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Effects of Optokinetic Stimulus Using Virtual Reality on Standing Posture Control—A Pilot Study

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Abstract

Purpose: This study aimed to investigate the immediate effects of optokinetic stimulation (OKS) using virtual reality (VR) on visual dependency and sensory reweighting in postural control during static standing. Specifically, it examined whether VR-based OKS could reduce visual dependency more effectively than visual deprivation through eye closure. **Methods:** Ten healthy adults participated in this study. A balance function meter was used to measure postural stability, including Romberg ratios before and after two conditions: VR-based OKS (VR + OKS) and eye closure (EC). Participants performed a two-minute standing task under each condition in random order, with adequate rest between tasks. In the VR + OKS condition, a smartphone-based VR headset presented a rotational OKS, while in the EC condition, participants stood with their eyes closed. Statistical analyses were conducted using paired t-tests to compare pre- and post-task Romberg ratios. **Results:** No significant differences were observed in the pre-task Romberg ratios between conditions. After the VR + OKS condition, significant reductions in Romberg A and Romberg V were observed. In contrast, no significant changes were noted in Romberg ratios after the EC condition. **Conclusion:** VR-based OKS significantly reduced visual dependency, as indicated by decreased Romberg ratios, suggesting its potential to facilitate sensory reweighting during postural control. These findings highlight the utility of low-cost VR devices in balance rehabilitation for conditions involving high visual dependency. Future studies should expand on this preliminary research by including larger sample sizes and diverse populations to confirm its clinical applicability.

Keywords

Virtual Reality, Optokinetic Stimulus, Sensory Weight

1. Introduction

In the context of postural control, the contributions of the visual, vestibular, and somatosensory systems are well-documented. Under bright conditions, somatosensorial have been shown to contribute approximately 70% of the information, with vision accounting for approximately 10% and vestibular sensation responsible for approximately 20% [1]. The sole of the foot, the sole area in contact with the ground while standing, provides feedback on the magnitude of force exertion, weight distribution between the lower limbs, and surface characteristics of the ground [2]-[4]. This has been shown to be associated with balance ability.

Aging and musculoskeletal disorders in the lower limbs can lead to a decline in somatosensory function, including morphological changes, reduction in the number of sensory receptors, decreased skin elasticity, and slowed nerve conduction velocity. However, since each sensory system has redundancy, a decline in somatosensory input increases dependence on vision, thereby compensating for sensory information and adapting sensory weighting. This process, termed "sensory reweighting," facilitates postural control under various environmental and task-related conditions [5].

Devices such as wobbles and balance boards are frequently utilized to enhance somatosensory input from the lower limbs. Nevertheless, the use of these devices has been observed to diminish the reliability of sensory information from foot contact, consequently augmenting reliance on vision [6]. In the domain of sensory reweighting, which encompasses redundancy and complementary relationships between sensory systems, visual interventions have recently garnered attention.

Specifically, postural control tasks involving visual deprivation (e.g., eye closure) have been shown to be effective in improving visual dependency in patients with stroke [7]. In healthy adults, visual deprivation has also been reported to improve balance ability more effectively than using a wobble board [8]. In addition, in patients experiencing dizziness due to vestibular dysfunction, administration of an optokinetic stimulus (OKS), which involves the presentation of moving target objects on a large display, has been documented to reduce visual dependency and alleviate symptoms of dizziness [9]. The OKS provides visual motion information, and its application during static posture maintenance has been shown to increase center-of-gravity sway [10]. The hypothesis that OKS reduces visual dependency is based on the premise that it lowers the reliability of visual information for postural control.

Visual interventions, akin to somatosensory interventions, are regarded as influential factors in sensory weighting. Nevertheless, except for eye closure, visual interventions frequently require dedicated environments and equipment, thereby impeding accessibility.

Virtual reality (VR) technology has witnessed a meteoric rise in its applications in the domains of medicine and welfare. VR engenders visual sensations that closely resemble reality, thereby enabling facile and quantitative manipulation of visual disturbances and facilitating its use in rehabilitation. Nevertheless, there is a paucity of studies that have employed VR for OKS, and research on the effect of VR on visual dependency remains limited and inconsistent. It may be beneficial to investigate the impact of VR-based OKS on visual dependency in postural control. Demonstrating the effectiveness of VR-based OKS in reducing visual dependency could lead to an expansion of options for balance rehabilitation involving visual interventions.

Akizuki *et al*. It was previously reported that the Romberg ratio decreased following repeated exposure to virtual reality (VR) images, in which visual information was inaccurate in relation to head movements [11]. The extant literature on the effects of VR technology on visual dependence currently presents inconclusive results. Although some studies have reported that VR technology improves visual dependence [12], others have found no effect [13]. As such, the effects of VR on visual dependence remain unclear, as does the impact of a single exposure to OKS with VR.

The present study constitutes a preliminary investigation of the effect of VR-based OKS on visual dependency, with a specific focus on the immediate impact of a single exposure to VR-based OKS on visual dependency. To evaluate this impact, the improvement in visual dependency during static standing posture was compared between two conditions: VR-based OKS (VR + OKS) and eye closure (EC).

2. Methods

2.1. Study Design

This study enrolled 10 healthy adults [mean (SD); age: 21 (0.6) years; two women; height: 165.8 (5.6) cm] as participants. All patients met the following criteria: no acute lower limb disorders, no motor system disorders, and no neurological disorders affecting postural control. The study was conducted in accordance with the Declaration of Helsinki, and its purpose and content were explained to the participants in advance, after which written informed consent was obtained. The research content and methodology were approved by the Ethical Review Committee of Biwako Rehabilitation Professional University (BR24011).

The study comprised a preliminary measurement (Pre), a two-minute standing task conducted under each condition (EC, VR + OKS), and a post-measurement (Post). During the preliminary and subsequent measurements, each participant was instructed to maintain a static standing position for 30 s on two occasions, with open and closed eyes, using a balance function meter (Gate View, Aison Ltd., Japan). The participants were further instructed to assume a static standing posture with their feet and heels together, and both upper limbs in a relaxed position while barefoot. In the open-eye measurement, an index finger was placed 1 m from the participant at eye level, and the participant was instructed to stare at it.

In the VR + OKS condition, a smartphone (iPhone SE, Apple Inc.) was attached to the VR goggles for smartphones (VRG-M02RBK, ELECOM Inc.) with their eyes open. Additionally, a participative visual vertical position application (SVV;

Kuroda ENT. Clinic, Version 2.6), which presents two images individually for each eye for stereoscopy. The participants were used to maintaining a closed leg standing posture with both legs, while a rotational optokinetic stimulus with a black dot rotating clockwise at 60˚/s was applied for 2 min. In the EC condition, participants were instructed to maintain a closed leg standing posture for a period of two minutes with their eyes closed, thus blocking visual information. The participants were instructed to perform each condition randomly, with sufficient rest periods between the conditions. Following a two-minute period of standing in each condition, the post-measurement was taken using an equilibrium function meter in a manner consistent with that employed for the Pre.

To calculate the visual dependence of each participant from the data obtained by the equilibrium function meter, the Romberg ratio was further calculated by dividing the center of pressure (COP) sway value during the closed eye by that during the open eye. Romberg ratio A (Area: Romberg A) was further calculated from the measured outer circumferential area, which represents the magnitude of the center of gravity sway. The Romberg ratio V (velocity: Romberg V) was calculated from the unit time trajectory length, which represents the speed of the center of gravity sway.

2.2. Statistical Analyses

In statistical processing, the training effect was examined by performing a paired t-test on Romberg A and Romberg V obtained before and after each condition. Statistical software (IBM SPSS Statistics version 29.0) was used to perform statistical analyses, with a significance level of <0.05 set in all cases.

3. Results

There were no significant differences in Romberg A ($p > 0.05$) and Romberg V ($p > 0.05$) during the Premeasurement between conditions.

Table 1 shows a Pre-Post comparison of Romberg rates before and after each condition task: in the VR + OKS condition. There was a significant decrease in Romberg A ($p < 0.05$) and Romberg V ($p < 0.05$) before and after the task. In the closed-eye condition, there was no significant change in Romberg A ($p > 0.05$) and Romberg V ($p > 0.05$) before and after the task.

A single exposure to VR + OKS in the present study produced a significant reduction in the Romberg ratio. However, a similar single exposure with the eyes

Table 1. Pre-post comparison of Romberg rates before and after each condition.

EC	Romberg A	pre	1.81 ± 0.72	VR + OKS	Romberg A	pre	1.92 ± 0.64
		post	1.54 ± 1.02			post	1.27 ± 0.60*
	Romberg V	pre	1.52 ± 0.24		Romberg V	pre	1.59 ± 0.39
		post	1.38 ± 0.50			post	1.18 ± 0.36*

Average ± SD., *p < 0.05, EC: Eye-Crosure, VR: Virtual Reality, OKS: optokinetic stimulus.

closed did not produce a significant change in the Romberg ratio.

4. Discussion

This study investigated the effects of optokinetic stimulation (OKS) using virtual reality (VR) on sensory reweighting of postural control during standing. The results showed a decrease in the Romberg ratio, an indicator of visual dependency in postural stability, after the VR-based OKS. In contrast, no effect on visual dependency was observed under the eyes-closed condition. These findings suggest that VR-based OKS effectively reduces visual dependency in static standing posture and influences sensory reweighting. Furthermore, visual motion stimuli using VR were found to have a high potential for facilitating sensory reweighting in postural control.

In this study, somatosensory input from the lower limbs and soles was not altered, whereas visual information was manipulated using VR-based OKS and the eyes-closed condition. The results demonstrated a significant reduction in the Romberg ratio following VR-based OKS, whereas no changes were observed under the eyes-closed condition. A key factor in sensory reweighting is the reduction in the reliability of sensory inputs [14] [15]. This study revealed that VR-based OKS significantly decreased visual dependency compared with the eyes-closed condition. Previous research has shown that the OKS induces visual disturbances and increases postural sway during stimulation. Similarly, VR-based OKS likely led to a greater reduction in the reliability of visual information compared with the eyes-closed condition. Consequently, sensory reweighting toward more reliable somatosensory and vestibular inputs occurred, leading to an observed reduction in the Romberg ratio after stimulation.

Methods to alter visual dependency in maintaining a standing posture have been previously investigated, including the use of balance boards and unstable platforms [14]. These studies reported increased reliance on visual input during postural control tasks on unstable platforms. In sports research, studies have shown that road cyclists rely more on visual inputs, whereas mountain bikers depend more on somatosensory inputs [14]. These findings highlight the fact that sensory weighting is strongly influenced by environmental and task-specific factors. However, traditionally, approaches targeting visual inputs require specialized environments. Advances in VR technology now allow for the manipulation of visual information without such environments, broadening the scope of sensory interventions in postural control.

In this study, a low-cost VR headset and smartphone application were used instead of expensive head-mounted displays, making it feasible for clinical applications. A single exposure to OKS was performed with participants using this setup. VR-based OKS, implemented without requiring specialized environments, holds promise for rehabilitation of balance and vestibular disorders with high visual dependency. The results suggest that VR goggles, head-mounted displays, visual content, and games can be effectively used in balance rehabilitation.

However, this study has limitations, including the small sample size and lack of comparisons with an eyes-open control condition. Further research is necessary to explore the clinical application of VR-based OKS. Therefore, we would like to conduct a study on more than 30 subjects and add open-eye condition in addition to the closed-eye condition. In addition, because this was a single exposure, the long-term effects could not be studied. Therefore, we aimed to study the long-term effects of OKS by using VR. Additionally, in populations with high visual dependency, such as older adults, there is a potential risk of balance deterioration after VR-based OKS owing to reduced visual dependency. Therefore, future investigations should consider sensory dependency in diverse populations, including older adults and individuals with various conditions, to facilitate the implementation of VR-based OKS in the clinical setting.

This preliminary study examined the effects of VR-based OKS on improving visual dependency. These results suggest that the VR-based OKS may influence sensory reweighting during postural control. These findings contribute to a better understanding of sensory and postural control mechanisms and may advance the development of effective balance rehabilitation strategies.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Horak, F.B. (2006) Postural Orientation and Equilibrium: What Do We Need to Know about Neural Control of Balance to Prevent Falls? *Age and Ageing*, **35**, II7-II11. https://doi.org/10.1093/ageing/afl077

[2] Tanaka, T., Ino, S. and Ifukube, T. (1996) Tactile Sense and Pressure of Toe Contribution to Standing in the Healthy Elderly. *Journal of Physical Therapy Science*, **8**, 19-24. https://doi.org/10.1589/jpts.8.19

[3] Kavounoudias, A., Roll, R. and Roll, J. (2001) Foot Sole and Ankle Muscle Inputs Contribute Jointly to Human Erect Posture Regulation. *The Journal of Physiology*, **532**, 869-878. https://doi.org/10.1111/j.1469-7793.2001.0869e.x

[4] Oddsson, L.I.E., De Luca, C.J. and Meyer, P.F. (2004) The Role of Plantar Cutaneous Sensation in Unperturbed Stance. *Experimental Brain Research*, **156**, 505-512. https://doi.org/10.1007/s00221-003-1804-y

[5] Horak, F.B. and Macpherson, J.M. (1992) Postural Orientation and Equilibrium. In: Shepherd, J. and Rowell, L., Eds., *Handbook of Physiology*, *Section* 12. *Exercise*: *Regulation and Integration of Multiple Systems*, Oxford University, 255-292. https://doi.org/10.1002/cphy.cp120107

[6] Logan, D., Kiemel, T. and Jeka, J.J. (2014) Asymmetric Sensory Reweighting in Human Upright Stance. *PLOS ONE*, **9**, e100418. https://doi.org/10.1371/journal.pone.0100418

[7] Bonan, I.V., Yelnik, A.P., Colle, F.M., Michaud, C., Normand, E., Panigot, B., *et al.* (2004) Reliance on Visual Information after Stroke. Part II: Effectiveness of a Balance Rehabilitation Program with Visual Cue Deprivation after Stroke: A Randomized Controlled Trial. *Archives of Physical Medicine and Rehabilitation*, **85**, 274-278. https://doi.org/10.1016/j.apmr.2003.06.016

[8] Jandaghi, S., Tahan, N., Akbarzadeh Baghban, A. and Zoghi, M. (2021) Stroke Patients Showed Improvements in Balance in Response to Visual Restriction Exercise. *Physical Therapy Research*, **24**, 211-217. https://doi.org/10.1298/ptr.e10081

[9] Van Ombergen, A., Lubeck, A.J., Van Rompaey, V., Maes, L.K., Stins, J.F., Van de Heyning, P.H., *et al.* (2016) The Effect of Optokinetic Stimulation on Perceptual and Postural Symptoms in Visual Vestibular Mismatch Patients. *PLOS ONE*, **11**, e0154528. https://doi.org/10.1371/journal.pone.0154528

[10] Guerraz, M. (2001) Visual Vertigo: Symptom Assessment, Spatial Orientation and Postural Control. *Brain*, **124**, 1646-1656. https://doi.org/10.1093/brain/124.8.1646

[11] Akizuki, H., Uno, A., Arai, K., Morioka, S., Ohyama, S., Nishiike, S., *et al.* (2005) Effects of Immersion in Virtual Reality on Postural Control. *Neuroscience Letters*, **379**, 23-26. https://doi.org/10.1016/j.neulet.2004.12.041

[12] Moraes, R., Freitas, P.B.d., Razuk, M. and Barela, J.A. (2016) Quality of Visual Cue Affects Visual Reweighting in Quiet Standing. *PLOS ONE*, **11**, e0150158. https://doi.org/10.1371/journal.pone.0150158

[13] Barbanchon, C., Mouraux, D. and Baudry, S. (2024) Repeated Exposure to Virtual Reality Decreases Reliance on Visual Inputs for Balance Control in Healthy Adults. *Human Movement Science*, **96**, Article ID: 103236. https://doi.org/10.1016/j.humov.2024.103236

[14] Dichgans, J., Held, R., Young, L.R. and Brandt, T. (1972) Moving Visual Scenes Influence the Apparent Direction of Gravity. *Science*, **178**, 1217-1219. https://doi.org/10.1126/science.178.4066.1217

[15] Bronstein, A.M. (1986) Suppression of Visually Evoked Postural Responses. *Experimental Brain Research*, **63**, 655-658. https://doi.org/10.1007/bf00237488