EFFICACY OF VIRTUAL REALITY ON NECK PAIN AND FUNCTION IN PATIENTS WITH NON-SPECIFIC NECK DYSFUNCTION: A RANDOMIZED CONTROL TRIAL

Kadrya H Battecha[1,2], Hebah A Takrouni[3], Rawan M Alzahrani[3], Razan M Alzahrani[3], Fatimah A Alzahrani[3], Hanaa S Mohamed[4]*

[1]Ph.D., Associate Professor, Department of Physical Therapy, Faculty of Applied Medical sciences, Umm Al-Qura University, Makkah, Kingdom of Saudi Arabia (KSA); [2]Professor of Physical Therapy, Department of Physical Therapy for Basic Science, Faculty of Physical Therapy, Cairo University, Egypt; [3]B.Sc., Department of Physical Therapy, Faculty of Applied Medical sciences, Umm Al-Qura University, Makkah, Kingdom of Saudi Arabia (KSA); [4]PhD, Lecturer, Department of Physical Therapy for Basic Science, Faculty of Physical Therapy, Modern University for Technology and Information, Egypt

Abstract

Objective: to evaluate the efficacy of Virtual reality on neck pain and function in patients with non-specific neck dysfunction**.**

Design: A pre-test post-test randomized control trial was performed at Umm Al-Qura University, Makkah, Saudi Arabia**.** Thirty female students, 18-25 years, were assigned to study group or control group randomly. The control group received traditional treatment in form of exercises; the study group received Virtual reality therapy plus traditional treatment. The intervention duration was 6 weeks. Before and after 6 weeks of training, pain, neck range of motion, and neck function were examined.

Results: there was no statistically significant difference in pain, neck range of motion, and neck functional activity between pre and post-treatment mean values of majority measured variables in both groups except pressure pain threshold variable in favor of the study group (P <0.05).

Conclusion: Virtual reality and traditional exercises have positive effect on non-specific neck dysfunction and they nearly have the same effect on neck pain, range of motion and functional level with favor of Virtual reality on pressure pain threshold.

Keywords: Neck pain. Non-specific neck pain. Virtual reality. Traditional treatment

Manuscrito recibido: 06/10/2023
Manuscrito aceptado: 20/10/2023

*Corresponding Author: Hanaa S Mohamed, Department of Physical Therapy for Basic Science, Faculty of Physical Therapy, Modern University for Technology and Information, Egypt

Correo-e: s_hanaa@yahoo.com

Introduction

Neck pain has negative impact on subject's life; it sometimes causes stress and anxiety over the already existed stress. As well as decreasing work hours, working quality, concentration during work, and daily activities[1].

Moreover, 13.2% of the medical student participated in previous study claimed that neck pain affected their quality of life, in the form of frequent absences from college and difficulties in carry out their daily activities. More than half of the participants claimed that they experienced depressive symptoms and may have experienced low self-esteem which reflected negatively on their performance[2].

Non-specific neck pain (NSNP) is one of the most significant health problems; occupy the fourth most common cause of musculoskeletal disorders around the world [3]. It is estimated that about 70% of people experience neck pain throughout the life, with a 15% to 50% incidence annually. According to statistics 11.8% of people in East Asia report having neck pain, West Asia at 10.14%, Australia at 10.13%, Latin America s 10.12%, Central Asia at 9.8%, Central Europe at 9.9%, Eastern Europe as 9.9%, the Caribbean at 9.7%, and Southeast Asia as 7.6%[4].

NSNP is a pain appears in the anatomical region of the neck that does not radiate to the upper limbs. It can also described as pain in the posterior region of the neck from the superior nuchal line to the spine of the scapula and the side region down to the superior border of the clavicle and the suprasternal notch[5]. It is connected with job-related and musculoskeletal factors including extended work hours, lack of physical activity, high workload and demands, poorly designed computer workstation, and desk-bound work position[6].

There are several traditional interventions to treat NSNP, including manual therapy like myofascial release which is applying a low-load, prolonged stretch manually to the myofascial complex to restore it to its ideal length, lessen discomfort, and enhance function[7], therapeutic exercises as stretching, strengthening, stabilization, and endurance training[8]. Also, Thermotherapy has been used to control persistent pain in muscles and joints. It was reported as a supplementary treatment. Since applying thermotherapy causes the temperature of the skin to rise and improve circulation to the muscle and reduces muscle spasm, it could be linked to a rise in muscle flexibility. According to these findings, using thermotherapy followed by exercise during the intervention may strengthen the stability of neck muscles[9].

Recently, virtual reality (VR) has been used as a new intervention in the treatment of many cases. It is a term of using computing system to create an artificial environment that gives individuals the impression that they can move around and interact with its objects. Three fundamental elements form the basis of VR treatment: simulation, interaction and immersion[10].

Patients with neck pain may benefit from using VR as a low-cost therapeutic measure for NSNP, because of its adaptability and the fact that it requires the player to constantly pay full attention to the game. Since human attention is restricted, playing diminishes a participant's cognitive capacity to understand pain, leading to a decreased perception of it[11].

VR has been shown its effectiveness not only in reducing pain, but also for increasing the range of motion and reducing kinesiophobia that play an important role in treating neck pain[12]. At opposite of regular conventional interventions, VR has much more motivation and social interactions which are very important practical benefits of it[13]. But unfortunately, the underlying mechanism of VR is still unclear and needs further studies to support its effects[14]. Therefore, the current study was conducted to investigate the effect of VR on neck pain and function of patients with non-specific neck pain.

Material and Methods

Design of the study

The present study was a prospective, pre-test post-test, randomised controlled trial with parallel groups. The current study was accepted by the university of Umm Al-Qura, biomedical research ethics committee (No: HAPO-02-K-012-2022-11- 1316).The study was performed at Faculty of Applied Medical Sciences, physical therapy department (Umm Al-Qura University/,Makkah, Saudi Arabia) from November 2022 to May 2023. The participants were informed about the study's purpose, advantages, the right to withdraw at any stage, and the confidentiality of the gathered data. Before participating, a formal consent form was signed.

Participants

Thirty female (physical therapists) student enrolled in the study based on the following criteria: The participants' ages ranged from 18 to 25 with a mean of 21.5 ± 0.845 years, body mass index (BMI) between 18-25 kg/m^2 with a mean of 20.6 ± 2.66., complaining from non- specific mechanical neck pain. The following were used as exclusion criteria: participants with neck pain resulting from serious pathology (tumor, rheumatoid arthritis, ankylosing spondylitis, fracture, dislocation, myelopathy, radiculopathy). Also any dermatological conditions, hemorrhagic blood diseases, epilepsy, long term use of corticosteroids or receiving any treatment for their pain currently, or have any previous cervical surgery.

They were assigned randomly into two groups: control group (n=15) who

received traditional treatment only (stretching and isometric exercises for neck muscles) and study group (n=15) who received VR therapy for all neck movements (flexion, extension, side bending and rotation) combined with traditional treatment.

Sample size

The sample size calculation was done before starting the study to avoid type II error, the sample size was estimated using G*POWER statistical software (version 3.0.10). Therefore, a total of thirty participants were chosen for the sample.

Randomization

Thirty females with non-specific neck pain and BMI between 18-25 kg/m^2 were randomly allocated to virtual reality group (study group) and traditional treatment group (control group) with computer-generated block randomization program at http://www.randomization.com/. To minimize bias and variation between the two groups, participants were randomly assigned to blocks with sizes of 4, 6, and 8 using a 1:1 allocation ratio. The randomization was carried out by the first author, who was not involved in the recruitment process, data collection, or treatment. To ensure disguised allocation, randomization codes were sequentially numbered and remain confidential in sealed, opaque envelopes.

Intervention

The last author opened envelopes after baseline measurements and continued treatment in accordance with group allocation. Control group received traditional treatment (stretching exercises and isometric strengthening) for three sessions per week [15]. Stretching protocol was applied for 3 minutes then strengthening exercises for 7 minutes. Passive stretching was applied in all directions (flexion, extension, side bending to both sides and rotation to both sides). Each direction was performed for 3 repetition, each one was maintained for 10 seconds. Patients were allowed to take rest before starting another direction. Strengthening exercises were initiated after the end of stretching repetitions. Isometric strengthening was performed for all directions; each direction was repeated 10 times for 2 sets. Isometric strengthening is sustained muscle contraction with an increase in tension that is accompanied by fixed length of the recruited muscle tissue or change in angle of the joint by giving maximum resistance for the head [16]. Movement maintained for 10 sec and repeated ten times[17].

Participants in the study group received both virtual reality training program and traditional exercises. The participant was immersed in an ocean environment collaborated with sound of Scuba Diving. VR systems immerse individuals in a data-created environment with 3D representation and perception and often spatial interaction in real time. Three VR devices (BOBOVR Z-6 model) attached to smartphones (SAMSUNG galaxy A30s) were used. The free mobile software "VR Ocean aquarium operated by HY Games Version 1.0.25" which included rotation, flexion, side bending, and extension movements. The participant moved forward and performed neck movements to view various marine species while immersed in a virtual environment that represented an ocean. The animals the participant was seeing were given names and also he can hear the sound of the sea. The application provided auditory and sensual inputs[18].

In the first session, The VR group was directed to carry out the same previous exercises in addition to VR intervention for two series, 10 repetitions of each movement (Flexion, Extension, Rotation, side bending) with 30 s rest between them (3 sessions per week). For each exercise, the participant's number of movements was counted, documented, and supervised by the physiotherapist to ensure that the recommended dosage was not exceeded.

Outcome measure

All the measured outcomes were evaluated before and after the six-week treatment program. The outcome measures were Range of motion, pain intensity, neck disability index (NDI) and pressure pain threshold (PPT).

1. Range of motion assessment: Inclinometer was used to measure neck range of motion in all directions in participant with non -specific neck pain. It is considered as high accuracy among the measuring tools for neck range in clinical practice, inclinometer is simple to use: place it close to the joint you intend to measure; turn the dial till the scale reaches zero; take the joint through its range; read the range-of-motion (in degrees) to determine the range from the dial [19].

2. Pain assessment: Visual analog scale (VAS) was used to assess pain intensity. VAS is a validated, subjective measure for pain. VAS consists of a 10 cm line, with two end points choosing 0 (which means "no pain") and 10 (which means "pain as severe as it could possibly be"). The participants were asked to identify how much pain they were currently suffering from by marking the line. The distance in centimeters between the present pain mark and the "no pain marker" (zero) was measured using a ruler[20].

3. Assessment of neck disability: Neck disability index questionnaire (NDI) was used to assess neck disability. It was introduced to participants to fill it. It is a condition-specific functional status questionnaire with 10 items including pain, private hygiene, carrying objects, reading, migraines, attention, job, driving, sleeping and recreation. Every item received a score between 0 and 5, where the highest number denotes a higher level of self-reported impairment. This questionnaire has an overall range of 0 to 50. For calculating the percentage, just multiply the total by two [21].

4. Assessment of pressure pain threshold (PPT): In this study, The PPT on the cervical muscles was measured using a Manual Muscle Test system (MMT) which is a device used to quantify PPT as the minimum quantum of pressure that produces pain[22]. There're several studies examined the reliability of Manual Muscle Test in myofascial detector points assessment and reported that they have high reliability[23, 24].

Statistical analysis

Descriptive analysis in the form of means and standard deviation for comparison of data of both groups was used in this study. Dependent and independent T-test was used to measure the mean values of pre and post for all variables in all subjects within the group and between both groups of treatment, respectively. Level of significance was set as 0.05. All statistical calculations were done using computer program SPSS release 22 for Microsoft Windows.

Results

30 subjects participated in this study. The subjects were randomly assigned into two groups. The mean for control group and study group in age was 21.26 ± 0.79 years, body mass index was 20.92 ± 2.1 kg/m and 21.23 ± 0.83 years and BMI was 21.33 ± 2.04 Kg/m, respectively. As shown in **Table 1** there was no significant difference in all demographic data mean values of all measured variables in both groups.

As shown in **Table 2** Independent T-test was performed to examine the VAS, NDI, cervical ROM and PPT mean values between both treatment groups. The results showed that there was no significant difference in all measured variables of pre and post treatment mean values between both studied groups except a significant difference was found between both groups at the post treatment values of Right and Left sides in PPT.

According to **Table 3**, dependent T-test was performed to examine the VAS, NDI, cervical ROMs and PPT between pre and post mean values for all variables within both groups. The results showed a significant difference between pre and post mean values in all measured variables except the extension ROM of both groups, flexion and Right side bending ROM of control group only. (Tables 1-3)

Discussion

This study was conducted to compare the effect of traditional treatment and virtual reality on non-specific neck pain. The results showed a significant difference between pre and post mean values in most of measured variables in each group while there was no significant difference between post treatment mean values of both groups in all variables except the post Right and Left PPT.

This results agreed with a study that was done on 30 patients who had Non-specific chronic neck pain, they were randomly split into two equal groups. Group A-control group received traditional treatment (chin tuck exercise for posture correction); for four weeks, three sets of ten repetitions, each lasting

Table 1: Patients demographic data of both groups.

	Group 1		Group 2		p value
	Mean	**± SD**	**Mean**	**± SD**	
Age	21.26	± 0.79	21.23	± 0.83	0.914 [b]
Weight	51.4	± 3.96	55.02	± 8.16	0.189[b]
Height	156.53	± 4.38	160.23	± 6.3	0.068[b]
BMI	20.92	± 2.21	21.33	± 2.04	0.595[b]
SD: standard deviation, b: Non significant					

Table 2: Comparison between the two treatment groups (Independent t test).

		Group 1		Group 2		p value
		Mean	SD	Mean	SD	
VAS	Pre	3،53	1،84	4،29	1،72	0،238[b]
	Post	1،2	1،14	2،23	1،52	0،297[b]
NDI	Pre	10،66	5،47	10،58	3،84	0،963[b]
	Post	5،86	5،82	5	3،88	0،621[b]
Flexion	Pre	61،6	14،46	61،29	13،57	0،951[b]
	Post	65،26	10،34	69،11	7،59	0،262[b]
Extension	Pre	62،33	17،3	69،05	11،9	0،206[b]
	Post	68،73	12،8	73،29	11،3	0،293[b]
Rt bending	Pre	46،53	9،53	45،88	9،72	0،85[b]
	Post	51،66	9،22	52،05	9،35	0،906[b]
Lt bending	Pre	43	9،41	45،7	7،966	0،385[b]
	Post	50،86	9،5	52	9،29	0،736[b]
Lt MMT	Pre	2،94	1،31	3،41	1،47	0،344[b]
	Post	4،01	1،27	5،08	1،41	**0،033[a]**
Rt MMT	Pre	3	1،19	3،53	1،92	0،36[b]
	Post	4،12	1،28	4،99	1،55	**0،048[a]**

a: significant, b: Non significant, MMT: manual muscle test, Rt: right, Lt: left, NDI: neck disability index.

Table 3: Comparison between the two treatment intervals within the same group (dependent t test).

	Group 1				p value	Group 2				p value
	Pre treatment		post treatment			Pre treatment		post treatment		
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
VAS	3,93	1,79	1,75	1,43	**0،0001[a]**	4,29	1,72	2,23	1,52	**0،004[a]**
NDI	10,62	4,59	5,40	4,83	**0،001[a]**	10,58	3,84	5,00	3,88	**0،0001[a]**
Flexion	61,43	13,76	67,31	9,04	0،315[b]	61,29	13,57	69,11	11,90	**0،034[a]**
Extension	65,90	14,83	71,15	12,05	0،109[b]	69,05	11,90	73,29	11,30	0،256[b]
Rt bending	46,18	9,48	51,87	9,14	0،11[b]	45,88	9,72	52,05	9,35	**0،012[a]**
Lt bending	44,43	8,63	51,46	9,25	**0،005[a]**	45,70	7,96	52,00	9,29	**0،016[a]**
LT MMT	3,28	1,62	4,58	1,43	**0،001[a]**	3,53	1,92	5,08	1,41	**0،001[a]**
Rt MMT	3,19	1,39	4,58	1,47	**0،016[a]**	3,41	1,47	4,99	1,55	**0،001[a]**

a: significant, b: Non significant, MMT: manual muscle test, Rt: right, Lt: left, NDI: neck disability index.

five seconds, were performed for three minutes every day. Group-B-study group obtained the same as group A in addition to VR training (15 min each session three times each week) for 4 weeks. The pain intensity "VAS" and neck disability "NDI" were measured pre and post treatment. The findings revealed that there was a significant decrease of neck pain and disability in both groups especially group B[25].

Also, another study found a significant difference in pain threshold and neck ROM after 4 weeks of intervention. Forty- four patients with Non-specific chronic neck pain participated and assigned into two equal groups, a VR treatment group and neck exercises group. The intervention consisted of two treatment sessions per week, for four weeks. After treatment there was a significant difference in pain threshold and neck ROM in both treatment groups[11].

A significant improvement in pain intensity that was measured by VAS for pre- and post-treatment mean values had been found. Many studies are compatible with this finding, one of these studies investigated the effect of VR technology on spinal pain versus exercises. It found that patients with chronic pain had statistically significant improvement as pain intensity significantly decreased and neck function quality increased, but these changes were found within treatment values of both groups. While, between post treatment mean values of both groups there was non-significant difference[26].

On the contrary, the current study's findings differed from previous study that assessed Virtual Reality Assisted Non-Pharmacological Treatments in Chronic neck pain management and showed a non-significant decrease in VAS scores for virtual reality therapy with other interventions, like exercise and laser therapy[14]. Also, a systematic review and meta-analysis study evaluated the effect of Virtual reality on neck pain and it showed a non-significant difference in pain intensity after applying VR, and there was a non-statistical difference in pain intensity at follow-up between the VR group and the control group[27].

The current study showed that there was a great improvement of post mean values of NDI in both groups and this finding was compatible with previous study that investigated the effect of virtual reality and traditional exercises treatment on cervical pain and neck function in forward head posture and they found that there was a statistically significant improvement in the NDI score after four weeks of treatment in both virtual reality and control groups [25].

Moreover, the results of current study showed that there was a non -significant difference in post mean values of ROM at both VR group and control group. This is compatible with the study that investigated the Impact of Virtual Reality on Pain, Function, Somatosensory, and Psychosocial Results in Patients with Non-specific Chronic Neck Pain in Comparison to Exercise[11], they found that there were not any significant differences in ROM post intervention mean values between both groups.

In contrast, another study that investigated the effect of virtual reality- based neck-specific sensory- Motor development for individuals with persistent cervical pain[28], and they divided the participants into 3 groups: VR group, sensorimotor group (SM), and control group (CG) found that neck ROM had been improved and there was a significant difference between the VR and both control and SM groups with favor to VR group. This may be due to the nature of VR intervention and time of single session.

Regarding to pain pressure threshold, the current study showed a significant improvement in pain pressure threshold measured with MMT, and this is consistent with a study that examined how exercise and virtual reality affected patients with non-specific chronic neck pain in terms of pain and function. They found statistically significant differences in the VR group between baseline and 1 month and 3 months measures[11].

Limitations

The study's limitations were acknowledged by the authors. This assessment was limited by the patient's lessened ability to finish treatment procedures, as patients were experiencing headaches, tired or impaired vision. It was the psycho-physiological elements that patients experienced at the time of testing and training, which were supposed to be consistent across the study.

Conclusion

From the obtained results, it could be concluded that patients with non-specific neck dysfunction who received VR and traditional treatment program can be improved, by decreasing their pain intensity and NDI, and increasing their pain threshold and neck ROM. Both modalities of treatment were successful in improvement and there was non-significant difference between them. So, they can be combined or applied alternatively to treat patients with non-specific neck dysfunction.

Recommendations

It is recommended to do the same study should carry out on a larger sample, utilize VR on patient with posture abnormalities will be helpful, such as, people with forward head posture, or to compare the effects of VR with another therapeutic modalities such as, TENS on cervical pain.

Contributions statement: The authors confirm contribution to the paper as follows: study conception and design: K.B., H.T. and H.M.; Data collection: R.A. and F.A.; Randomization: K.B.; Analysis and interpretation of results: K.B., H.M.; Performing the practical part of the study: R.A.; draft manuscript preparation: H.T. and F.A.; All authors reviewed the results and approved the final version of the manuscript.

Competing interests: There was no conflict of interest stated by the authors.

Funding: The authors received no funding for their research, authorship or publication.

Data access: Original data are available upon request

References

Alhakami AM, Madkhli A, Ghareeb M, Faqih A, Abu-Shamla, I., Batt, T. & Alhazmi, A. H. (2022, July). The Prevalence and Associated Factors of Neck Pain among Ministry of Health Office Workers in Saudi Arabia: A Cross Sectional Study. In Healthcare (Vol. 10, No. 7, p. 1320). MDPI.

Algarni, A. D., Al-Saran, Y., Al-Moawi, A., Bin Dous, A., Al-Ahaideb, A., & Kachanathu, S. J. (2017). The prevalence of and factors associated with neck, shoulder, and low-back pains among medical students at university hospitals in Central Saudi Arabia. Pain research and treatment.

de Campos, T. F., Maher, C. G., Steffens, D., Fuller, J. T., & Hancock, M. J. (2018). Exercise programs may be effective in preventing a new episode of neck pain: a systematic review and meta-analysis. Journal of physiotherapy, 64(3), 159-165.

Han, Z.K., Ahmed, S.I., Baig, A.A.M. et al. Effect of post-isometric relaxation versus myofascial release therapy on pain, functional disability, rom and qol in the management of non-specific neck pain: a randomized controlled trial. BMC Musculoskelet Disord 23, 567 (2022). https://doi.org/10.1186/s12891-022-05516-1

Guzman J, Hurwitz EL, Carroll LJ, Haldeman S, Côté P, Carragee EJ, Peloso PM, et al. A new conceptual model of neck pain: linking onset, course, and care: the Bone and Joint Decade 2000–2010 Task Force on Neck Pain and Its Associated Disorders. J Manipulative Physiol Ther. 2009; 32(2):17-28.

Paksaichol A, Janwantanakul P, Purepong N, Pensri P, van der Beek AJ. Office workers' risk factors for the development of non-specific neck pain: a systematic review of prospective cohort studies. Occup Environ Med. 2012; 69(9):610–8.

Ajimsha MS, Daniel B, Chithra S: Effectiveness of myofascial release in the management of chronic low back pain in nursing professionals. J Bodyw Mov Ther 2014;18:273–81

Gross, A., Kay, T. M., Paquin, J. P., Blanchette, S., Lalonde, P., Christie, T. & Cervical Overview Group. (2015). Exercises for mechanical neck disorders. Cochrane Database of Systematic Reviews, (1).

Shin HJ, Kim SH, Hahm SC, Cho HY. Thermotherapy Plus Neck Stabilization Exercise for Chronic Nonspecific Neck Pain in Elderly: A Single-Blinded Randomized Controlled Trial. *Int J Environ Res Public Health*. 2020; 17(15):5572. Published 2020 Aug 1.

Lopez-de-Uralde-Villanueva, I.; Beltran-Alacreu, H.; Fernandez-Carnero, J.; Kindelan-Calvo, P.; La Touche, R. Widespread Pressure Pain Hyperalgesia in Chronic Nonspecific Neck Pain with Neuropathic Features: A Descriptive Cross-Sectional Study. Pain Physician 2016, 19, 77–88.

Tejera DM, Beltran-Alacreu H, Cano-de-la-Cuerda R, Leon Hernández JV, Martín-Pintado-Zugasti A, Calvo-Lobo C, Gil-Martínez A, Fernández-Carnero J. Effects of Virtual Reality versus Exercise on Pain, Functional, Somatosensory and Psychosocial Outcomes in Patients with Non-specific Chronic Neck Pain: A Randomized Clinical Trial. Int J Environ Res Public Health. 2020 Aug 16; 17(16):5950..

Mbada, C. E., Makinde, M. O., Odole, A. C., Dada, O. O., Ayanniyi, O., Salami, A. J., & Gambo, I. P. (2019). Comparative effects of clinic-and virtual reality-based McKenzie extension therapy in chronic non-specific low-back pain. Human Movement, 20(3), 66-79.

Fang, Zongwei BS; Wu, Tingting BS; Lv, Meina BS; Chen, Mingrong BS; Zeng, Zhiwei BS; Qian, Jiafen BS; Chen, Wenjun BS; Jiang, Shaojun BS; Zhang, Jinhua PhD. Effect of Traditional Plus Virtual Reality Rehabilitation on Prognosis of Stroke Survivors: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. American Journal of Physical Medicine & Rehabilitation 101(3):p 217-228, March 2022.

Grassini S. Virtual Reality Assisted Non-Pharmacological Treatments in Chronic Pain Management: A Systematic Review and Quantitative Meta-Analysis. Int J Environ Res Public Health. 2022 Mar 29; 19(7):4071. doi: 10.3390/ijerph19074071. PMID: 35409751; PMCID: PMC8998682.

Anderson BG, Benzinger B, Chickness J, et al. Effects of Cervical Spine Exercise Protocol on Neck Pain, Pericervical Muscle Endurance, and Range of Motion in Medical Students: A Prospective Study. *Cureus*. 2022; 14(7):e27160. Published 2022 Jul 22. doi:10.7759/cureus.27160

Rickson JJ, Maris SA, Headley SAE. Isometric Exercise Training: A Review of Hypothesized Mechanisms and Protocol Application in Persons with Hypertension. *Int J Exerc Sci*. 2021; 14(2):1261-1276. Published 2021 Nov 1.

M V, Sowmya. (2014). Isometric Neck Exercises versus Dynamic Neck Exercises in Chronic Neck Pain. IOSR Journal of Nursing and Health Science. 3. 32-43. 10.9790/1959-03213243.

Morales Tejera, D., Beltran-Alacreu, H., Cano-de-la-Cuerda, R., Leon Hernández, J. V., Martín-Pintado-Zugasti, A., Calvo-Lobo, C., ... & Fernández-Carnero, J. (2020). Effects of virtual reality versus exercise on pain, functional, somatosensory and psychosocial outcomes in patients with non-specific chronic neck pain: a randomized clinical trial. International Journal of Environmental Research and Public Health, 17(16), 5950.

De Koning CH, van den Heuvel SP, Staal JB, Smits-Engelsman BC, Hen- driks EJ (2008) Clinimetric evaluation of active range of motion measures in patients with non specific neck pain: a systematic review. Eur Spine J 17: 905-921.

Breivika, H. (2016). Fifty years on the Visual Analogue Scale (VAS) for pain-intensity is still good for acute pain. But multidimensional assessment is needed for chronic pain. Scandinavian Journal of Pain, 11(1), 150-152.

De las Penas, C. F., Cleland, J., & Huijbregts, P. (2011). Neck and arm pain syndromes. Elsevier.

Kinser, A. M., Sands, W. A., & Stone, M. H. (2009). Reliability and validity of a pressure algometer. The Journal of Strength & Conditioning Research, 23(1), 312-314.

Reeves, J. L., Jaeger, B., & Graff-Radford, S. B. (1986). Reliability of the pressure algometer as a measure of myofascial trigger point sensitivity. Pain, 24(3), 313-321.

Delaney G, McKee A. Inter-and intra-rater reliability of the pressure threshold meter in measurement of myofascial trigger point sensitivity. American journal of physical medicine & rehabilitation. 1993; 72(3):136-9.

Elhafez, H. M., Abd Elmageed, S. N., & Ali, E. A. (2022). Effect of Interactive Virtual Reality Device on Cervical Pain and Neck Function in Forward Head Posture. The Egyptian Journal of Hospital Medicine, 89(1), 6024–6029. doi.org/10.21608/ejhm.2022.266835

Ahern M.M., Dean L.V., Stoddard C.C., Agrawal A., Kim K., Cook C.E., Narciso Garcia A. The Effectiveness of Virtual Reality in Patients with Spinal Pain: A Systematic Review and Meta-Analysis. Pain Pract. 2020;20:656–675. doi: 10.1111/papr.12885.

Guo, Q., Zhang, Lim., Gui, C., Chen, G., Chen, Y., Tan, H., Su, W., Zhang, R. and Gao, Q. (2023). Virtual Reality Intervention for Patients with Neck Pain: Systematic Review and Meta-analysis of Randomized Controlled Trials. Journal of Medical Internet Research, 25, p.e38256. doi.org/10.2196/38256.

Nusser, M., Knapp, S., Kramer, M., & Krischak, G. (2021, February 10). Effects of virtual reality-based neck-specific sensorimotor training in patients with chronic neck pain: A randomized controlled pilot trial. Journal of rehabilitation medicine.