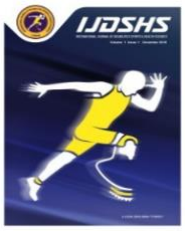

International Journal of
Disabilities Sports and Health Sciences

e-ISSN: 2645-9094

RESEARCH ARTICLE

Unveiling the Therapeutic Impact of Virtual Reality Game-Based Exercises on Cervicocephalic Kinesthetic Sensibility in Individuals Battling Cervical Vertigo

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Abstract
This study was aimed to investigate the therapeutic impact of Virtual Reality game-based exercises with Epley maneuver on cervicocephalic kinesthetic sensibility in individuals experiencing cervical vertigo. 8 subjects were selected by simple random sampling method included clinically diagnosed male and female cervical vertigo patients between 40-55 years of age, who had recurring symptom of dizziness over three months, episodic dizziness lasting minutes to hours .Written consent was taken and a detailed outcome assessment was done.Intervention includes Virtual Reality abyss sharks & sea worlds for a duration of 10 minutes with a five-minute rest period and Virtual Reality thrills, for a duration of 10 minutes with a five-minute rest period along with epley maneuver 10 minutes targeting cervicocephalic kinesthetic sensibility.Total duration of the intervention includes 40min/day for 6 days for 12 weeks. Pre test included Cervical Joint Position Error Test for cervicocephalic kinesthetic sensibility and Videonystagmography measures nystagmus, rapid eye movements with a slow and fast phase, to provide objective information about vertigo. Post test done on 6th and 12th week of intervention with the same measures. On comparing pre- and post-intervention outcomes shows higher mean value ($P \leq 0.001$).In conclusion the findings of this study had the potential to contribute valuable insights into the therapeutic utility of Virtual Reality game-based exercises in managing cervical vertigo, offering a novel and engaging approach to rehabilitation. Virtual Reality-based interventions is found effective treatment for individuals battling cervicocephalic kinesthetic sensibility among patients with cervical vertigo.

Keywords
Cervicocephalic Kinesthetic Sensibility, Videonystagmography, JPE,Vırtual Realıty

INTRODUCTION

Cervicogenic dizziness, originally termed "cervical vertigo" by (Ryan and Cope, 1955) has been a topic of controversy in its diagnosis. It is also referred to as proprioceptive vertigo, cervicogenic vertigo, and cervical dizziness (Reiley et al., 2017). Vertigo, characterized by a sensation of spinning, particularly upon changes in position, is a key feature (Brandt et al., 2019). Cervical origins contribute to 7.5% of dizziness causes, impacting quality of life and emerging as a growing concern in community health. Numerous studies highlight dizziness, encompassing both vertigo and non-vestibular forms, as one of the most common medical complaints, affecting about 20-30% of the overall population (Chu et al., 2019).

Cervicogenic dizziness is often associated with flexion-extension injuries and has been observed in individuals with severe cervical arthritis, herniated cervical discs, and head trauma12. However, symptoms may not manifest until months or even years after the initial event. Linked to neurological, vestibular, psychosomatic,

Received: 14 August 2024 ; **Revised** ; 22 September 2024 ; **Accepted:** 04 November 2024; **Published:** 25 November 2024

How to cite this article: Giridharan, G.V., Paul, J., Suganthirababu, P., and Nathan, C.V.S. (2024). Unveiling the Therapeutic Impact of Virtual Reality game-Based Exercises on Cervicocephalic Kinesthetic Sensibility in Individuals Battling Cervical Vertigo . *Int J Disabil Sports Health Sci*;7(6):1322-1328.https://doi.org/10.33438/ijdshs.1533155

and cervical spine dysfunction, cervicogenic dizziness is characterized as a disorienting condition leading to impaired postural awareness (Li et al., 2015).

Cervicogenic dizziness, initially termed "cervical vertigo" by Ryan and Cope (1955), has occasionally been a subject of controversy in its diagnosis. It is also referred to as proprioceptive vertigo, cervicogenic vertigo, and cervical dizziness. Vertigo, characterized by a sensation of spinning, particularly upon changes in position, is a key aspect. Cervical factors contribute to 7.5% of dizziness causes, impacting quality of life and emerging as a growing concern in community health (Wrisley et al., 2000). Numerous studies underscore dizziness, covering both vertigo and non-vestibular types, as one of the most common medical complaints, affecting approximately 20-30% of the general population. Cervicogenic dizziness is often associated with flexion-extension injuries and has been identified in individuals with severe cervical arthritis, herniated cervical discs, and head trauma (Revel et al., 2015). However, symptoms may not manifest until months or even years after the initial incident. Associated with neurological, vestibular, psychosomatic, and cervical spine dysfunction, cervicogenic dizziness is described as a disorienting condition leading to compromised postural awareness (Sunget al., 2020).

The cervical muscles have a greater distribution of muscle spindles compared to other muscle groups, particularly the suboccipital muscles which have numerous muscle spindles per unit, indicating a high proprioceptive function requirement (Sung et al., 2008). Proprioception is crucial for proper joint function during movements, aids in motor control, and enhances muscle stiffness, providing dynamic stability to joints. Impairment of functional mobility often results from a lack of proprioceptive feedback. Mechanoreceptor density is higher in deep neck muscles than superficial ones. Proprioceptive input from the neck assists in coordinating eye, head, and body posture, as well as spatial orientation. Based on this, there is a suggestion that a syndrome of cervical vertigo may exist (Rix et al., 2001).

The application of Virtual Reality is a promising approach used for educating cervical kinematics. The benefits of virtual training include diverting attention, thereby reducing pain and kinesiophobia, motivating physical activities, and improving the effectiveness of exercises (Li et al., 2011). Virtual Reality presents the digital environment using computer software, with a head-mounted display utilized to present the imagery to the user. Virtual Reality employs the concept of immersion, allowing Virtual Reality environments to engage and distract the patient. Virtual Reality can assess the integration between the neurocognitive and musculoskeletal systems, which is crucial for motor control and is suggested to play a significant role in the recurrence and chronicity of certain orthopedic disorders. Patients engage in therapeutic activities repeatedly to achieve higher scores without becoming bored. Feedback is a crucial element in motor learning and is a prominent feature in virtual environments (Mahrer et al., 2009).

The Cervical JPE Test measures the ability of a blindfolded patient to accurately relocate their head position back to a predetermined neutral point after cervical joint movement (Takahashi et al., 2018; (Jull et al., 2007).

Videonystagmography (VNG) is a complete diagnostic system for recording, analyzing, and reporting eye movements using video imaging technology, in which hi-tech video goggles with infrared cameras are used. VNG includes a series of tests used to determine whether a vestibular disease may be causing a balance or dizziness problem. Aim of the current study is find the effectiveness of Virtual Reality game based exercise on cervicocephalic kinesthetic sensibility among patients with cervical vertigo.

MATERIALS AND METHODS

Research Model / Design

The methodology employs a randomised experimental design,with pre and post test and was carried out with the approval by the ethics committee of institution's review board, Acs Medıcal College And Hospıtal with the letter numbered 646/2022/IEC/ACSMCH on 14/12/2022. Participants were provided with informed consent, with the volunteer form covering research details, risks, benefits, confidentiality, and participant rights. The research procedures adhered to the guidelines outlined in the updated Helsinki Declaration from 2008, prioritizing participant's rights and well-being in design, procedures, and confidentiality measures.

Research Sample

Study was done at Physiotherapy OPD, ACS Medical College and Hospital. Eight subjects were selected between 40-55 years, clinically diagnosed male and female cervical vertigo patients. All the patients had recurring symptom of dizziness over three months, episodic dizziness lasting minutes to hours were included with their voluntary consent. Other causes of vertigo, including those arising from disturbances of the ear, nose, and throat (ENT); central nervous system (CNS); and cardiovascular system, cervical myelopathy or cervical stenosis, Inflammatory arthritis, neoplastic diseases, infection, trauma, Meniere's disease ,History of previous cervical surgeries or cervical spine surgery, medical conditions that could have a negative effect on balance and patients with significant neurological disorders or spinal cord damage are excluded. All the subjects received Virtual Reality with Epley maneuver 40min/day for 6 days a week for 12 weeks.

Research Instruments and Procedures

Virtual Reality Abyss Sharks & Sea Worlds

The patient is positioned sitting upright with their back supported and head maintained in a neutral position. In this game, the participant wears Virtual Reality goggles and immerses themselves in a virtual underwater environment, collecting various objects such as coins and bottles to achieve a high score by moving their head in all directions. The subjects engage in the game for a duration of 10 minutes with a five-minute rest period interspersed.

Virtual Reality Thrills

The patient is positioned sitting upright with their back supported and head in a neutral position. In this game, the participant wears Virtual Reality goggles and experiences riding a virtual roller coaster, adjusting their head movements accordingly. The subjects engage in the game for a duration of 10 minutes with a five-minute rest period included.

Epley Maneuver

The examiner rotates the patient's head 45 degrees to the right and quickly lays the head back over the end table. The patient's eyes should exhibit torsional nystagmus. Rotate the patient's head 90 degrees to the left, again hold .Instruct the patient to turn their entire head and body in the left lateral position, with the head facing 135 degrees from supine or 225 degrees from the starting position (looking at the floor).Assist the patient in returning back to the sitting supine position while holding their head in place. The head position should be maintained as they are assisted in the sitting position. Total procedure was assisted to do in 10 minutes.

Table 1. Virtual reality training program with the epley maneuver

Research Instrument	Activity	Duration	RestPeriod
Virtual Reality	Abyss Sharks & Sea Worlds	10 Minutes	5 Minutes
Virtual Reality	Thrills	10 Minutes	5 Minutes
Epley maneuver	1. The examiner rotates the patient's head 45 degrees to the right 2. Rotate the patient's head 90 degrees to the left, again hold. 3.Move patient head 90° toward the opposite ear 4. patient should turn their entire head and body in the left lateral position, with the head facing 135 degrees from supine or 225 degrees from the starting position 5.Assist the patient in returning back to the sitting from supine position while holding their head in place	10 Minutes	

Data Collection Tools

Pre test was done before intervention using Cervical Joint Position Error Test for Cervicocephalic Kinesthetic Sensibility (Jull et al., 2007) and Videonystagmography (Gabriele Noreikaite et al., 2024) for cervical vertigo.Post test done on 6th and 12th week of intervention

Cervical Joint Position Error Test

The patient was made to stand. A target was positioned 90 cm in front of the patient, adjustable to their neutral head position (NHP), serving as the zero point. The patient is equipped with a laser pointer mounted on a helmet. They are then instructed to do flexion and return to the starting position, extension and return to the starting position ,left lateral flexion and return to the starting position, right lateral flexion and return to the starting position with the laser pointer indicating the global error relative to the target center. Three trials are conducted for each direction of motion,

with the best score recorded. The difference between the starting and ending positions of the laser beam on the target reflects cervical joint position error (JPE) and proprioception impairment, with greater displacement indicating more significant impairment (Jull et al., 2007).

Videonystagmography (VNG)

It is a sophisticated diagnostic technique utilizing video imaging technology to capture, analyze, and document eye movements. This method employs advanced goggles fitted with infrared cameras.It measures nystagmus, which are rhythmic, rapid eye movements with a slow and fast phase (Gabriele Noreikaite et al., 2024).

Spontaneous Nystagmus

Denotes the occurrence of nystagmus without external stimuli, typically observed in darkness, with the head upright, and at a distance of at least 3 feet from any stimulus.

Gaze-Evoked Nystagmus

Gaze-evoked nystagmus is provoked by directing the patient's gaze in specific directions. The patient is directed to look forward, left, right, upward, and downward, each at angles of 15°, while recording the nystagmus response.

Smooth Pursuit

Smooth pursuit tracking assesses the eyes' ability to accurately follow moving targets, aiding in the detection of potential central pathology affecting eye movement coordination.

Head-Shaking

Head-shaking entails observing the patient's eyes for nystagmus immediately following rapid shaking of the head along a vertical axis.

RESULTS

The collected data were tabulated and analyzed using both descriptive and inferential statistics. All the parameters were assessed using statistical package for (SPSS), with a significance level of p value and a 95% confidence interval set for all analysis.

Table 2 shows significant effect of Virtual Reality training on proprioception among cervical vertigo patients using Joint Position Error Test Flexion comparing the mean values of pre (12) and post-tests (8.27) which has the higher mean value at (***-P≤0.001), Extension comparing the mean values of pre (11.35) and post-tests (8.00) which has the higher mean value at (***-P≤0.001) , Right Lateral Flexion comparing the mean values of pre (9.22) and post-tests (6.37) which has the higher mean value at (***-P≤0.001), Left Lateral Flexion comparing the mean values of pre (13.5) and post-tests (8.75) which has the higher mean value at (***-P≤0.001).

Table 2. Comparison of joint position error test- pre and post

	Pre-Test		Post- Test		Post -Test		F -value	df	P-value
JPET	Mean	SD	Mean	SD	Mean	SD			
Flexion	12	2.0	9.78	1.33	8.27	.96	56.0	2	0.000***
Extension	11.35	2.05	9.08	1.63	8.00	1.70	54.801	2	0.000***
Right Lateral Flexion	9.2250	.46522	7.96	0.89	6.37	0.38	68.611	2	0.000***
Left Lateral Flexion	13.562	2.096	10.32	1.08	8.75	0.73	48.163	2	0.000***

Table 3. Comparison of videonystagmography –pre and post

	Pre-Test		Post- Test		Post -Test		F -value	P-value
JPET	Mean	SD	Mean	SD	Mean	SD		
Spontanous Nystagmus (Right)	16.37	1.40	15.37	1.76	8.625	1.30	351.23	0.000***
Spontanous Nystagmus (Left)	15.87	1.88	15.12	1.24	12.75	1.48	351.235	0.000***
Head Shake (Right)	16.37	15.00	15.00	1.06	9.375	.744	96.791	0.000***
Head Shake (Left)	17.50	17.87	17.87	.834	18.37	.916	426.33	0.000***
Smooth Pursuit	17.87	1.55	17.37	1.18	8.250	1.28	588.940	0.000***
Gaze Nystagmus	27.62	2.13	26.87	1.95	27.25	1.66	781.94	0.000***

Table 3 shows significant effect of VIRTUAL REALITYTraining on cervical vertigo patients using Videonystagmography –Spontaneous Nystagmus (Right) comparing the mean values of

pre (16.37) and post-tests (8.62) which has the higher mean value at (***-P≤0.001) , Spontaneous Nystagmus (Left) comparing the mean values of pre (15.87) and post-tests (12.75) which has the higher mean value at (***-P≤0.001), Head Shake (Right) comparing the mean values of pre (16.37) and post-tests (9.37) which has the higher mean value at (***-P≤0.001) , Head Shake (Left) comparing the mean values of pre (17.5) and post-tests (18.3) which has the higher mean value at (***-P≤0.001) , Smooth Pursuit comparing the mean values of pre (17.8) and post-tests (8.2) which has the higher mean value at (***-P≤0.001) , Gaze Nystagmus comparing the mean values of pre (27.6) and post-tests (27.2) which has the higher mean value at (***-P≤0.001).

DISCUSSION

The present study was aimed to evaluate the effectiveness of virtual reality based exercise on cervicogenic kinesthetic sensation among patient with cervical vertigo improve the functional disability of the patients. Virtual reality , sensory perception is provided through visual analyzer proprioception is organized complexly by bodily sensation and the formation is influenced by receptor apparatus of sensory system activation16. A study by Jozefowicz-Korczynska et al on the effect of VR on vertigo patients undergoing rehabilitation suggested that this is an effective and well tolerated method of therapy (Tomasz Stankiewicz et al., 2021).

According to Vugt et al., (2019), vestibular rehabilitation is a safe and effective management for unilateral peripheral vestibular dysfunction, showed benefits of new technologies involved in vestibular rehabilitation. Use of internet-based vestibular rehabilitation protocols is a safe, effective, and easy accessible form of therapy for adults aged 50 and older with a chronic vestibular syndrome. studies have shown the great potential and efficacy of VR when treating patients suffering from vertigo.

According to Falla et al., (2007) many proprioceptors are distributed over the longus colli and longus capitis muscles. Because these proprioceptors provide postural information as quickly as possible with early contraction during movements of the head or upper limbs, they facilitate suitable movements depending on the stability and posture of the neck region. Pavlou et al demonstrated that virtual reality patients improved 59.2%. Saw Wah Wah et al., (2021) stated that proprioceptive training group targeting the suboccipital muscles was effective than the craniocervical flexion training group and control group in improving static balance. Cervical muscle spindles are the important proprioceptors in maintaining balance control. The enhancement of suboccipital muscle on proprioceptive training is responsible for accurate kinesthesia and proprioception.

This study is aimed to analyze the effect of virtual reality on cervicocephalic kinesthetic sensibility in patients with cervical vertigo. MEDLINE, EMBASE, CENTRAL, CINAHL, PsychInfo, PsychBITE, OTSeeker, Ei Compendex, IEE, Clinical trials.gov and Web of Science databases were searched and reviewed for similar article. A potential mechanism of cervicogenic dizziness would have to be based on altered upper cervical somatosensory input associated with neck problems. If the firing characteristics (the symmetricity) of the cervical somatosensors alter as a consequence of neck pain, a sensory mismatch between vestibular and cervical inputs would be expected to result in cervicogenic dizziness. Physiological studies have shown that small flexion of the upper cervical joints can cause major changes in firing rate of the spindle afferents from perivertebral muscles.

Virtual reality gaming systems construct simulation models that allow players to interact with computer-generated environments, providing them with the sensation of being immersed in a real-world setting (Tomasz Stankiewicz et al., 2021). Virtual Reality (VR) is extensively utilized to create virtual environments, interactive simulations replicating the real world, utilizing diverse display formats such as spherical, flat screens, or head-mounted displays. Users can engage with objects within VR through bodily movements, and additional hardware devices can be incorporated to track motion kinematics or deliver simulated force feedback or haptic feedback to participants (Holden et al., 2005).

In this study Eight participants aged between 40 and 55 years, comprising both male and female individuals clinically diagnosed with cervical vertigo, were selected for the study. VR exercises involving abyss sharks, sea worlds, and thrilling scenarios were used. These VR experiences were designed to challenge and stimulate proprioceptive systems, which are critical in managing cervicocephalic kinesthetic sensibility. In patients with cervical vertigo, abnormal eye movements

detected through VNG can indicate disruptions in the vestibular system, which is closely linked to the proprioceptive input from the cervical spine.The post-intervention VNG results in this study demonstrated a significant reduction in nystagmus, suggesting an improvement . The immersive nature of VR allows patients to engage in dynamic head movements within a controlled and interactive environment, thus facilitating better proprioceptive feedback and motor learning. This improvement in CJPE suggests that VR-based exercises can effectively retrain the cervical proprioceptive system, leading to reduced joint position error and, consequently, a decrease in vertigo symptoms

After analyzing the statistical data, the significant pre- and post-intervention differences ($P \leq 0.001$) highlight the potential of VR exercises to complement traditional therapeutic approaches, offering a more engaging and potentially more effective treatment modality. Hence Virtual Reality was effective in improving cervicocephalic kinesthetic sensibility among patients with cervical vertigo.

Conclusions

The integration of Virtual Reality technology into rehabilitation programs represents a promising avenue for improving cervicocephalic kinesthetic sensibility and overall outcomes in patients with cervical vertigo. Embracing such innovative approaches underscores the commitment to providing holistic and effective care to individuals with cervical vertigo. the positive outcomes observed in this study underscore the importance of adopting innovative technologies in healthcare settings. Virtual Reality offers a novel and engaging platform for rehabilitation, potentially enhancing patient motivation and compliance with exercise programs. Moreover, the ability to customize Virtual Reality experiences to suit individual patient needs and progressions highlights its versatility as a therapeutic tool.

Acknowledgment

The authors would like to thank the authorities of Dr.MGR Educational & Research Institute and the Principal, Faculty of Physiotherapy for providing all the facilities needed for the successful completion of this study.

Conflict of Interest

The authors declare no conflicts of interest.

Funding

This research did not receive any financial support.

Author Contribution

Research Design, GVG; Research Data Input, GVG, JP; Statistical Data Analysis, CVSN; Data Processing, GVG, PS; Manuscript Preparation, PS; Journal Literacy, GVG, JP, PS, CVSN. All authors were contributors and responsible for the manuscript's content and approved the version submitted for publication.

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