Global Journal of
Otolaryngology
ISSN 2474-7556

Research Article
Volume 24 Issue 5- November 2021
DOI: 10.19080/GJO.2021.24.556150

Glob J Otolaryngol

Influence of Somatosensory Inputs to the Shoulder on the Semicircular-Ocular Reflex and Otolith-Ocular Reflex

Yoshiyuki Sasano*, Fumihiro Mochizuki, Yasuhiro Miyamoto, Toru Seo and Izumi Koizuka

Department of Otolaryngology, St. Marianna University, Japan

Submission: October 20, 2021; **Published:** November 09, 2021

***Corresponding author:** Yoshiyuki Sasano, Department of Otolaryngology, St. Marianna University, School of Medicine, 2-16-1 Sugao, Miyamae-ku, Kawasaki-city, Kanagawa, Japan

Abstract

Background: Visual, somatic, and vestibular sensations play an important role in maintaining body balance and stabilizing visual images.

Objective: To clarify the influence of somatosensory input on the vestibulo-ocular reflex (VOR) using earth vertical axis rotation (EVAR) and off-vertical axis rotation (OVAR).

Material and methods: The participants were 25 healthy adult volunteers. EVAR and OVAR (0.16 Hz with a maximal angular velocity of 60°/s) were performed both when they grasped a bar fixed to the rotating chair and when they did not.

Results: The VOR gain was significantly higher in both the EVAR and OVAR groups when the bar was grasped than when it was not. There was a significant difference between VOR gain in OVAR (nose-up) and OVAR (nose-down) when the bar was not grasped; however, there was no difference between them when the bar was grasped.

Conclusions: Somatosensory inputs have a stronger influence on VOR than otolith inputs. Therefore, vestibular rehabilitation using joint movements as somatosensory input may be an effective exercise method.

Keywords: Vestibulo-ocular-reflex; Rotation test; Somatosensory

Abbreviations: VOR: Vestibulo-Ocular Reflex; ScOR: Semicircular-Ocular Reflex; OOR: Otolith-Ocular Reflex; EVAR: Earth's Vertical Axis Rotation; OVAR: Off-Vertical Axis Rotation

Introduction

The vestibulo-ocular reflex (VOR) is responsible for correcting the eye position during head and body movements. The VOR primarily consists of the semicircular ocular reflex (ScOR) and otolith-ocular reflex (OOR). The Earth's vertical axis rotation (EVAR) causes ScOR due to angular acceleration (Figure 1A). The off-vertical axis rotation (OVAR) (Figure 1B) generates angular and linear accelerations that cause combined eye movements, ScOR and OOR [1,2]. The function of the otolith organs can be assessed by comparing eye movements caused by EVAR and OVAR. Vestibular input, which is from the semicircular canals and otolith organs, visual input, and somatosensory input interact to maintain balance and eye position. We previously reported a somatosensory effect on VOR. Although somatosensory stimulation with linear motion reduced the EVAR gain, which consisted of ScOR, it did not affect the OVAR gain, which consisted of ScOR+OOR [3,4].

Somatic sensation with linear motion reduced the ScOR and increased OOR. ScOR gain was significantly increased by the somatosensory stimulus of grasping a bar [5]. Under this condition, the subjects felt rotation through the bar. Somatic sensation with rotatory motion increases the ScOR. These findings concluded that the somatic sensation with linear motion affected the additive in OOR and that with rotatory motion did in ScOR. Therefore, we postulated that when the somatosensory system conducted a similar motion as an optimal stimulus for the vestibular apparatus, VOR gain may increase, and when it is not, the VOR gain may decrease.

Based on this hypothesis, somatosensory equivalent to angular acceleration attenuates OOR. Therefore, the aim of this study was to investigate how the application of a somatic sensation, given in the form of rotational angular acceleration to the shoulder joint, affects OOR.

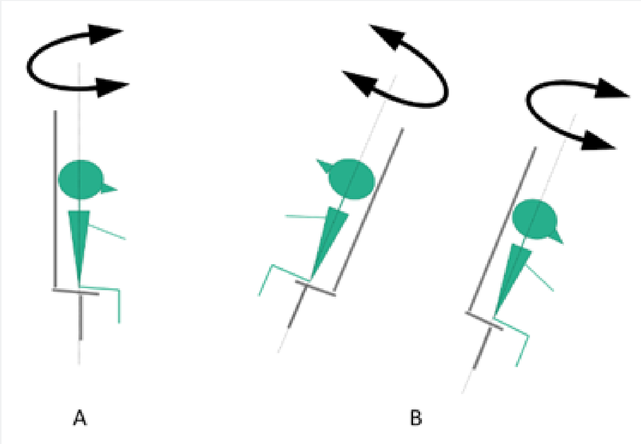

Figure 1: A) In the Earth's vertical axis rotation, the lateral semicircular canals are stimulated by angular acceleration, and the semicircular ocular reflex (ScOR) causes eye movements. B) In the off-vertical axis rotation (in the nose-up and nose-down positions), the rotational axis is tilted so that the direction of gravitational acceleration continuously changes during rotation. Consequently, the otolith organs are stimulated, and eye movements reflecting both the ScOR and otolith-ocular reflex occur.

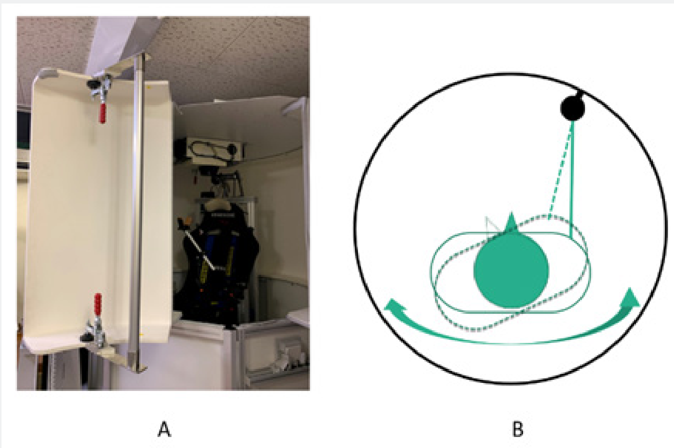

Figure 2: A) A bar is seen fixed to the edge of the ceiling of the rotating apparatus. B) View of the rotation device from above. The bar did not rotate when the chair and the subject rotated. When rotational stimulation was applied to the volunteer gasping the bar, somatic sensations were passively applied to the shoulder joint.

Materials and Methods

The present study included 25 healthy adult volunteers (15 men and 10 women, mean age: 24.7 ± 2.1 years) without any history of cochlear and vestibular symptoms. EVAR and OVAR were measured when a bar that fixed the chair was grasped (with bar) and when it was not (without bar). In the bar condition, the bar was grasped with the right hand, and the arms were kept movable. Somatosensory input was applied to the shoulder joint (Figures 2A & 2B). In the without bar condition, it was not. The subjects sat on a rotating chair (KN-VAR1000, Nagashima Medical, and Tokyo, Japan) and were secured with a 5-point seatbelt. To record eye movement, an infrared eye movement recorder (2D VOG-Video-Oculography, version 3.2 Senso-Motric Instruments GmbH, Teltow, Germany) was firmly fixed with a band on the head.

EVAR with a bar was measured first, followed by EVAR without a bar. After the rotating chair stopped completely, it was tilted forward by 30° for 7s. Further, the OVAR with a bar was measured; both the nose-up and nose-down positions were measured at random to avoid order effects. Then, OVAR without a bar was measured under the same conditions. Sinusoidal rotation at a frequency of 0.16Hz with a maximal angular velocity of 60°/s was used for both EVAR and OVAR. During rotation, subjects were instructed not to voluntarily move their eyes, to open their eyes at the midline at rest, and not to blink too much. They were instructed to perform mental calculations to remain awake.

After all examinations, horizontal eye movements were analyzed according to our previously described methods. Using custom-made computer software (FNG-1004S Daiichi Medical,

How to cite this article: Yoshiyuki S, Fumihiro M, Yasuhiro M, Toru S, Izumi K. Influence of Somatosensory Inputs to the Shoulder on the Semicircular-Ocular Reflex and Otolith-Ocular Reflex. Glob J Oto, 2021; 24 (5): 556150. DOI: 10.19080/GJO.2021.24.556150

Japan), the obtained eye velocity waveforms were smoothed. The relative amplitude of the eye and chair velocity were determined by fast Fourier transformation, and then the VOR gain was determined by the ratio of the eyer velocity to that of the chair [6,7]. A paired t-test was used for statistical analysis, and a P value less than 0.05 was considered significant. This study was conducted in compliance with the tenets of the Declaration of Helsinki. We explained all details regarding this study to the subjects and obtained their written consent. The study was approved by the ethics committee of St. Marianna University School of Medicine.

Results

Figure 3 shows the VOR gain during EVAR and OVAR (nose-up and nose-down). The VOR gain was significantly higher under all conditions when the bar was grasped compared to when it was not. The rate of change in the VOR gain under each condition was calculated using the following formula:

$$\frac{(VOR\ gain\ with\ bar\ -\ VOR\ gain\ without\ bar)}{VOR\ gain\ without\ bar}100(\%) \quad (1)$$

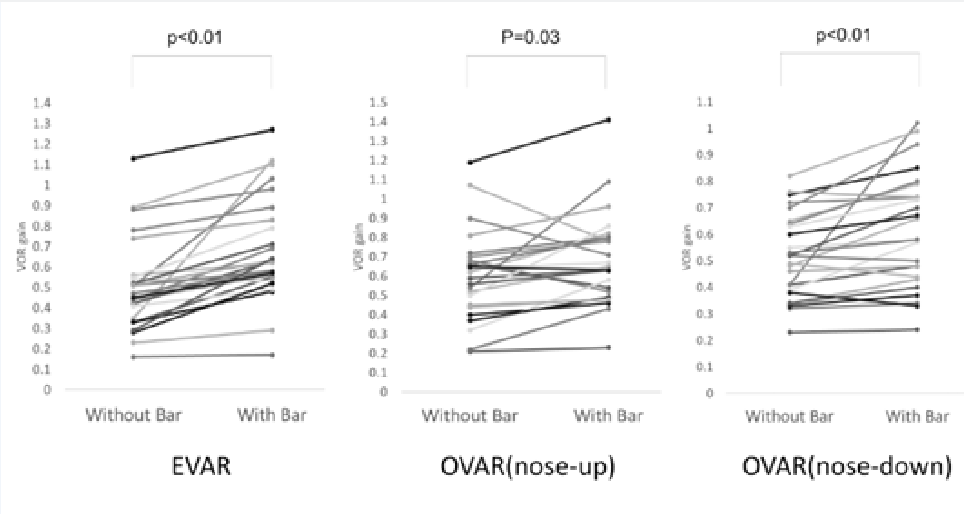

Figure 2: A) A bar is seen fixed to the edge of the ceiling of the rotating apparatus. B) View of the rotation device from above. The bar did not rotate when the chair and the subject rotated. When rotational stimulation was applied to the volunteer gasping the bar, somatic sensations were passively applied to the shoulder joint.

The rates of change in VOR gain during EVAR, OVAR (nose-up), and OVAR (nose-down) were 43.1%, 13.3%, and 18.5%, respectively. The VOR gain was higher during EVAR than during OVAR. When subjects did not grasp the bar, the VOR gain was significantly different between the OVAR (nose-up, 0.60±0.24) and OVAR (nose-down, 0.52±0.16) (P<0.01). In contrast, when subjects grasped the bar to add somatosensory input to the shoulder joint, the VOR gain was 0.68±0.27 and 0.61±0.22, respectively, showing no significant difference (P=0.08).

Discussion

We found that the VOR gain was significantly higher when the bar was grasped than when it was not in both EVAR and OVAR. This suggests that somatosensory input by shoulder joint movements might have a stronger influence on VOR than OOR. Somatic sensations are known to affect the vestibular function. Previous reports have demonstrated that touching a subject's index finger contributes to stabilization of postural sway [8,9]. A recent study has shown that changes in VOR occur due to dorsal and plantar flexion of the ankle joint when a sinusoidal stimulus is applied in the vertical direction, with a platform moving up and down [10]. Lackner et al. observed that, when situated in a dark environment, subjects with vestibular loss who lightly touched a stationary object with their fingers were significantly more stable than normal subjects who did not touch the object. They reported that when the experiment was repeated, arthrokinetic nystagmus (AKN) with the fast phase in the opposite direction of rotation of the upper arm occurred despite the absence of optokinetic or vestibular stimulation [11].

In the present study, the VOR gain during EVAR was significantly higher when the bar was grasped than when it was not. Similar results have been obtained in previous studies using different stimulus frequencies. In one study, when sinusoidal rotational stimulation was applied to volunteers grasping a bar, somatosensory stimulation with passive movement of the right shoulder joint had an additive effect on the VOR and increased the VOR gain [5]. As the stimuli applied in the present study were not limited to somatic sensations, we cannot assert that they were identical to AKN. However, we confirmed that ScOR was enhanced by somatosensory stimulation with rotational movements.

How to cite this article: Yoshiyuki S, Fumihiro M, Yasuhiro M, Toru S, Izumi K. Influence of Somatosensory Inputs to the Shoulder on the Semicircular-Ocular Reflex and Otolith-Ocular Reflex. Glob J Oto, 2021; 24 (5): 556150. DOI: 10.19080/GJO.2021.24.556150

When the bar was grasped, the VOR gain significantly increased under all conditions of EVAR and OVAR, and the change rates were lower during OVAR than during EVAR. This could have occurred because the rotational motion used as a somatosensory stimulus in the present study might not be an appropriate stimulus for OOR derived from the otolith organs, which are receptors of linear motion. Thus, VOR may have been suppressed. When the bar was not grasped, the gain was greater during OVAR (nose-up) than during EVAR and OVAR (nose-down). The following could be plausible reasons for this finding. During OVAR, which induces eye movements by a combination of ScOR and OOR, the OOR moves the eyes in the direction opposite to that of gravity in the nose-up position, leading to an increase in the gain [7]. In contrast, in the nose-down position, the OOR moves the eyes in the direction of gravity, leading to a decrease in the gain [12]. In other words, in the absence of somatosensory input, the OOR is a factor involved in VOR increases.

However, when the bar was grasped, no significant difference in the gain was observed between the OVAR (nose-up) and OVAR (nose-down). This could have occurred because the effect of increasing OOR gain became smaller during OVAR (nose-up), and the decrease in OOR gain became smaller during OVAR (nose-down). This leads to a significant difference between the two. By comparing OVAR (nose-up) and OVAR (nose-down), it became more obvious that somatosensory stimuli of rotational motion acted as unsuitable stimuli for OOR. Regarding the ScOR, the somatosensory input with linear motion did not affect the VOR gain, whereas a somatosensory input with rotational motion enhanced this gain. These effects were found to be sufficiently large for the influence of OOR derived from the otolith organs. The subjects in this study were healthy adults. If similar effects are observed in patients with vestibular dysfunction, the VOR gain can be expected to increase by maintaining the semicircular canal function even if the otolith function is abolished. We recommend the active application of our findings for vestibular rehabilitation in patients with vestibular dysfunction. We plan to investigate specific rehabilitation methods for these patients in the future.

Conclusion

In summary, we examined the influence of somatosensory input on OOR using a rotating chair apparatus and found that the VOR gain during OVAR was significantly higher when a bar was grasped than when it was not. This finding suggests that somatosensory inputs by joint movements may have a stronger influence on VOR than OOR. We suggest that exercise therapy using joint movements as somatosensory input can be used as a potential rehabilitation modality for patients with vertigo and balance disorders.

References

1. J M Furman, R H Schor (2001) Semicircular canal-otolith organ interaction during off-vertical axis rotation in humans. J Assoc Res Otolaryngol 2(1): 22-30.
2. J M Furman, M S Redfern (2001) Effect of aging on the otolith-ocular reflex. J Vestib Res 11(2): 91-103.
3. K Mikami, K Suzuki, Y Miyamoto, M Fukasawa, I Koizuka (2009) Somatosensory induced adaptation in the human vestibulo-ocular reflex. Equilibrium Res 68(1): 28-33.
4. Y Miyamoto, K Mikami, K Suzuki, M Fukasawa, I Koizuka (2010) Somatosensory induced adaptation in the human otolith-ocular reflex. Equilibrium Res 69: 437-444.
5. A Sugita Kitajima, I Koizuka (2009) Somatosensory input influences the vestibulo-ocular reflex. Neurosci Lett 463(3): 207-209.
6. V E Das, C W Thomas, A Z Zivotofsky, R J Leigh (1996) Measuring eye movements during locomotion: filtering techniques for obtaining velocity signals from a video-based eye monitor. J Vestib Res 6(6): 455-461.
7. A Sugita Kitajima, I Koizuka (2008) Recovery of otolith function in patients with benign paroxysmal positional vertigo evaluated by sinusoidal off-vertical axis rotation. Neurosci. Lett 436(2): 124-127.
8. J R Lackner, P DiZio, J Jeka, F Horak, D Krebs, et al. (1999) Precision contact of the fingertip reduces postural sway of individuals with bilateral vestibular loss. Exp Brain Res 126(4): 459-466.
9. J R Lackner, E Rabin, P DiZio (2001) Stabilization of posture by precision touch of the index finger with rigid and flexible filaments. Exp Brain Res 139(4): 454-464.
10. D F Kutz, F P Kolb, S Glasauer, H Straka (2020) Somatosensory Influence on Platform-Induced Translational Vestibulo-Ocular Reflex in Vertical Direction in Humans. Front Neurol 11: 332.
11. T Brandt, W Büchele, F Arnold (1977) Arthrokinetic nystagmus and ego-motion sensation. Exp Brain Res 30(2-3): 331-338.
12. M Azuma, S Watanabe, K Hattori, I Koizuka (2001) Evaluation of the Otolith function using Sinusoidal Off-Vertical Axis Rotation in Humans. Equilibrium Res 60(6): 456-463.

How to cite this article: Yoshiyuki S, Fumihiro M, Yasuhiro M, Toru S, Izumi K. Influence of Somatosensory Inputs to the Shoulder on the Semicircular-Ocular Reflex and Otolith-Ocular Reflex. Glob J Oto, 2021; 24 (5): 556150. DOI: 10.19080/GJO.2021.24.556150

DOI: 10.19080/GJO.2021.24.556150