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Impact of Virtual Reality Training on Pain, Forward Head Posture and Functional Outcome in Patients with Cervical Radiculopathy

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ABSTRACT

Background: Cervical radiculopathy (CR) encompasses a range of symptoms caused by the compression or irritation of nerve roots within the cervical spine. Forward Head Posture (FHP) is a common musculoskeletal condition. Virtual Reality (VR) Training presents an innovative and potentially effective method for delivering physical therapy interventions.

Purpose: This study aimed to investigate the effect of VR training on pain, forward head posture and functional outcome in patients with cervical radiculopathy.

Methods: Forty patients of both genders diagnosed with cervical radiculopathy participated in this study. The participants' ages ranged from 35 to 50 years, with a body mass index (BMI) not exceeding 30 kg/m². Patients were randomly assigned to study and control groups. Both groups underwent a selected physical therapy program that included electrotherapy, manual therapy, and strengthening exercises. The study group additionally received VR training. Visual Analogue Scale (VAS) was used to assess pain intensity; Kinovea software was used to measure Craniovertebral Angle (CVA); and Neck Disability Index (NDI) was used to evaluate functional outcome. Treatment was conducted three sessions per week over a duration of six weeks. Assessment of all variables was done before and after completion of treatment.

Results: There were no statistically significant differences between both groups in pretreatment mean values of all measured variables (VAS, CVA and NDI). In within-group comparison, all outcome measures demonstrated significant improvement in both the study and control groups after treatment ($p < 0.001$). Between-groups comparison revealed statistically significant differences across all outcome variables post treatment, favoring the study group ($P< 0.05$).

Conclusion: Virtual Reality (VR) training serves as an effective intervention for alleviating pain, correcting forward head posture, and enhancing functional outcomes in individuals with cervical radiculopathy. The immersive and engaging characteristics may improve patient adherence and motivation, positioning it as a promising adjunct to specific physical therapy programs.

Keywords: *Cervical Radiculopathy, Virtual Realty, Cranio-vertbral Angle, Pain, Functional Outcome*

1. INTRODUCTION

Cervical radiculopathy (CR) is a condition marked by neck pain that radiates to the arm, frequently associated with sensory disturbances, motor weakness, and functional limitations (1,2). The condition results from compression or irritation of the cervical nerve roots, typically due to degenerative changes including disc herniation, osteophyte formation, or ligament hypertrophy (3).

Cervical radiculopathy exhibits an annual prevalence of roughly 83.2 cases per 100,000 individuals worldwide, with a greater incidence observed in men (107.3 per 100,000) than in women (63.5 per 100,000) (1,4). The prevalence of cervical spine

disorders, including radiculopathy, is increasing in Egypt, attributed to lifestyle changes, heightened use of electronic devices, and inadequate postural habits. However, specific epidemiological data regarding cervical radiculopathy in the Egyptian population is still limited (5).

Forward head posture (FHP) is a prevalent postural abnormality linked to cervical radiculopathy, impacting around 66% of the population (6). Forward head posture (FHP) is an anterior displacement of the head in relation to the shoulders, leading to heightened mechanical stress on the cervical spine and adjacent soft tissues (7). This postural dysfunction intensifies neck pain, limits cervical range of motion, and leads to muscle imbalances, thereby further hindering functional capabilities (8,9). The craniovertebral angle (CVA), an important measure of forward head posture (FHP), is frequently diminished in patients with cervical radiculopathy, indicating the extent of postural deviation (10).

The physical therapy program for cervical radiculopathy, including electrotherapy, manual therapy, and strengthening exercises, primarily aims at pain relief and functional restoration (11). Nevertheless, these methods frequently do not tackle the fundamental postural issues, such as forward head posture (FHP), which are crucial in the ongoing presence of symptoms and the recurrence of pain (12). Additionally, patient adherence to conventional therapy may be restricted by the repetitive and monotonous characteristics of the exercises **(13)**.

In recent years, virtual reality training has developed as a valuable complement to conventional rehabilitation techniques. Virtual reality provides an immersive and interactive environment that improves patient engagement, motivation, and adherence to therapy. Virtual reality has been employed as a distraction therapy to diminish pain perception in individuals with chronic pain conditions, including cervical radiculopathy. Immersion in a virtual environment facilitates distraction from pain signals, consequently diminishing the subjective experience of pain. Virtual reality stimulates the brain's pain modulation pathways, facilitating the release of endorphins and the activation of the prefrontal cortex, thereby diminishing pain perception. It also reduces activity in pain-processing areas of the brain, including the anterior cingulate cortex and insula (13).

Virtual reality training enhances motor learning, proprioception, and postural control through the simulation of real-world activities and the provision of real-time feedback, thereby effectively addressing pain and postural dysfunction in cervical radiculopathy (14). Preliminary studies indicate that VR is effective in alleviating pain and enhancing functional outcomes in various musculoskeletal conditions; however, its use in cervical radiculopathy has not been thoroughly investigated (10,12). This research examines the effect of virtual reality training on pain levels, forward head posture, and functional outcome in individuals diagnosed with cervical radiculopathy.

2. MATERIALS AND METHODS

Study design

This randomized controlled trial (RCT) was carried out at the outpatient clinic of the Faculty of Physical Therapy, Cairo University, Egypt, from June 2024 to January 2025. The approval from the local ethical committee of the Faculty of Physical Therapy at Cairo University was obtained for the study. All participants signed written informed consent prior to their involvement, and their rights and confidentiality were upheld throughout the duration of the study.

Sample size calculation

Sample size calculation was performed using G*POWER statistical software (version 3.1.9.2; Franz Faul, Universitat Kiel, Germany) based on data of cervical radiculopathy and revealed that the required sample size this study was 20 subjects in each group. Calculation is made with α=0.05, power = 80% and effect size = 0.93.

Participants

Forty patients of both genders diagnosed with unilateral cervical radiculopathy and forward head posture (FHP) were enrolled in the study. Patients were diagnosed from a neurosurgeon as having cervical radiculopathy based on a careful clinical evaluation. This diagnosis was confirmed by MRI of the cervical spine.

Inclusion criteria were: Patients with unilateral cervical radiculopathy with FHP (craniovertebral angle < 49°), age ranged between 35 and 50 years, body mass index not exceeding 30 kg/m², duration of neck pain for more than six months, mild to moderate neck pain (Visual Analog Scale score ≥ 3), Neck Disability Index (NDI) score > 20% and positive findings in at least 3 out of 4 clinical tests: Spurling's test, distraction test, upper limb tension test, and ipsilateral cervical rotation < 60 degrees.

Exclusion Criteria were: Temporomandibular joint disorders, primary shoulder or upper extremity problems, neurological deficits, cognitive impairments (MOCA>25), history of cervical spine surgery, neck pain with vertigo or bilateral upper limb referred pain, clinical instability, recent trauma, or vertebrobasilar insufficiency and structural abnormalities of the spine (e.g., osteoporosis, ankylosing spondylitis, or rheumatoid arthritis).

Participants were randomly allocated to one of two groups through a sealed envelope method: Group I (Control Group) received a selected physical therapy program that included electrotherapy, manual therapy, and strengthening exercises and

Group II (study group): received VR training alongside a selected physical therapy program.

Procedures

Assessment Procedures

All outcome measures were assessed for each patient individually before and after physical therapy treatment.

Assessment of pain intensity

Pain was evaluated using a visual analog scale (VAS), characterized by a straight line with one end denoting no pain and the opposite end indicating the most intolerable pain. The subject indicates a position on the line that reflects the current pain level (15). The instrument demonstrates both validity and reliability. Numerous studies indicate that it is the most straightforward method and yields the most dependable measures of pain severity (16).

Measurement of Cranio-vertebral Angle

The cranio-vertebral angle was evaluated through a lateral photograph of the subject's cervical region. The camera (Sony HDR-CX190 Camcorder) was positioned on a fixed tripod, remaining stationary without rotation or tilt. The camera was calibrated to align with the patient's shoulder height. A self-balanced position was employed to standardize patient head and neck posture. Patients positioned their head and neck in complete flexion and extension to achieve this posture. The patients progressively reduced the range of motion until movement ceased, maintaining the head and neck in a neutral position.

Patients underwent evaluation while in a standing position. Participants were instructed to stand comfortably with their arms positioned at their sides. Patients were instructed to direct their visual attention to a specific location on the wall directly ahead of them. The necessity of maintaining a natural position prior to photography was communicated to them. Plastic marker was adhered to the skin above the spinous process of the C7 vertebra, and the tragus of the ear was marked prior to capturing a photograph.

Upon acquiring the image, the Kinovea software was initiated, and the image was subsequently uploaded. The angle tool icon was utilized to generate the initial horizontal line intersecting the marker positioned directly above the C7 spinous process, thereby establishing the angle. The arrows were generated by clicking, holding, and dragging a line from the mark on the tragus of the ear to the marker located above the C7 spinous process in the image. A smaller cranio-cervical angle indicated a larger forward head posture (FHP). A cranio-cervical angle (CVA) below 49 degrees signifies the presence of forward head posture (FHP) (9).

Assessment of functional outcome

Arabic version on the Neck Disability Index (NDI) is a patient-reported outcome measure designed to evaluate neck pain and its effects on daily functioning. It comprises 10 items that address different aspects of daily life, with each item scored from 0 to 5, where 0 signifies no disability and 5 denotes complete disability. The total score ranges from 0 to 50, where higher scores reflect increased levels of disability. The score may be represented as a percentage (e.g., 20/50 = 40% disability) (17).

Treatment procedure

Each treatment session lasted 60 minutes at a frequency of three sessions per week for six successive weeks as follows:

Control Group

Participants in the control group received a combination of electrotherapy, manual therapy and stabilization exercises. **Electrotherapy included Transcutaneous Electrical Nerve Stimulation (TENS) and ultrasound therapy. TENS was applied at a f**requency of 50–100 Hz, pulse duration of 50–200 µs, and intensity set to a comfortable, non-painful level for 20 minutes per session **(18)**. **Ultrasound Therapy was applied at a f**requency of 1 MHz, intensity of 0.5–1.0 W/cm², and a 50% duty cycle for pulsed ultrasound for 5 minutes per session **(19)**. **Manual Therapy included Cervical Mobilization and soft tissue manipulation.** Grade III or IV mobilizations were applied to the cervical spine to improve joint mobility and reduce stiffness for 10 minutes per session **(20)**. Deep tissue massage and myofascial release techniques were applied to the cervical and upper trapezius muscles for 5 minutes per session **(21)**. **Strengthening Exercises included Cervical Isometric Exercises in which p**rticipants performed isometric contractions of the cervical flexors, extensors, and lateral flexors against manual resistance, 10 minutes per session **(22) and Upper Limb Strengthening in the form of** resistance exercises for the shoulder, elbow, and wrist muscles using resistance bands or light dumbbells, 10 minutes per session **(23)**.

Study group

Participants in the VR training group received the same selected physical therapy program as the control group, in the addition to **VR-based Training. The VR Equipment** composed of Shinecon Virtual Reality 3D Glasses connected to a mobile phone via Bluetooth and a Custom VR application designed to simulate real-world activities and provide real-time feedback. Participants were engaged in virtual tasks designed to improve cervical range of motion, posture, and functional abilities for 30 minutes per session **(13)**.

Statistical Analysis

Statistical analysis and comparison of the measured variables were conducted using SPSS for Windows version 23 (SPSS, Inc., Chicago, IL), with an alpha level set at 0.05. The data were evaluated for normality, variance homogeneity, and the presence of outliers. The Shapiro-Wilk test for normality demonstrated that the measured variables conformed to a normal distribution ($p > 0.5$). Outcomes are reported as mean and standard deviation, except for gender and occupation, which are presented as counts. A two-way mixed design MANOVA was utilized to compare the groups concerning the collective impact of all outcomes. Following the attainment of statistically significant results from MANOVA with Bonferroni correction was performed for each outcome measure to reduce the likelihood of type I error.

3. RESULTS

The data presented in Tables 1 and 2 indicated no statistically significant difference in general and baseline clinical characteristics between the two groups ($p > 0.5$). A mixed design multivariate analysis was performed to evaluate the differences in score changes on the outcome measures between participants in both groups. Multivariate analyses revealed statistically significant main effects for groups, with Wilk's $\Lambda = 0.28$, $F(12, 27) = 5.69$, $p < 0.001$, $\eta 2 = 0.72$; for time, Wilk's $\Lambda = 0.01$, $F(12, 27) = 337.85$, $p < 0.001$, $\eta 2 = 0.99$; and for the interaction between groups and time, Wilk's $\Lambda = 0.08$, $F(12, 27) = 25.07$, $p < 0.001$, $\eta 2 = 0.92$.

Following a six-weeks intervention, between-groups comparison revealed statistically significant differences across all outcome variables post treatment, favoring the study group ($P< 0.05$), as illustrated in Table 3. In within-group comparison, all outcome measures demonstrated significant improvement in both the study and control groups after treatment ($p < 0.001$), as presented in Table 4.

Table 1: General characteristics of participants in both groups.

Characteristics	Study Group (n=20)	Control Group (n=20)	T value	P Value
Age(years)	42.85 ±4.13	42.35±3.57	0.41	0.69
Weight(kg)	65.75±8.97	66.7±8.48	-0.34	0.73
Height(cm)	165.5±9.22	167.1±7.26	-0.57	0.57
BMI (kg/m2)	24.07±3.52	23.88±2.73	0.19	0.85
Chronicity (months)	13.35±3.01	13.3±2.3	0.06	0.95
Occupation, n (%)				
Accountant	4 (20%)	3(15%)		
Lawyer	2(10%)	2(10%)		
Employee	3(15%)	2(10%)		
Teacher	3(15%)	4 (20%)		
Engineer	2(10%)	2(10%)	X2=1.17	0.88
Banker	2(10%)	1(5%)		
Doctor	1(5%)	1(5%)		
Fashion designer	1(5%)	3(15%)		
Social media marketing	2(10%)	2(10%)		
Gender, n (%)				
Female	15 (75%)	14 (70%)	X2=0.13	0.72
Male	5 (25%)	6 (30%)		

BMI, body mass index; X2, Chi Square; MD, Mean Difference; CI, confidence interval; * Data are mean± SD for all demographics except dominance (%), P-Value < 0.05 indicate statistical significance.

Table 2: Clinical Characteristics of participants pretreatment.

Outcomes	Study Group (n=20)	Control Group (n=20)	P Value
CVA (degree)	35.79±3.82	36.74±2.72	0.37
VAS (mm)	61±7.88	59.5±7.6	0.54
ANDI (score)	28.75±5.82	29.5±4.65	0.66

* Data are mean± SD, P-Value < 0.05 indicate statistical significance; CVA: craniovertebral angle, VAS: visual analogue scale, ANDI: Arabic neck disability index.

Table 3: Clinical Characteristics of participants after six weeks of intervention (N=40)*

Outcomes	Study Group (n=20)	Control Group (n=20)	MD(95% CI)	P Value	Partial η2
CVA (degree)	47.33±3.13	41.67±2.11	5.66 (3.95, 7.37)	<0.001	0.54
VAS (mm)	29±3.65	37±2.62	-8 (-14.2, -17.7)	<0.001	0.15
ANDI (score)	17.9±4.14	22.3±4.91	-4.4 (-7.31, -1.49)	<0.001	0.2

*** Data are mean± SD, MD; mean difference, CI; confidence interval; P-Value < 0.05 indicate statistical significance; CVA: craniovertebral angle, VAS: visual analogue scale, ANDI: Arabic neck disability index.**

Table 4: Within-groups Comparisons for all outcome measures.

Outcomes	Study Group (n=20)		Control Group(n=20)	
	Change from baseline to 6 weeks		Change from baseline to 6 weeks	
	MD (95% CI)	P Value	MD (95% CI)	P Value
CVA (degree)	-11.54(-12.5,-10.57)	< 0.001	-4.94(-5.9,3.97)	< 0.001
VAS (mm)	32 (28.64,35.36)	< 0.001	22.5 (19.14,25.86)	< 0.001
ANDI (score)	10.85(9.31,12.39)	< 0.001	7.2(5.66,8.74)	< 0.001

MD; mean difference, CI; confidence interval; P-Value < 0.05 indicate statistical significance; CVA: craniovertebral angle, VAS: visual analogue scale, ANDI: Arabic neck disability index.

4. DISCUSSION

This study examined the impact of virtual reality (VR) training on pain levels, forward head posture (FHP), and functional outcomes in individuals suffering from cervical radiculopathy. The findings indicated that the integration of VR Training with a chosen physical therapy program resulted in notable enhancements in pain alleviation, postural adjustment, and functional capabilities when contrasted with the physical therapy program used in isolation. This indicates that virtual reality training could serve as a valuable complement to traditional rehabilitation approaches for cervical radiculopathy.

The VR training group demonstrated a notable decrease in pain intensity compared to the control group following treatment. This is consistent with earlier investigations that have underscored the efficacy of virtual reality in pain management due to its immersive and captivating qualities, which divert patients' attention from discomfort and improve their commitment to treatment (13). The immediate feedback offered by VR systems has the potential to enhance motor control and minimize compensatory movements, which can help alleviate pain resulting from muscle imbalances and poor posture **(12)**.

The enhancement in forward head posture (FHP), as evidenced by a rise in the craniovertebral angle (CVA), was notably more pronounced in the VR training group post treatment. The targeted cervical stabilization exercises conducted in the VR environment are responsible for this, highlighting the importance of proper alignment and the activation of deep cervical

muscles (24). The immersive qualities of VR probably heightened participants' awareness of their posture and promoted more effective motor learning, resulting in lasting postural enhancements **(21)**.

The group undergoing VR training exhibited more significant enhancements in functional outcomes. This indicates that VR-based exercises not only tackle pain and posture issues but also improve overall functional capabilities, including neck mobility and upper limb strength. The engaging and goal-focused characteristics of VR training likely played a role in these enhancements by replicating real-life tasks and fostering neuromuscular coordination **(23)**.

The results of this study align with previous research into the application of VR in rehabilitation. For instance, investigations have indicated that VR training can enhance motor function and alleviate pain in individuals suffering from stroke and chronic neck pain (12,13). Nonetheless, the use of VR in the context of cervical radiculopathy and forward head posture remains inadequately investigated, positioning this study as a significant addition to existing literature. The findings reinforce the increasing body of evidence indicating that virtual reality can serve as a valuable intervention for managing pain and postural issues in musculoskeletal disorders.

Incorporation of VR training into rehabilitation programs for cervical radiculopathy presents numerous clinical advantages. The immersive and interactive qualities of VR significantly boost patient engagement and motivation, potentially leading to better adherence to therapy. Secondly, virtual reality offers immediate feedback, enabling patients to adjust their posture and movement patterns while engaging in exercises. Ultimately, VR-based exercises offer the flexibility to be tailored to the specific requirements of patients, establishing it as a valuable resource for physical therapists **(13)**.

5. LIMITATIONS

This study has a number of limitations in spite of the encouraging results. First, the findings may not be as broadly applicable as they could be due to the small sample size. Secondly, there was no evaluation of the long-term impacts of VR training, and the study was only conducted for six weeks. To validate these findings, larger sample sizes and longer follow-up times are required in future research. The cost-effectiveness of VR training was also not examined in the study, despite this being a crucial factor in its broad use in clinical settings.

6. FUTURE DIRECTIONS

Future studies should examine the cost-effectiveness of VR training in comparison to conventional therapy, as well as its long-term effects on cervical radiculopathy and FHP. To further improve results, research could also look into using VR in conjunction with other therapies like manual therapy or cognitive-behavioral therapy. Furthermore, patients may benefit even more from the creation of more sophisticated VR systems with haptic feedback and artificial intelligence.

7. CONCLUSION

This study indicates that VR Training effectively reduces pain, corrects forward head posture, and enhances functional outcomes in patients with cervical radiculopathy. The immersive and interactive characteristics of VR training improve patient engagement and offer real-time feedback, thereby serving as a beneficial adjunct to conventional physical therapy. This study's findings will enhance the existing evidence regarding the application of VR in rehabilitation and offer insights into its potential as a comprehensive method for managing cervical radiculopathy.

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