Musculoskeletal Science and Practice 62 (2022) 102636

Contents lists available at ScienceDirect

Musculoskeletal Science and Practice

journal homepage: www.elsevier.com/locate/msksp

Original article

Virtual reality and motor control exercises to treat chronic neck pain: A randomized controlled trial

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ARTICLE INFO

Keywords:
Neck pain
Virtual reality
Pain threshold
Proprioception
Exercise
Anxiety
Quality of life

ABSTRACT

Aim: To compare the effects of virtual reality (VR) and motor control (MC) exercises.

Methods: Forty-one participants with chronic neck pain (CNP) were randomized into the VR or MC group. Both groups performed 18 sessions over 6 weeks. The primary outcomes were pain intensity (visual analogue scale), pain pressure thresholds (PPTs), joint position sense error (JPSE), and muscle performance. The secondary outcomes were the Profile Fitness Mapping Questionnaire (ProFitMap-Neck), Hospital Anxiety-Depression Scale (HADS), and quality of life (SF-36). Data were analysed using T-Tests, and Fisher's Exact Test. Mean (standard deviation), median (interquartile range), effect size and %95 confidence interval (CI) were reported.

Results: The results of Independent T-Tests showed that VR was advantageous in terms of PPTs of the C1/C2 and C5/C6 articular pillar bilaterally and large effect size (Cohen's $d > 0.8$, $p < 0.05$). Moreover, VR was more effective in decreasing JPSE (Cohen's $d > 0.08$; mean difference changes between −2.91 and −1.24, %95 CI -4.47 to 0.80) and functional limitation (ProFitMap-Neck) (Cohen's $d = 0.7$, mean difference 8.27, %95 CI 0.20 to 16.35). The results of T-Tests demonstrated that neither intervention was superior in terms of pain intensity, muscle performance, symptoms (ProFitMap-Neck), HADS, or SF-36 (Cohen's $d < 0.5$).

Conclusions: VR can be applied for improving proprioception and for decreasing cervical articular pain in CNP patients. In addition, VR may be more effective for decreasing functional limitations in patients. Clinicians can choose MC exercises with or without VR for improving pain, muscle performance, symptoms, anxiety/depression, and quality of life.

1. Introduction

Neck pain is a common musculoskeletal problem that has significant effects on individuals, families, and health systems (Hogg-Johnson et al., 2008). The estimated one-year incidence of neck pain ranges from 10.4% to 21.3%, and the prevalence of neck pain in the general population from 0.4% to 86.8% (Genebra et al., 2017). Passive and active physical therapy approaches play a very important role in the treatment of neck pain (Vernon et al., 2005).

With the rapid development of technology, new developments such as virtual reality (VR) have begun to be used in the treatment of chronic neck pain (CNP) (Ahern et al., 2020a). VR creates a sense of reality and enables one to experience a multisensory, three-dimensional, and impressive virtual environment. The physiological effects of VR are explained by diversion of attention and provision of multisensory input such as visual, auditory, and proprioceptive stimuli (Li et al., 2011). VR application with glasses facilitates a reduction in the perception of pain and range of motion (ROM) of the cervical region in all directions. Based on the physiology of the cervical spine, joint proprioceptors, and spindles localized in the deep cervical muscles (Treleaven, 2008), use of VR can result in changes in the sense of joint position. There are studies in the literature in which VR is applied in addition to kinematic training (Bahat et al., 2015) or compared with cervical ROM (Tejera et al., 2020) or proprioceptive training (Rezaei et al., 2019) in CNP patients. These studies indicated that VR can be effective in reducing pain and disability levels and improving active ROM in people with CNP.

Another treatment approach that has proven to be effective in people with neck pain is motor control (MC) exercise. Studies indicate that MC exercises are useful in reducing pain and contribute to the development of sensorimotor control and stability by focusing on the control abilities of the deep cervical muscles for the training of the cervical muscles (Southerst et al., 2016). To the best of our knowledge, there is no study

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https://doi.org/10.1016/j.msksp.2022.102636
Received 15 March 2022; Received in revised form 21 July 2022; Accepted 25 July 2022
Available online 5 August 2022

in the literature investigating the effects of MC exercises with VR.

In the present study we investigated the effects of VR in addition to MC exercises on joint position sense error (JPSE), pain, muscle performance, functional limitation, psychosocial status, and quality of life. We hypothesized that VR in addition to MC exercises is more effective than MC exercises alone in improving JPSE, pain reduction, pain pressure threshold (PPT), functional limitation, muscle performance, psychosocial status, and quality of life.

2. Methods

2.1. Study design

This was a randomized controlled trial conducted in conformity with the requirements set out in the Consolidated Standards of Reporting Trials (CONSORT) (Schulz et al., 2010) and approved by the ethics committee of Hacettepe University. The study was registered in the United States Randomized Trials Register at clinicaltrial.gov NCT04014998.

2.2. Participants

The study was conducted at Hacettepe University's Faculty of Physical Therapy and Rehabilitation. Patients were recruited from Hacettepe University Hospital's Neurosurgery Department between June 2020 and May 2021. Eligible patients were aged between 18 and 65 years with a minimum of 6 months of neck pain, a baseline NDI score of at least 20% (10 points), and the neck region as the primary pain area. The exclusion criteria were as follows: having undergone cervical spine surgery; having rheumatologic, vestibular, neurological, or cardiopulmonary diseases; having receiving interventions including exercise or physical therapy in the previous 6 months; and being pregnant. All patients were asked to give their written informed consent for participation in the study.

2.3. Interventions

The patients were randomly assigned into 2 groups: the VR or MC group. Both groups received 3 sessions of training per week for 6 weeks, making a total of 18 sessions. Each session lasted 40 min in both groups. The VR group first performed MC exercises for 20 min and then VR for 20 min *(5 repetitions for each exercise)*. The MC group performed only MC exercises for 40 min *(10 repetitions for each exercise)*.

2.3.1. Virtual reality

VR was applied with Oculus Go VR glasses. These glasses (weight 470 g) are a portable, all-in-one headset that does not require a computer or phone, and can be controlled by remote control. The VR glasses have a 5.5-inch display with a resolution of 2560 × 1440 pixels. In the first session, the patients were trained to use the VR glasses and remote control. For the present study, two VR applications were installed: "Ocean Rift" and "Gala 360". "Ocean Rift" provides a VR experience that allows watching sea animals that can be selected with the remote control. "Gala 360" provides views from countries and cities all over the world. These applications were chosen for the following reasons: they would not cause VR sickness (such as nausea, dizziness, fullness of head, etc.), they did not cause feelings of fear or excitement, and they allowed neck movements in all directions.

For the VR treatment, a calm and quiet environment was ensured and each patient experienced the VR treatment in the same environmental conditions. The patients were seated in a chair that allowed 360° movement and were asked to look in all directions during the VR application. The screen watched by the patients was simultaneously projected onto the phone and the patients were guided by the physiotherapist (HÇ). They were encouraged to move their necks by expressions such as *"follow that dolphin, the sea turtles you chose will come soon, there may be a starfish below. Now you are in front of the Eiffel Tower, you can look around"*. In addition, the VR glasses and remote control were sterilized with a sterilization device after each session.

2.3.2. Motor control exercises

The MC exercises included strengthening of the deep cervical flexors (DCFs), deep cervical extensors (DCEs), and axioscapular muscles; stretching exercises; and postural correction exercises.

The 3-level treatment protocol developed by Jull was used in the training of the cervical muscles in our study (Jull et al., 2004). *In the first level,* craniocervical flexion (CCF) exercises were used for low-load endurance training of the DCFs and cervical extension exercises were used for endurance training of the DCEs. The exercises were performed slowly to provide MC and increase kinesthetic awareness. The ability to do the CCF exercises for 10 s was used as a reference to indicate progress in the exercises. *In the second level,* elastic bands were used to increase the strength and endurance of the DCFs and DCEs. *In the third level*, the aim was to gain dynamic balance and this was achieved by the patient holding an exercise ball against a wall with the front/back of the head.

All patients were informed about neutral spinal posture from the first session. They were trained to actively correct postures and maintain them for 10 s (in sitting and standing positions) as described in a previous study (Jull et al., 2004). Stretching was performed before each exercise session.

2.4. Outcome measurements

The sociodemographic characteristics of all participants were obtained, including sex, age, body mass index (BMI), occupation, education status, and pain characteristics (location, duration, and frequency). Neck pain location was assessed using a figure of the body and categorized as upper or lower neck pain and right or left. Pain duration and frequency were recorded using multiple-choice questions (Jull et al., 2002; Sremakaew et al., 2018). All outcome measurements were recorded at baseline and immediately after the end of the study (after 6 weeks).

2.4.1. Primary outcomes

2.4.1.1. Range of motion and joint position sense error (JPSE). Range of motion and JPSE were assessed with a Cervical Range of Motion 3 (CROM 3) device in six different positions: flexion, extension, right/left lateral flexion, and right/left rotation. Firstly, the patients were asked to actively move their neck in all positions and maximum ROM were recorded for each position. The participant's head was moved slowly and passively by the researcher to 65% of the maximum range of motion while in the sitting position. The participant was asked to keep his or her head at this point for 3 s and feel the position. The participant's head was then moved back to the neutral position. Then the researcher asked the participants to find actively the point described above, with their eyes closed. The error in degrees was recorded. This procedure was performed three times and the mean value of the errors recorded (Kubas et al., 2017).

2.4.2. Secondary outcomes

2.4.2.1. Pain intensity. Pain intensity was measured using a 10-cm visual analogue scale (VAS) anchored by "no pain" and "worst pain imaginable". Individuals were asked to mark the average pain they felt in the last week on this scale (Clark et al., 2003).

2.4.2.2. Pain pressure thresholds (PPTs). A pressure algometer (JTech Medical Industries, ZEVEX Company) was used to assess PPTs. PPTs were measured for both the right and the left upper trapezius (UT), the right and left articular pillar of C1/C2 and C5/C6, and over the right tibialis anterior (TA). Before measurements at these points were taken, PPT measurement was demonstrated on the patient's hand to familiarize the patient with the procedure. The participants were instructed to say "stop" when the sensation changed from pressure to pain. Three measurements were taken at each point with a probe of 0.5 cm of diameter and pressure was applied at a rate of approximately 3 N/s up to a maximum of 60 N. A 30-s resting period was allowed between each measurement. The mean of the measurements was recorded (Turkmen et al., 2020).

2.4.2.3. Muscle performance. The strengths of cervical flexors and extensors were assessed by digital hand dynamometer (Lafayette Instrument Company, USA). Lovett's muscle test positions were used for measuring strength (Lovett and Martin, 1916). The resistance region was the frontal region for the cervical flexors and the occipital region for the cervical extensors. The highest value of three measurements was recorded. Between the repetitions, the patients were asked to rest for 1 min (Kubas et al., 2017).

The endurance of the DCFs was assessed with a pressure biofeedback device (Stabilizer™, Chattanooga Group Inc., USA). The pressure biofeedback stabilizer was placed in the suboccipital space and inflated until a stable pressure of 20 mmHg was achieved in a supine position. The highest value of three maximal voluntary isometric cervical flexion contraction of 3-s duration was selected as the reference pressure value (mmHg). This value was used to calculate the sub-maximal of 50% pressure for exercising. After 1 min of rest, the patients were asked to maintain a target pressure value (sub-maximal of 50% reference value) and a stopwatch was used. This procedure was performed three times and the average value of these measurements was recorded (Chung and Jeong, 2018).

2.4.2.4. Symptoms and functional limitations. For measuring the symptoms and functional limitations of the patients, the Profile Fitness Mapping Neck Questionnaire (ProFitMap-Neck) was used. ProFitMap-Neck was designed by Björklund et al. (2012) and the validity and reliability of the Turkish version were established by Çetin et al. (Cetin et al., 2020). The questionnaire consists of two indexes: a symptom scale (27 items) and a functional limitation scale (20 items). It was scored with a 6-point scale for symptom frequency (1: never, 6: very often) and for symptom intensity (7: nothing, 12: almost unbearable), and for functional limitations (1: very good, 6: very bad). Four scores were obtained from this questionnaire: symptom frequency, symptom intensity, functional limitation, and total score. The result of each index is expressed as the percentage of the maximum score, where 100% is the best possible result (Björklund et al., 2012).

2.4.2.5. Anxiety/depression. The Hospital Anxiety and Depression Scale (HADS) was used for assessing the anxiety and depression levels of the patients. HADS consists of seven items for anxiety and seven items for depression. The items were scored from 0 (not present) and 3 (considerable). The cutoff score was 10 for anxiety and 7 for depression. Values above these values indicate a risk for anxiety and depression (Aydemir et al., 1997).

2.4.2.6. Quality of life. Quality of life was assessed with the Short Form Health Survey (SF-36). It includes 8 health concepts with 36 items: physical functioning (PF), role limitations due to physical health (PRL), emotional role limitations (ERL), vitality (V), physical role limitations (PRL), social functioning (SF), bodily pain (BP), and general health (GH). The best score is "100" (best possible health state) and the worst score is "0" (worst possible health state) (Ware et al., 1999).

2.5. Sample size calculation and randomization

The sample size was calculated using the program G*Power 3.0. The minimum sample size was sought to allow detection of significant differences for JPSE between the two groups subjected to different treatments (two-tailed test) with a power of 80% and a 5% alpha error. Considering the physiological mechanisms of VR on the stimulation of joint receptors, we used the JPSE variable in the power analysis. Using the data provided by Sofia et al. (2017) for a difference between two groups of 1.85–3.79° for JPSE in each group, a total of 17 patients per group were required, making a total of 34 patients. Because of the dropouts, a total of 41 patients were enrolled in the trial.

The randomized sequence for allocation into the treatment groups was created by an independent researcher using a random allocation computer-generated program. After the pretests, 41 participants with CNP were randomly allocated to either the VR group (n = 21) or the MC group (n = 20).

2.6. Statistical analysis

The statistical analyses were performed using IBM SPSS Statistics version 21.0 (IBM Corp., Armonk, NY, USA). Visual (histograms/probability graphs) and analytical methods (Kolmogorov–Smirnov/Shapiro–Wilk test) were used to evaluate whether the variables were normally distributed. The descriptive data were presented as mean and standard deviation (SD), median, interquartile range, and confidence interval. Fisher's χ^2 test was used for comparing categorical variables between the two groups. Comparisons of quantitative variables between the groups were done with the independent samples *t*-test for normally distributed variables and the Mann–Whitney *U* test for nonnormally distributed variables *(for SF-36 variables)*. The statistical significance level was set at 0.05. For within groups comparisons, p value was set at 0.05 divided by 4 with Bonferroni correction. Within group comparisons are demonstrated in Table 3 by asterisks. The formula $r = Z/\sqrt{n}$ was used for the effect size of the data not normally distributed (r = 0.10 small effect, r = 0.30 medium effect, r = 0.5 large effect). The formula d=(X¯_1-X¯_2)/ ⟦SD_pooled (Cohen's d) was used for the effect size of normally distributed data (d = 0.2 small effect, d = 0.50 medium effect, d = 0.8 large effect).

3. Results

Forty-one patients with CNP were randomly assigned to the VR or MC group. Fig. 1 shows the flowchart describing the numbers of participants for the groups, group allocation, follow-up, and analysis, including dropouts and reasons. No adverse effects were observed in either group.

3.1. Baseline measurements

The sociodemographic and pain characteristics of each group are presented in Table 1. The participants in both groups were homogeneous in terms of age, BMI, sex, education, occupation, and pain characteristics (location, duration, and frequency) ($p > 0.05$).

Table 2 contains the baseline characteristics of the groups. There were no significant differences between the groups in VAS score, PPT values of all reference points, JPSEs, cervical muscle strengths, DCF endurance, ProFitMap-Neck scores, HADS-anxiety score, or some parameters of SF-36 (PF, PRL, ERL, social functioning, pain, health change) ($p > 0.05$). On the other hand, HADS-depression score and some parameters of SF-36 (energy, emotional well-being) differed between the groups at baseline ($p < 0.05$).

3.2. Between-group differences

The deltas in the groups are compared in Table 3. There were no differences in the deltas of VAS, muscle strength and endurance, HADS, and SF-36 ($p > 0.05$). Analysis of the deltas of PPTs showed there were no significant differences in the UT (right/left) and TA between the

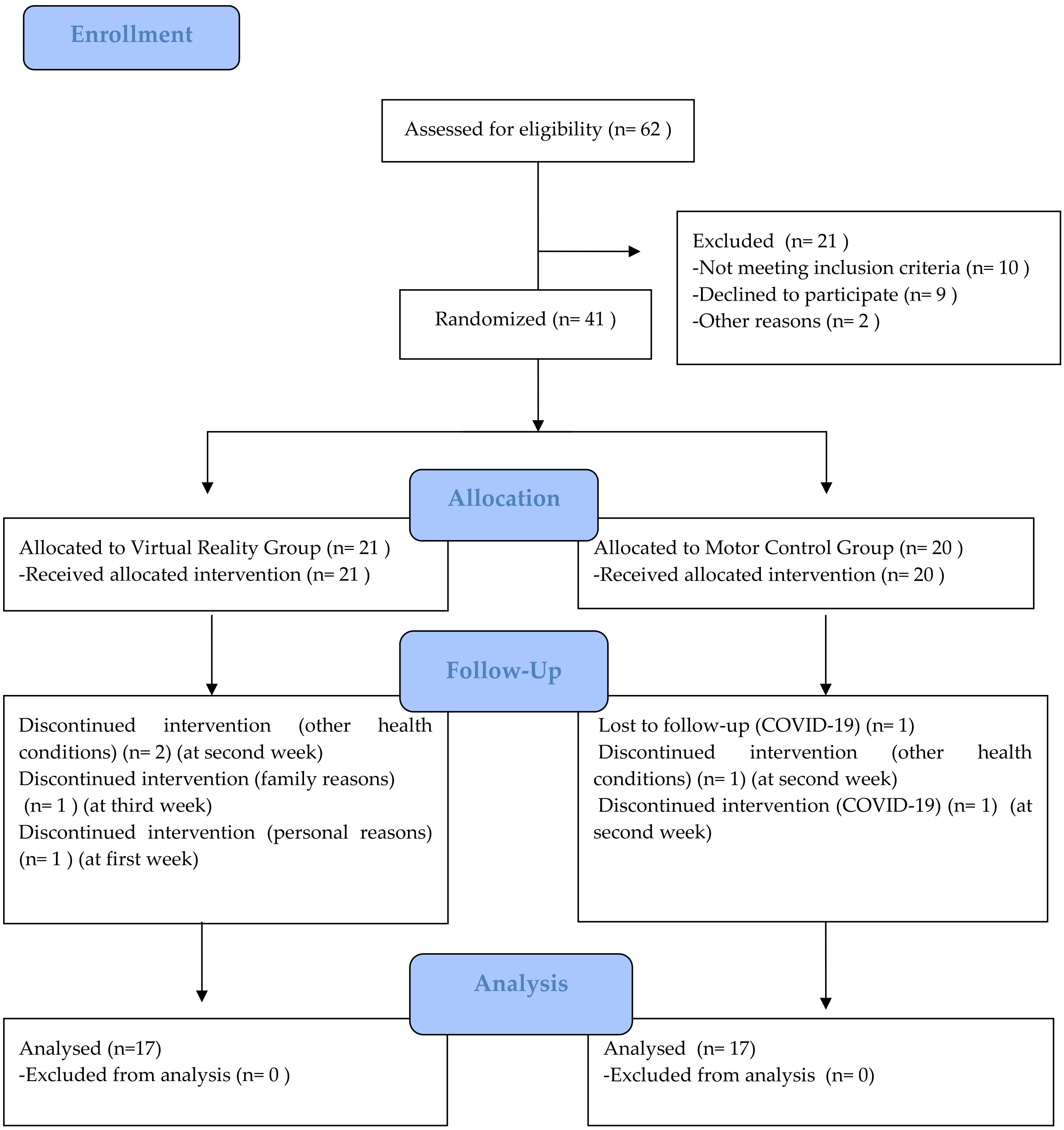

Fig. 1. Flowchart of the study.

groups. Contrary to these results, the VR group had a significant advantage in PPTs of the C1/C2 articular pillar, C5/C6 articular pillar bilaterally, and large effect size (Cohen's $d > 0.8$). Moreover, the deltas of JPEs in the six directions had a large effect size (Cohen's $d > 0.8$) in the VR group. ProFitMap-Neck scores showed no significant differences between the groups ($p > 0.05$), except for functional limitation index ($p < 0.05$, the VR group had a greater improvement).

3.3. *Within-group differences*

The VR group showed significant differences in ROM, JPSEs, PPTs, muscle strength and endurance, ProFitMap-Neck (symptom frequency and total index), and some parameters of SF-36 ($p < 0.01$). The MC group had significant differences in ROM (except lateral flexions), some PPT values, muscle strength, ProFitMap-Neck (symptom frequency, functional limitation and total index), and some parameters of SF-36 ($p < 0.01$) (Table 3).

4. Discussion

Our study presents the effects of VR in addition to MC exercises on ROM, JPSE, pain, PPTs, muscle performance, functional limitation, psychosocial status, and quality of life. The results indicated that VR in addition to MC exercises was more effective than MC exercises alone in improving PPTs (C1/2 and C5/6), JPSE, and functional limitation. However, neither intervention was superior in improving ROM, pain, muscle performance, symptoms, psychosocial status, or quality of life.

All the cervical ROMs were improved similarly in the two groups, although the VR group had more neck movements during the VR application. However, the studies showed that DCF training and stabilization exercises provided increases in cervical ROMs in CNP (Kuo et al., 2020; Thoomes-de Graaf and Schmitt, 2012). MC exercises,

Table 1
Baseline sociodemographic and pain characteristics of each group.

Variable	VR Group Mean ± SD	MC Group Mean ± SD	p
Age (years)	40.0 ± 11.88	41.94 ± 10.76	0.62[a]
BMI (kg/m²)	25.58 ± 4.35	26.31 ± 4.01	0.61[a]
	n (%)	**n (%)**	
Gender			0.71[b]
Female	12 (70.5)	11 (64.7)	
Male	5 (29.5)	6 (35.3)	
Education			0.54[b]
Preliminary School	2 (11.8)	5 (29.4)	
Secondary School	3 (17.7)	2 (11.8)	
High School	8 (47.0)	8 (47.0)	
University	4 (23.5)	2 (11.8)	
Occupation			0.97 [b]
Housewife	3 (17.6)	3 (17.6)	
Workers	11 (64.7)	10 (58.9)	
Retired	2 (11.8)	3 (17.6)	
Student	1 (5.9)	1 (5.9)	
Pain location			0.51[b]
Upper neck	10 (58.9)	7 (41.2)	
Lower neck	3 (17.6)	3 (17.6)	
Upper/Lower neck	4 (23.5)	7 (41.2)	
Pain location			0.65[b]
Right	11 (64.7)	10 (58.9)	
Left	4 (23.6)	3 (17.6)	
Right/Left	2 (11.7)	4 (23.5)	
Pain duration			0.72 [b]
6–12 months	6 (35.3)	4 (23.5)	
1–2 years	4 (23.6)	3 (17.6)	
2–5 years	5 (29.4)	6 (35.3)	
>5 years	2 (11.7)	4 (23.5)	
Pain frequency			0.25 [b]
≤1 once a week	1 (5.9)	0	
2–3 times a week	4 (23.5)	8 (47)	
>3 times a week	12 (70.6)	9 (53)	

VR: Virtual Reality, MC: Motor Control. SD: Standart deviation, BMI: Body Mass Index.
[a] Independent Samples T-Test.
[b] Fisher x^2 Test.

Table 2
Baseline characteristics of the virtual reality and motor control group.

Variables	VR Group Mean ± SD	MC Group Mean ± SD	p value
Range of Motion (°)			
Flexion	49.05 ± 7.89	44.64 ± 9.92	0.32 [a]
Extension	62.47 ± 11,88	61.23 ± 9.44	0.73 [a]
Right lateral flexion	40.23 ± 8.35	39.42 ± 7.83	0.76 [a]
Left lateral flexion	42.56 ± 8.25	43.66 ± 7.23	0.45 [a]
Right rotation	56.76 ± 9.83	51.47 ± 8.43	0.15 [a]
Left rotation	55.0 ± 9.18	49.11 ± 8.33	0.09 [a]
JPSE (°)			
Flexion	4.99 ± 1.67	4.77 ± 1.91	0.72 [a]
Extension	4.79 ± 2.2	5.1 ± 2.0	0.66 [a]
Right lateral flexion	5.56 ± 2.88	5.80 ± 1.74	0.69 [a]
Left lateral flexion	6.33 ± 1.83	5.66 ± 2.49	0.56 [a]
Right rotation	6.65 ± 3.18	5.2 ± 1.69	0.24 [a]
Left rotation	5.09 ± 2.55	5.4 ± 1.75	0.68 [a]
Pain intensity- VAS (0–10 cm)	5.77 ± 1.39	5.98 ± 1.93	0.70 [a]
PPT (N/cm²)			
Trapezius (R)	7.75 ± 1.52	8.12 ± 1.48	0.54[a]
Trapezius (L)	8.21 ± 2.17	8.84 ± 2.21	0.40 [a]
C1-2 articular pillar (R)	3.64 ± 0.92	3.18 ± 0.56	0.18 [a]
C1-2 articular pillar (L)	3.78 ± 1.07	3.32 ± 0.72	0.14 [a]
C5-6 articular pillar (R)	3.18 ± 0.76	3.29 ± 1.0	0.20 [a]
C5-6 articular pillar (L)	3.70 ± 1.03	3.52 ± 0.64	0.42 [a]
Tibialis anterior	14.79 ± 6.92	16.26 ± 4.18	0.45 [a]
Muscle strength (N)			
Cervical flexor muscles	26.09 ± 7.94	29.03 ± 7.11	0.26 [a]
Cervical extensor muscles	33.62 ± 9.22	38.24 ± 6.25	0.09 [a]
Muscle endurance			
DCF (second)	12.32 ± 11.69	12.2 ± 5.73	0.83 [a]
ProfitMap-Neck (%)			
Symptom frequency	66.39 ± 13.63	60.91 ± 12.62	0.23[a]
Symptom intensity	72.73 ± 11.47	68.76 ± 13.87	0.37[a]
Functional limitation	67.5 ± 14.97	64.39 ± 13.48	0.52[a]
Total Score	69.3 ± 11.3	65.22 ± 63.49	0.30[a]
HADS			
Anxiety	6.52 ± 2.91	7.76 ± 2.92	0.14[a]
Depression	4.23 ± 3.03	7.03 ± 3.78	**0.01**[a]
	Median (IQR)	**Median (IQR)**	**p**
Quality of Life			
Physical functioning	75.0 (60.0–85.0)	75.0 (60.0–90.0)	1.0 [b]
PRL	66.7 (33.3–83.3)	33.3 (33.3–66.7)	0.08 [b]
ERL	55.0 (55.0–60.0)	45.0 (32.6–55.0)	0.08 [b]
Energy	75.0 (62.5–87.5)	55.0 (38.7–62.5)	**0.02** [b]
Emotional weel-being	68.0 (52.0–74.0)	52.0 (46.0–64.0)	**0.01** [b]
Social functioning	75.0 (25.0–90.0)	62.5 (37.5–100.0)	0.08 [b]
Pain	45.0 (40.0–62.5)	45.0 (21.2–65.0)	0.49 [b]
Health Change	57.5 (50.0–65.0)	50.0 (42.5–60.0)	0.07 [b]

[a] Independent Samples T-Test.
[b] Mann Whitney *U* Test used for group comparisons, PPT: Pain pressure threshold, JPSE: Joint position sense error, DCF: Deep cervical flexor muscles, PRL: Role limitations due to physical health, ERL: Role limitations due to emotional health.

involving these trainings and exercises in the present study, can induce similar improvements in the ROMs of the two groups. Contrary to these results, the VR group was superior in terms of JPSE improvements. When evaluating JPSE, the eyes are closed and the proprioceptive system is more active. The superiority of the VR group could be attributed to greater stimulation of the cervical joint proprioceptors with VR application and the cervical region is very important in terms of the proprioceptive system (Amaral et al., 2018). The MC exercises might have contributed to the larger improvement in JPSE in the VR group. Although no study has investigated JPSE, Bahat et al. demonstrated that VR kinematics (peak and mean velocity) improved after VR application in addition to kinematic training in CNP (Bahat et al., 2015). In our opinion, VR kinematics is related to JPSE because the kinematics comprises the acceleration, velocity, accuracy, etc. of movement. For this reason, their results are similar to those of the current study (Bahat et al., 2015).

We found that pain intensity decreased similarly in the two groups. Previous studies about CNP and VR reported that VR was more effective than proprioceptive training (Rezaei et al., 2019) and kinematic training (Bahat et al., 2015) in reducing pain. Those results are in contrast with ours. A meta-analysis indicated that MC exercises are quite effective in reducing the level of pain and disability, and even more effective than other treatment methods (such as strengthening and endurance exercises, mobilization, and proprioceptive training) in CNP (Martin-Gomez et al., 2019). We think that the reason the reduction in pain was similar between the groups could have been the effects of the MC exercises. The reduction may also have been due to the physiological effects of VR, such as distraction and feedback mechanisms (Ahern et al., 2020b).

The VR group was superior in improving the PPT values of the C1/2 and C5/6 articular pillar, contrary to the UT and TA. However, the PPT values of UT and TA were increased similarly in both groups. To the best of our knowledge, there is no study in the literature that investigated cervical PPTs and VR. However, when considering the biomechanics of the cervical spine, atlantooccipital (C1-2) and uncovertebral (C3-6) joints contribute to the ROM of the cervical region (Kotani et al., 1998). The greater increase in the PPTs of C1/2 and C5/6 could be related to the greater ROM used and more proprioceptive input in the VR group. On the other hand, the increase in the PPTs of the UT and TA might have been observed because of similar effects of the MC exercises and VR on maladaptive changes in chronic pain (Malfliet et al., 2017). The patients with chronic pain experience maladaptive neuroplastic changes that could lead to impaired cortical-motor representation (Schabrun et al., 2017). Javanshir et al. measured PPTs in a group of adult participants with chronic neck pain and an asymptomatic group and reported that chronic neck pain participants showed lower PPTs in the articular pillar of C5/C6 compared to asymptomatic participants (Salom-Moreno et al.,

Table 3
Between group mean and SD differences, analysed by comparing deltas in groups and within group comparisons.

Delta (Δ) analysed		Post-pre changes				
Group		VR Group Mean ± SD	MC Group Mean ± SD	Mean difference at 6 weeks (95% CI)	Cohen's d	p[a]
Range of Motion (°)	Flexion	10.64 ± 7.44[c]	8.47 ± 7.21[c]	2.17 (-2.94 to 7.29)	0.29	0.41
	Extension	10.05 ± 9.25[c]	7.70 ± 7.05[c]	2.35 (-3.39 to 8.10)	0.28	0.39
	Right lateral flexion	7.63 ± 8.84[c]	7.30 ± 5.81	0.33 (−3.76 to 5.14)	0.04	0.64
	Left lateral flexion	4.96 ± 7.41[c]	4.92 ± 5.78	0.04 (−4.02 to 5.02)	0.00	0.86
	Right rotation	6.05 ± 13.6[c]	8.52 ± 6.06[c]	−2.47 (-9.83 to 4.88)	−0.23	0.56
	Left rotation	7.35 ± 9.0[c]	9.41 ± 9.98[c]	−2.05 (−8.70 to 4.59)	−0.21	0.41
JPSE (°)	Flexion	**−2.81 ± 1.82**[c]	−1.16 ± 1.17[c]	−1.65 (-2.72 to 0.57)	−1.07	**0.04**
	Extension	**−2.80 ± 1.84**[c]	−1.52 ± 1.16[c]	−1.27 (-2.35 to 0.20)	−0.82	**0.02**
	Right lateral flexion	**−3.53 ± 1.35**[c]	−2.62 ± 1.36[c]	−2.91 (-4.47 to −1.35)	−1.10	**0.03**
	Left lateral flexion	**−3.95 ± 1.03**[c]	−2.95 ± 4.27[c]	−1.64 (-2.66 to −0.62)	−1.08	**0.04**
	Right rotation	**−4.07 ± 2.99**[c]	−1.15 ± 1.0[c]	−1.58 (-2.25 to 0.80)	−1.30	**0.001**
	Left rotation	**−2.81 ± 1.64**[c]	−1.17 ± 1.24[c]	−1.24 (-2.42 to 0.18)	−1.12	**0.002**
Pain intensity- VAS (0–10 cm)		−3.69 ± 1.85[c]	−2.44 ± 2.14[c]	−1.25 (-2.65 to 0.15)	0.62	0.07
PPT (N/cm^2)	Upper Trapezius (R)	3.5 ± 1.82[c]	2.06 ± 2.23	1.44 (0.01–2.86)	0.70	0.06
	Upper Trapezius (L)	4.38 ± 2.56[c]	3.02 ± 1.92[c]	1.36 (−0.22 to 2.94)	0.60	0.09
	C_{1-2} articular pillar (R)	**2.92 ± 0.89**[c]	2.51 ± 0.73[c]	0.40 (−0.16 to 0.98)	0.82	**0.03**
	C_{1-2} articular pillar (L)	**3.49 ± 1.24**[c]	2.03 ± 0.99	1.46 (0.67–2.25)	1.30	**0.001**
	C_{5-6} articular pillar (R)	**2.24 ± 1.36**[c]	1.32 ± 0.81[c]	1.07 (0.41–1.74)	1.13	**0.02**
	C_{5-6} articular pillar (L)	**2.04 ± 1.01**[c]	0.96 ± 0.88	0.91 (1.13–1.70)	0.81	**0.002**
	Tibialis anterior	6.87 ± 5.41[c]	4.63 ± 3.32[c]	2.23 (−0.90 to 5.37)	0.49	0.15
Muscle strength (N)			7.91 ± 4.3[c]			
	Cervical flexor	9.76 ± 6.06[c]	9.76 ± 7.52[c]	1.85 (-1.82 to 5.52)	0.35	0.31
	Cervical extensor	11.68 ± 4.47[c]		1.91 (-2.47 to 6.24)	0.31	0.73
Muscle endurance	DCF (second)	20.49 ± 15.38[c]	12.56 ± 12.76	7.92 (-1.95 to 17.80)	0.56	0.11
ProFitMap-Neck (%)	Symptom frequency	13.88 ± 8.52[c]	14.05 ± 11.34[c]	0.17 (−7.18 to 6.84)	−0.01	0.96
	Symptom intensity	10.45 ± 13.88	10.82 ± 13.37	−0.36 (-9.89 to 9.15)	−0.02	0.93
	Functional limitation	**14.64 ± 8.93**[c]	6.36 ± 13.68[c]	8.27 (0.20–16.35)	0.71	**0.04**
	Total Score	12.97 ± 9.91	10.59 ± 10.78[c]	2.37 (-4.85 to 9.61)	0.23	0.75
HADS	Anxiety	−2.0 ± 2.76	−1.23 ± 2.99	−0.76 (-2.77 to 1.24)	−0.26	0.54
(0–7)	Depression	−1.82 ± 5.39[c]	−1.62 ± 3.72	0 (−2.14 to 2.14)	0.00	0.90
Delta (Δ) analysed		**VR Group Median (IQR)**	**MC Group Median (IQR)**	**Median difference at 6 weeks (95% CI)**	**r**	**p[b]**
SF-36 (0–100)	Physical functioning	15.0 (5.0–17.5)[c]	5.0 (0–17.5)[c]	2.94 (-5.17 to 11.05)	0.21	0.46
	PRL	25.0 (0–46.0)[c]	25.0 (10–50.0)	−3.62 (-27.62to 20.36)	0.10	0.97
	ERL	33.3 (0–33.5)	33.4 (0–66.7)	−5.86 (-18.76 to 7.03)	0.00	0.37
	Energy	10.0 (2.5–15.0)[c]	10.0 (2.5–22.5)	−11.94 (-25.91to 2.91)	0.15	0.25
	Emotional weelbeing	0 (8.0–16.0)[c]	12.0 (2.0–20.0)	−5.29 (-13.06 to 2.47)	0.15	0.37
	Social functioning	0 (0–12.5)[c]	12.5 (0–36.2)	11.62 (-14.22 to37.46)	0.19	0.56
	Pain	22.5 (10–17.5)[c]	22.5 (5.0–38.7)	1.91 (−17.94 to14.11)	0.19	0.89
	General Health	5.0 (10.0–17.5)[c]	15.0 (2.5–20.0)[c]	−1.12 (−9.63 to 7.38)	0.03	0.78

Delta (Δ) indicates post-pre changes. PPT: Pain pressure threshold, JPSE: Joint position sense error, DCF: Deep cervical flexor muscles, HADS: Hospital Anxiety and Depression Scale, SF-36: Short Form-36, PRL: Role limitations due to physical health, ERL: Role limitations due to emotional health.
Bold values indicate a significant advantage.
CI: Confidence Interval, SF-36 datas are reported as median (IQR).
[a] Independent Samples T-Test.
[b] Mann Whitney *U* Test used for deltas (Δ) comparisons between groups.
[c] Indicates $p < 0.0125$ (0.05/4) for within group comparisons with Bonferroni correction.

2014). The local increased sensitivity to pain can be classified as primary hyperalgesia and is thought to reflect nociceptor sensitization. Increased pain sensitivity at body sites distal to the neck region is defined as secondary hyperalgesia (Malfliet et al., 2015). However, the central mechanism and sensitivity might be changed with pain modulation after exercise (Suso-Martí et al., 2019). Malfiet et al. indicated that motor control training was effective for improving pressure pain sensitivity and symptoms of central sensitization (Malfliet et al., 2018). MC exercises may have contributed to improving the PPT values of both groups in our study, similar to Malfiet's study.

With regard to the ProFitMap-Neck results, we found that symptoms improved similarly between the groups and functional limitation decreased in favor of the VR group. A study comparing VR and laser training indicated that the disability level decreased in both groups, but VR may have some advantages in velocity, accuracy, pain intensity, and health status compared to laser training provided by a head-mounted laser beam and poster (Bahat et al., 2018). Furthermore, VR was more effective than proprioceptive training for decreasing disability in another study (Rezaei et al., 2019). In addition, VR was reported to be effective in decreasing fear of movement (Takasaki et al., 2013). The functional limitations of the participants might have been decreased due to the decrease in fear of movement in our study. Our clinical experience and patient feedback support this idea.

Nowadays, the terms "virtual reality" and "metaverse" are very popular and people find VR is quite intriguing. Although the patients were told that exercise is currently a valid method and VR is a very new approach for chronic neck pain before the study, we observed that the patients in the VR group had positive expectations. The results in favor of VR in some parameters may have been due to the placebo effect, since VR is a technological and novel approach. However, future research can be conducted to examine the placebo effect involving watching videos without neck movements with VR glasses.

The limitations of our study should be noted. The applications chosen for VR were not developed for neck pain. Future studies may be conducted with special applications for neck pain. CNP patients with mild disability were included in our study. We recommend that studies including CNP patients with greater disability be conducted in the future. Moreover, the assessor was not blinded and the study was not planned to include a follow-up in the long term. Studies with long-term follow-up are needed in this field.

5. Conclusions

Clinicians can choose MC exercises with or without VR to improve pain, muscle performance, symptoms, psychosocial status, and quality of life. VR with MC exercises can be applied for improving cervical proprioception and decreasing cervical articular pain and functional limitation in CNP patients. The present study has provided several directions for future research exploring the potential benefit of VR and different physical therapy modalities in those with neck pain.

Acknowledgment

We would like to thank Hatice Yağmur Zengin, a lecturer at Hacettepe University, Department of Biostatistics, who we consulted about the statistical analysis of the study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.msksp.2022.102636.

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