analysis was performed using SPSS version 16.0 (SPSS Inc., Chicago, IL). Descriptive statistics were used to report the demographic characteristics of the participants. Statistical analysis was performed on the data obtained from all the participants with no missing data. Shapiro–Wilk test showed that data were not normally distributed. Mann–Whitney *U* test was used to detect between-group significance and Wilcoxon signed rank test was used to determine within-group significance. The data obtained from CCFT performance were analysed using the Cochran–Mantel–Haenszel correlation test.

Results

Participant flow is presented in Fig. 1. Twenty-six participants (16 females) with a mean age of 31.12 ± 8.40 years completed the study. Participant baseline demographic characteristics are described in Table 1. There were no significant differences in age, height, weight, or pain intensity between the two groups at baseline. No patients were lost after randomisation and no adverse effects were reported during the intervention.

Tables 2 and 3 demonstrate the comparison of pain and ROM scores within the exercise group and Mulligan mobilisation group, respectively. A significant interaction between group and time was observed for the exercise group and the Mulligan mobilisation group for pain intensity immediately after the intervention (Tables 2 and 3) with no statistically significant difference between groups (Table 4). ROM improved in all directions for both groups post-intervention (Tables 2 and 3) except bilateral rotation ranges for the Mulligan mobilisation group. However, between groups, there was no statistically significant difference for ROM of the cervical spine (Table 4).

A significant improvement in the level of CCFT achieved was observed immediately after the intervention for the exercise group (pre: 3 (2.5, 4), post: 4 (3, 5); $p = 0.038$) and mobilisation group (pre: 3 (2.5, 5), post: 5 (3, 5); $p = 0.023$) with no significant difference between the two groups for

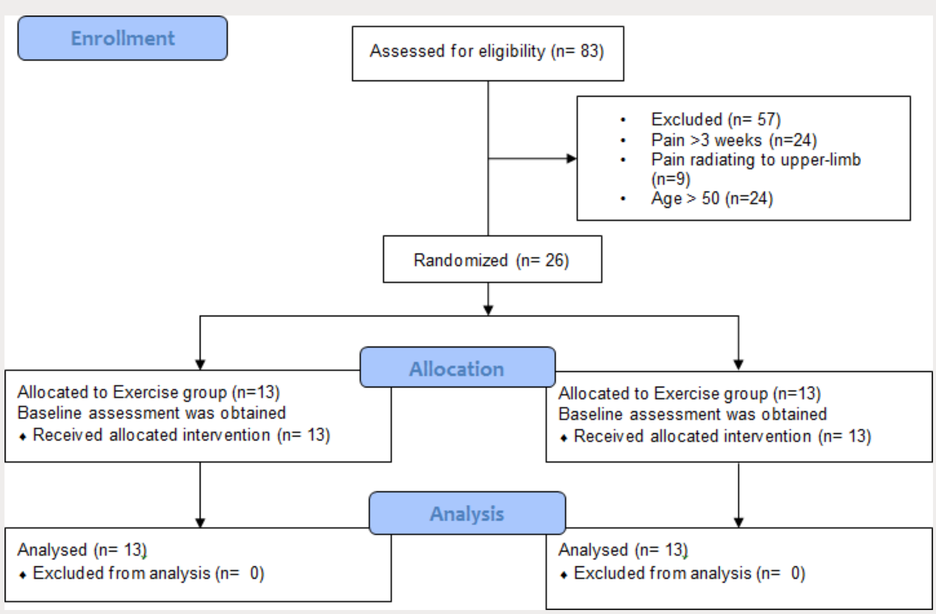


Fig. 1. CONSORT 2010 flow diagram for recruitment of participants.

Table 1. Baseline characteristics of the participants ($n = 26$).

	Exercise group ($n = 13$)	Mulligan group ($n = 13$)	p-value
Age (years)	30.00 ± 8.38	32.23 ± 8.61	0.512
Gender (M/F)	4/9	6/7	0.18
Height (cm)	158.77 ± 5.37	160.23 ± 6.69	0.545
Weight (kg)	61.38 ± 8.06	62.54 ± 7.12	0.70
Pain intensity (NPRS)	5.00 ± 1.00	5.23 ± 1.53	0.65

Notes: NPRS; numerical pain rating scale.

Table 2. Comparison of pain and ROM scores within the exercise group.

Variables	Pre-median (IQR)	Post-median (IQR)	p-value
NPRS	5 (4.5, 5.5)	4 (3.5, 5)	0.018*
Flexion (°)	50 (41, 50)	50 (43, 55)	0.042*
Extension (°)	50 (40, 54)	50 (44, 60)	0.011*
Left side flexion (°)	38 (30, 40)	40 (32, 43)	0.027*
Right side flexion (°)	40 (30, 40)	40 (35, 41)	0.041*
Left rotation (°)	60 (40, 60)	60 (42, 60)	0.042*
Right rotation (°)	54 (48, 60)	54 (50, 60)	0.041*

Notes: Abbreviation: NPRS, numerical pain rating scale. Table 2 depicts the within-group difference for the exercise group. A statistically significant difference was observed within the group for the outcome variables of pain and ROM in different directions ($p \leq 0.05$)*.

Table 3. Comparison of pain and ROM scores within the Mulligan group.

Variables	Pre-median (IQR)	Post-median (IQR)	p-value
NPRS	5 (4, 6)	4 (3, 5)	0.033*
Flexion (°)	50 (35, 51)	50 (45, 60)	0.007*
Extension (°)	50 (34, 56)	60 (50, 60)	0.011*
Left side flexion (°)	30 (22, 40)	38 (30, 40)	0.012*
Right side flexion (°)	30 (30, 40)	40 (30, 44)	0.005*
Left rotation (°)	50 (32, 60)	50 (38, 60)	0.068
Right rotation (°)	60 (43, 60)	60 (44, 60)	0.102

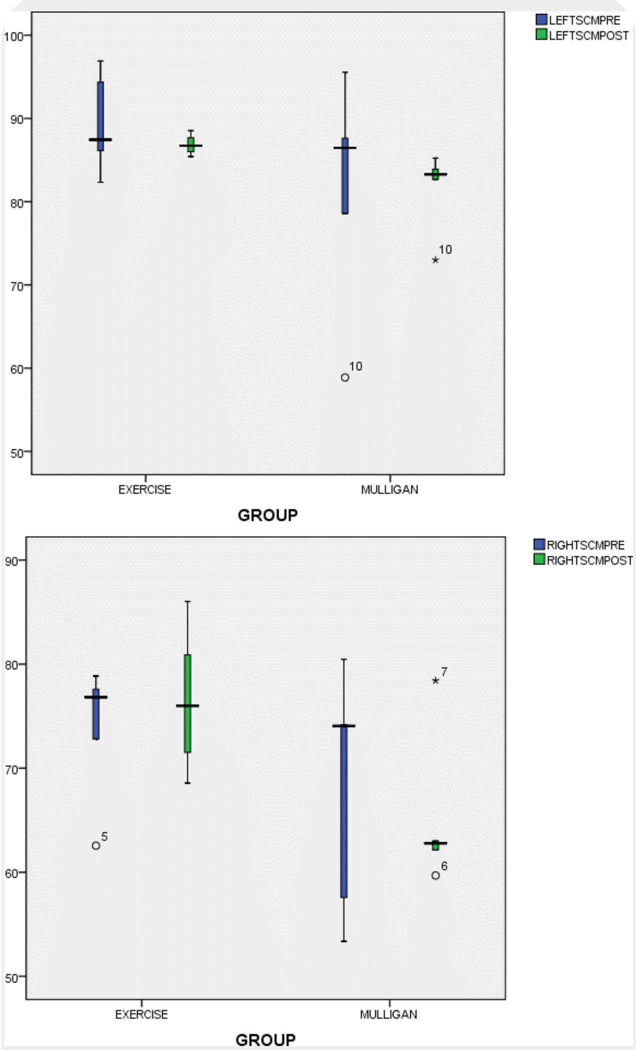
Notes: Abbreviation: NPRS, numerical pain rating scale. Table 3 depicts the within-group difference for the Mulligan group. A statistically significant difference was observed within the group for the outcome variables of pain and ROM in all directions ($p \leq 0.05$) * except right and left rotation.

the level of CCFT performance ($p = 0.377$). Furthermore, there was a decrease in the SCM muscle sEMG amplitude post-intervention for both groups (Fig. 2). The EMG amplitude for AS muscle reduced on the right side and increased on the left side post-intervention in the exercise group whereas post-Mulligan mobilisation there was an increase in the amplitude on both sides (Fig. 3).

Table 4. Comparison of pain and ROM scores between the Mulligan and exercise groups.

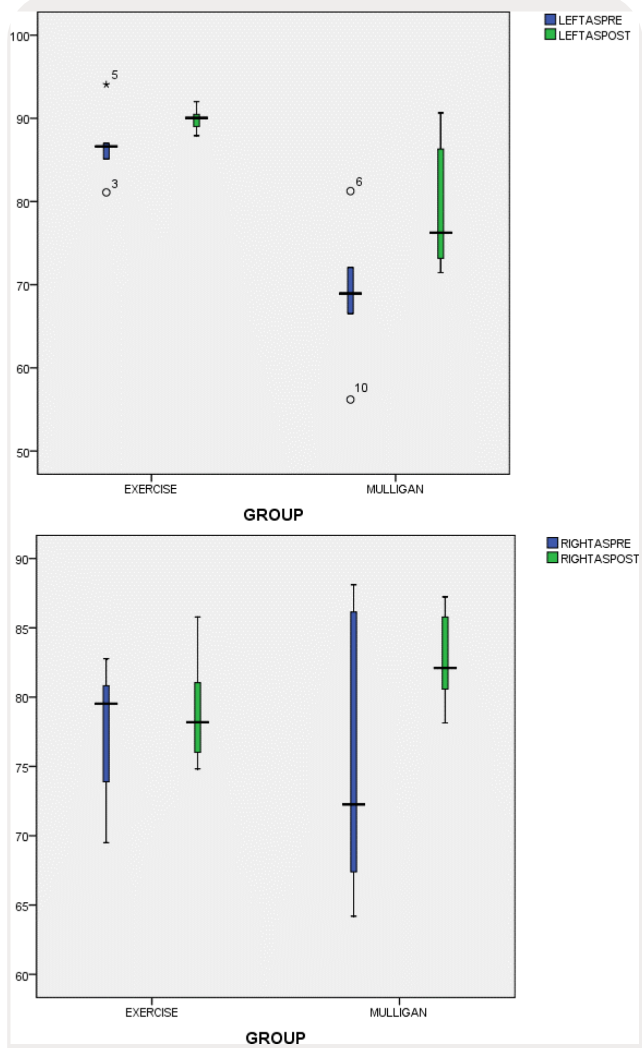
Variables	Exercise post-median (IQR)	Mulligan post-median (IQR)	*p*-value
NPRS	4 (3.5, 5)	4 (3, 5)	0.958
Flexion (°)	50 (43, 55)	50 (45, 60)	0.425
Extension (°)	50 (44, 60)	60 (50, 60)	0.369
Left side flexion (°)	40 (32, 43)	38 (30, 40)	0.271
Right side flexion (°)	40 (35, 41)	40 (30, 44)	0.696
Left rotation (°)	60 (42, 60)	50 (38, 60)	0.323
Right rotation (°)	54 (50, 60)	60 (44, 60)	0.766

Notes: Table 4 represents the difference for pain and ROM between the exercise and the Mulligan group. No statistical significance was observed between the groups for any of the outcomes.



Notes: Figure 2 depicts normalized root mean square (RMS) values for bilateral SCM muscle while performing CCFT. Data are presented for the CCF exercise group and Mulligan mobilisation group both pre- and post-intervention.

Fig. 2. Activation of left and right SCM muscle.



Notes: Figure 3 depicts normalized RMS values for the bilateral AS muscle while performing CCFT. Data are presented for the CCF exercise group and Mulligan mobilisation group both pre- and post-intervention.

Fig. 3. Activation of left and right AS muscle.

Discussion

This study reports the findings from an randomised clinical trial (RCT) investigating the effectiveness of CCF exercise and Mulligan mobilisation on MNP patients. The results demonstrated that both interventions helped in reducing resting pain and improving cervical mobility and CCFT performance with a statistical intra-group significance in all the outcome variables. There was no significant difference found between two interventions working through different mechanisms which suggests that the application of either intervention is equally effective in patients with MNP.

Spinal manipulative therapy is reported to have specific hypoalgesic effects.[19,20] A significant reduction of pain immediately post-intervention noted in this study is in line with the previous studies which have incorporated Mulligan mobilisation in patients with neck pain.[29,30] The reduction in pain with Mulligan mobilisation could be explained through the correction of positional faults in the bony structure.[31] Pain reduction with Mulligan mobilisation has appeared to produce more significant therapeutic results compared to other manual therapy methods in the peripheral joints.[32] This could be attributed to the nature of Mulligan mobilisation which requires the performance of active movements as in SNAG's, unlike other joint mobilisation techniques which are completely passive. CCF exercise has demonstrated an immediate exercise-induced hypoalgesic effect, the results of this study further support an immediate reduction of pain, thereby confirming the pain-modulation properties of active neck exercise.[33,34]

The results demonstrated an improvement in the ROM in both groups. However, the increase of ROM in the Mulligan mobilisation group could be attributed to repositioning the articular facet using SNAG through which the biomechanical alteration is corrected thereby reducing the positional impairment and thus resulting in alleviation of pain and increased ROM. Mulligan mobilisation has demonstrated an increase in the ROM, thereby it is recommended as an appropriate manual therapy approach for the management of patients with neck pain and stiffness.[35,36] Contrary to other studies our study did not show improvement in the rotation ROM in the Mulligan mobilisation group.[37] This could be attributed to the involvement of sagittal plane and frontal plane movements as a comparable sign in the majority of our patients, which could have resulted in a lack of improvement in the transverse plane movements in the Mulligan mobilisation group.

A previous study investigating the immediate effect of CCF exercise and passive mobilisation intervention concluded that both these interventions actuate immediate pain relief in chronic neck pain patients, albeit the improvement in performance on CCFT was seen only in the exercise group which implemented active intervention.[38] Our results support and reinforce the fact that active intervention enhances motor performance in patients with MNP. The mode of exercise protocol determines changes in motor performance.[39] As opposed to the previous study our study involved joint mobilisation using the Mulligan technique which involves passive mobilisation with active movement. Active movements of the cervical spine could have contributed to the immediate improvement in the motor performance seen in our study.

Enhanced DCF performance following the CCF exercise corroborates with previous observations.[39] In this study, both groups have elicited a higher level of CCFT performance post-interventions indicating a positive effect of CCF exercise and Mulligan mobilisation technique in improving motor control of DCFs in patients with neck pain. The improvement in the performance was seen immediately post-intervention suggesting the role of neurophysiological mechanisms in affecting the muscle spindle or motor neuron activity which alters the synergy of muscles.

The effect of intervention on the EMG activity of superficial neck muscles was one of the objectives of this study. The EMG amplitude of the SCM muscle was reduced, whereas the EMG amplitude of AS muscle increased post-intervention in both groups. This result of our study could be supported by the findings of a study conducted by Jull and Falla which stated a stronger negative correlation between SCM and DCF and a non-significant negative relationship between AS and DCF.[40] The probable mechanism for the increase in the EMG amplitude of AS is the fibre composition of the muscle. AS consists of predominant Type I fibres (71%) compared to SCM which contains fewer Type I fibres (35%).[41] Type I fibres are slow-twitch fibres with small motor units which are recruited first when performing a low-level force production activity such as CCF. As the demand for CCFTs increased with higher levels more AS motor units were recruited.

In accordance, this study demonstrated an improvement in motor performance in both groups. Since both interventions resulted in an improvement in outcomes, this confirms the pain-modulation properties of active neck exercise and highlights the importance of active mobilisation techniques in the management of neck pain. Future studies can look into the progressive effect of these interventions on the intensity of pain, CROM, CCFT performance and disability measures in patients with chronic neck pain.

Clinical implication

As CCF exercise and Mulligan mobilisation have shown comparable immediate effects on pain, ROM and CCFT performance, the therapist can choose either of the interventions for the management of patients with MNP.

Limitations

Our study has few limitations, we only assessed immediate effect, thereby, we cannot determine if the treatment effects were maintained after the session. Our study findings are limited to participants presenting with mid and lower cervical impairments, there is a lack of representation of patients with upper cervical dysfunctions. The lack of a control group fails to explain the role of the placebo effect as a potential reason for improvement in outcome measures.

Conclusion

This study demonstrated an improvement in motor performance in both the CCF exercise and Mulligan mobilisation group. Since both interventions resulted in an improvement in outcomes, it highlights the pain-modulating properties of active neck exercise and emphasises the importance of active intervention in the management of MNP. This study suggests that active CCF exercise and Mulligan mobilisation induce immediate pain relief, improvement in CROM, and CCFT performance in patients with MNP.

Conflict of Interest

The authors claim that there are no conflicts of interest.

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Author Contributions

Conception of design, data analysis, and interpretation of data was conducted by all the authors. Data collection was performed by A.S. Final version of the manuscript was approved by all the authors.

References

1. Lindstrom R, Schomacher J, Farina D, et al. Association between neck muscle coactivation, pain, and strength in women with neck pain. Man Ther 2011;16(1):80–6.
2. Falla D, O'Leary S, Farina D, et al. The change in deep cervical flexor activity after training is associated with the degree of pain reduction in patients with chronic neck pain. Clin J Pain 2012;28 (7):628–34.
3. Cote P, van der Velde G, Cassidy JD, et al. The burden and determinants of neck pain in workers: Results of the Bone and Joint Decade 2000–2010 Task Force on neck pain and its associated disorders. J Manipulative Physiol Ther 2009;32(2 Suppl):S70–86.
4. Moffett J, McLean S. The role of physiotherapy in the management of non-specific back pain and neck pain. Rheumatology (Oxford) 2006;45(4):371–8.
5. Walker MJ, Boyles RE, Young BA, et al. The effectiveness of manual physical therapy and exercise for mechanical neck pain: A randomized clinical trial. Spine 2008;33(22):2371–8.
6. Miller J, Gross A, D'Sylva J, et al. Manual therapy and exercise for neck pain: A systematic review. Man Ther 2010;15(4):334–54.
7. Bogduk, N, McGuirk, B. Management of Acute and Chronic Neck Pain. Elsevier, 2007:1–2.
8. Smith AR. Manual therapy: The historical, current, and future role in the treatment of pain. Sci World J 2007;7:109–20.
9. Mulligan BR. Mobilisations with movement (MWM'S). J Man Manip Ther 1993;1(4):154–6.
10. Exelby L. The Mulligan concept: Its application in the management of spinal conditions. Man Ther 2002;7(2):64–70.
11. Vicenzino B, Paungmali A, Teys P. Mulligan's mobilization-with-movement, positional faults and pain relief: Current concepts from a critical review of literature. Man Ther 2007;12(2):98–108.

12. Panjabi MM, Cholewicki J, Nibu K, et al. Critical load of the human cervical spine: An in vitro experimental study. Clin Biomech 1998;13(1):11–7.
13. Chiu TTW, Law EYH, Chiu THF. Performance of the craniocervical flexion test in subjects with and without chronic neck pain. J Orthop Sports Phys Ther 2005;35(9):567–71.
14. Falla D, Jull G, Edwards S, et al. Neuromuscular efficiency of the sternocleidomastoid and anterior scalene muscles in patients with chronic neck pain. Disabil Rehabil 2004;26(12):712–7.
15. Jull G, Trott P, Potter H, et al. A randomized controlled trial of exercise and manipulative therapy for cervicogenic headache. Spine 2002;27(17): 1835–43.
16. Jull G. Deep cervical flexor muscle dysfunction in whiplash. J Musculoskelet Pain 2000;8:143–54.
17. Jull G. Physiotherapy management of the cervical spine. In: Giles L, Singer K, eds. Clinical Anatomy and Management of Cervical Spine Pain. London, UK: Butterworth-Heinemann, 1998:168–91.
18. Jull GA, Falla D, Vicenzino B, et al. The effect of therapeutic exercise on activation of the deep cervical flexor muscles in people with chronic neck pain. Man Ther 2009;14(6):696–701.
19. Naugle KM, Fillingim RB, Riley III JL. A meta-analytic review of the hypoalgesic effects of exercise. J Pain 2012;13(12):1139–50.
20. Vaegter HB, Handberg G, Graven-Nielsen T. Isometric exercises reduce temporal summation of pressure pain in humans. Eur J Pain 2015;19(7): 973–83.
21. Bronfort G, Evans R, Nelson B, Aker PD, Goldsmith CH, Vernon H. A randomized clinical trial of exercise and spinal manipulation for patients with chronic neck pain. Spine 2001;26(7):788–99.
22. Rezkallah SS, Abdullah GA. Comparison between sustained natural apophyseal glides (SNAG's) and myofascial release techniques combined with exercises in non specific neck pain. Physiother Pract Res 2018;39(2):135–45.
23. Fredin K, Loras H. Manual therapy, exercise therapy or combined treatment in the management of adult neck pain — A systematic review and meta-analysis. Musculoskelet Sci Pract 2017;31: 62–71.
24. Cleland JA, Childs JD, Whitman JM. Psychometric properties of the neck disability index and numeric pain rating scale in patients with mechanical neck pain. Arch Phys Med Rehabil 2008;89(1):69–74.
25. Jull GA, O'Leary SP, Falla DL. Clinical assessment of the deep cervical flexor muscles: The craniocervical flexion test. J Manipulative Physiol Ther 2008;31(7):525–33.
26. Fletcher JP, Bandy WD. Intrarater reliability of CROM measurement of cervical spine active range of motion in persons with and without neck pain. J Orthop Sports Phys Ther 2008;38(10):640–5.
27. Cram JR, Kneebone WJ. Cervical flexion: A study of dynamic surface electromyography and range of motion. J Manipulative Physiol Ther 1999;22(9): 570–5.
28. Falla D, Dall'Alba P, Rainoldi A, et al. Location of innervation zones of sternocleidomastoid and scalene muscles — A basis for clinical and research electromyoraphy applications. Clin Neurophysiol 2001;113(1):57–63.
29. Izquierdo Perez H, Alonso Perez JL, Gil Martinez A, et al. Is one better than another?: A randomized clinical trial of manual therapy for patients with chronic neck pain. Man Ther 2014;19(3):215–21, doi: 10.1016/j.math.2013.12.002.
30. Lopez-Lopez A, Alonso Perez JL, Gonzalez Gutierez JL, La Touche R, Lerma Lara S, Izquierdo H, Fernandez-Carnero J. Mobilization versus manipulations versus sustain apophyseal natural glide techniques and interaction with psychological factors for patients with chronic neck pain: Randomized controlled trial. Eur J Phys Rehabil Med 2015;51(2):121–32.
31. Buyukturan O, Buyukturan B, Sas S, Kararti C, Ceylan I. The effect of Mulligan mobilization technique in older adults with neck pain: A randomized controlled, double-blind study. Pain Res Manag 2018;2018:2856375, doi: 10.1155/2018/2856375.
32. Stathopoulos N, Dimitriadis Z, Koumantakis GA. Effectiveness of Mulligan's mobilization with movement techniques on pain and disability of peripheral joints: A systematic review with meta-analysis between 2008–2017. Physiotherapy 2019;105:1–9, doi: 10.1016/j.physio.2018.10.001.
33. O'Leary S, Falla D, Hodges PW, et al. Specific therapeutic exercise of the neck induces immediate local hypoalgesia. J Pain 2007;8(11):832–9.
34. Chung SH, Jeong Y-G. Effects of the craniocervical flexion and isometric neck exercise compared in patients with chronic neck pain: A randomized controlled trial. Physiother Theory Pract 2018;34 (12):916–25.
35. McNair PJ, Portero P, Chiquet C, Mawston G, Lavaste F. Acute neck pain: Cervical spine range of motion and position sense prior to and after joint mobilization. Man Ther 2007;12(4):390–4, doi: 10.1016/j.math.2006.08.002.
36. Hearn A, Rivett DA. Cervical SNAGs: A biomechanical analysis. Man Ther 2002;7(2):71–9.
37. Neil B, Paul B, Ion LA. The effects of cervical sustained natural apophyseal glides on neck range

of movement and sympathetic nervous system activity. Int J Osteopath Med 2017;25:15–20.

38. Lluch E, Schomacher J, Gizzi L, et al. Immediate effects of active cranio-cervical flexion exercise versus passive mobilisation of the upper cervical spine on pain and performance on the cranio-cervical flexion test. Man Ther 2014;19(1):25–31.
39. Gallego Izquierdo T, Pecos-Martin D, Lluch Girbes E, et al. Comparison of cranio-cervical flexion training versus cervical proprioception training in patients with chronic neck pain: A randomized controlled clinical trial. J Rehabil Med 2016;48(1):48–55, doi: 10.2340/16501977-2034.
40. Jull G, Falla D. Does increased superficial neck flexor activity in the craniocervical flexion test reflect reduced deep flexor activity in people with neck pain? Man Ther 2016;25:43–7, doi: 10.1016/j.math.2016.05.336.
41. Cornwall J, Kennedy E. Fiber types of the anterior and lateral cervical muscles in elderly males. Eur Spine J 2015;24(9):1986–91.