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ORIGINAL ARTICLE

Post-rotatory Visual Fixation and Angular Velocity-specific Vestibular Habituation is Useful in Improving Post-rotatory Vertigo

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Objectives: We tried to: (1) evaluate the effect of visual fixation quantitatively by comparing the degree of subjective dizziness and time constant (Tc) before and after fixation, and (2) determine the optimal angular velocity for vestibular habituation by giving rotatory stimulus repeatedly with different angular velocity.

Methods: In 18 healthy volunteers, the degree of dizziness using Visual Analogue Scale (VAS) and Tc were checked after 100°/sec angular velocity of rotation. Then, they were asked to exert visual fixation technique (1) during-, (2) during and after- and (3) after- the rotatory movements. After rotation with each fixation methods, VAS and Tc were repeated and compared with baseline value with no fixation. Then subjects were divided into 3 groups. Each group experienced habituation protocol using different angular velocity (60°/sec, 100°/sec and 360°/sec) for 7 day and 10 times of rotation for a day. After habituation was completed, VAS and Tc were re-checked after 100°/sec angular velocity of rotation. Results were compared with baseline value with no habituation.

Results: Less dizziness and more decreased Tc were observed when they exerted fixation (1) after- and (2) during- and after- rotatory stimulus ($p<0.05$). There was a significant correlation between VAS score for dizziness and Tc ($R=0.86$, $p<0.001$). After 7 days of habituation training, those who trained with angular velocity of 100°/sec showed significantly less dizziness and Tc compared with their pre-training values ($p<0.05$).

Conclusions: Post-rotatory visual fixation and angular velocity-specific habituation is more useful in alleviating rotatory dizziness.

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Introduction

Visual, vestibular and proprioceptive sensations provide information for us to maintain equilibrium [1,2]. According to Collins and researchers, visual sensation is more important in maintaining equilibrium when subjects were exposed to repeated rotation [3]. For example, ballet dancers and figure skaters could feel less dizzy by gazing one spot continuously during rotation. It is a kind of 'visual fixation' called 'spotting technique' [1,3-5]. The whirling dervishes performing sufi spinning, which is composed of repeated rotation, use similar strategy also. They report that by using this spotting technique, they could feel less dizzy during and after periods of rotation. However, there were very few studies concerning the quantitative analysis of the influence of visual fixation during repeated rotation.

Aside from visual fixation, there is another way that ballet dancers or figure skaters could overcome dizziness. It's called 'vestibular habituation' which is induced by continuous rotatory training [3,4,6-15]. We could get objective data about vestibular habituation through analyzing vestibulo-ocular reflex (VOR), which is the

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reflex ocular movements stabilizing image on the retina during head movement, by making ocular movement in the opposite direction of head movement. VOR can be measured by the "Time Constant (Tc)", which represents the time that slow phase velocity of eyeball movement has decreased by 67% of the initial value after onset of the stimulus [8,14-17]. Habituation is induced by repeated rotatory stimulation of the vestibular organ, and several researchers have identified this phenomena by proving decrease of Tc after several sessions of rotatory period in experimental animals and humans [4,7,10-17]. However, there is still no study about the optimal angular velocity which could induce maximal degree of vestibular habituation.

Therefore, we tried to: 1) evaluate the effect of visual fixation quantitatively by comparing the degree of subjective dizziness and Tc before and after 'spotting technique', and 2) determine the optimal angular velocity for vestibular habituation by giving rotatory stimulus repeatedly with different angular velocity.

Materials and Methods

Patients

Eighteen healthy volunteers (16 males and 2 females, 28.3 ± 2.8 years old) with neither past dizzy episodes nor sudden hearing difficulty or tinnitus were enrolled. We excluded those with occupational rotatory movements and those who got previous rotatory training. All volunteers participating in this study gave informed consent after full explanation, and the study was approved by the institutional review board of Inha University Hospital.

Step 1: Initial Rotatory Stimulus without Visual Fixation or Habituation

For the rotatory stimulus and data collection, we used rotatory chair test machinery (Micromedical Co. System 2000, USA). The machinery is composed of big cylinder, in which light and sound were completely intercepted. All participants got initial clockwise rotatory stimulus (acceleration of 100°/sec^2 and velocity of 100°/sec) for 1 minute (*Step 1: No Fixation, No Habituation*). During and after rotatory stimulus, participants' nystagmus was recorded and analyzed by electronystagmography. One minute after rotation, participants reported their subjective degree of dizziness by visual analogue scale (VAS) questionnaire, which was composed of 10 cm-long line with dots for every 1 centimeter. Patients marked at 0 if they felt 'absolutely free of dizziness' and marked at 10 if they felt 'overwhelmingly uncomfortable dizziness'. We analyzed VOR and Tc immediately after rotatory period by computer also.

Step 2: Effect of Visual Fixation during and/or after Rotatory Stimulus

We directed all participants to fix their gaze during and/or after the rotatory stimulus. To be more concrete, all participants were asked to gaze a light source 50 cm ahead of their eyes *during the rotatory period (Step 2a: Fixation during the rotatory period)*. After 1 minute of rest, they answered VAS sheets. After 9 minutes of more break time, they got rotatory stimulus again. This time, they were asked to gaze a light source from the start of rotation until 1 minute after the cessation of rotatory stimulus (*Step 2b: Fixation during and after the rotatory period*). Then they answered VAS sheets again. After 9 minutes of break, they got additional rotatory stimulus. This time, they gazed a light source only 1 minute after the cessation of rotatory stimulus (Step 2c: *Fixation after the rotatory period*). Then they answered final VAS sheets. We analyzed VOR and Tc after each rotatory period also.

Step 3: Effect of Vestibular Habituation by Repetitive Rotatory Training

All participants were randomly divided into 3 groups (n=6 each). There were no differences in demographic variables (such as sex and age) and the results of former study (step 2, Effect of Visual Fixation during and/or after Rotatory Stimulus) between each group. For the repetitive rotatory training, Group A got 10 times of repeated clockwise rotatory stimulus (1 minute of rotation and 9 minutes of rest X 10 times) for 7 consecutive days, at an angular velocity of 60°/sec. Group B and C also received the same protocol of 10 repetitive rotatory stimulus for 7 days, with different angular velocity (Group B: 100°/sec, Group C: 360°/sec).

One day after this training period, all participants got clockwise rotatory stimulus (acceleration of 100°/sec^2

and velocity of 100°/sec) for 1 minute, as before rotatory training period. VAS questionnaire, VOR and Tc analysis were repeated and compared with initial values, to evaluate the effect of vestibular habituation.

For statistical analysis, we used Kruskal-Wallis and Mann-Whitney Tests (for comparison between groups) and Wilcoxon Signed Rank Tests (for comparison before and after each experimental protocol). SPSS 18.0 (SPSS Inc., Chicago, IL, USA) software was used and *p* value less than 0.05 were considered as statistically significant.

Results

Compared with Step 1 (*No Fixation,* VAS score 5.5 ± 1.4, Tc = 12.7 ± 3.3), participants reported significantly less VAS score for dizziness and Tc by practicing Step 2b (*Fixation during and after the rotatory period,* VAS score 2.9 ± 1.0, Tc = 7.8 ± 3.0, $p<0.05$) and Step 2c (*Fixation after the rotatory period,* VAS score 3.0 ± 1.5, Tc = 8.0 ± 3.0, $p<0.05$). However, there were no significant differences in VAS score and Tc between Step 1 and Step 2a (*Fixation during the rotatory period*, 5.2 ± 1.3, Tc = 13.9 ± 2.4, $p>0.05$) (Figure 1). By linear correlation analysis, a significant correlation between VAS for dizziness and Tc was found ($R=0.86$, $p<0.001$).

After 7 days of rotatory training, Group B (angular velocity of 100°/sec) showed significantly less dizziness and Tc compared with their pre-training values (VAS score: 5.8 ± 1.2 to 2.0 ± 1.8, Tc: 13.0 ± 3.0 to 7.0 ± 3.0, $p<0.05$, Figure 2). In Group A (angular velocity 60°/sec) and Group C (360°/sec), however, there were no

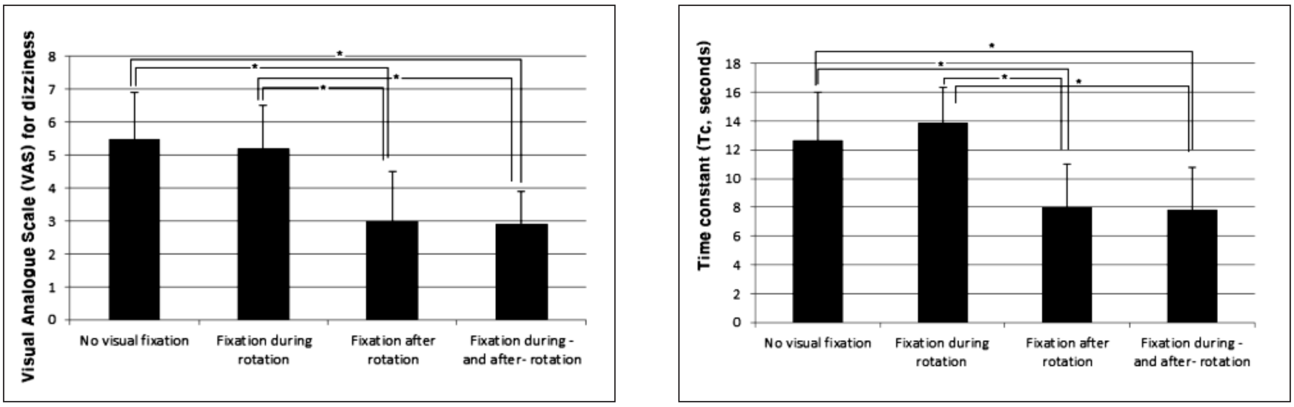

Figure 1. (a) The subjective dizziness evaluated by Visual Analog Scale (VAS) questionnaire and **(b)** time constant (Tc). Compared with values with no visual fixation (first column), VAS score and Tc were significantly reduced when they exerted visual fixation technique after-(third column) or during and after-(fourth column) rotatory movements. However, no significant difference was observed when subjects exerted visual fixation only during rotation (second column). (Wilcoxon Signed Rank Test, *: p<0.05)

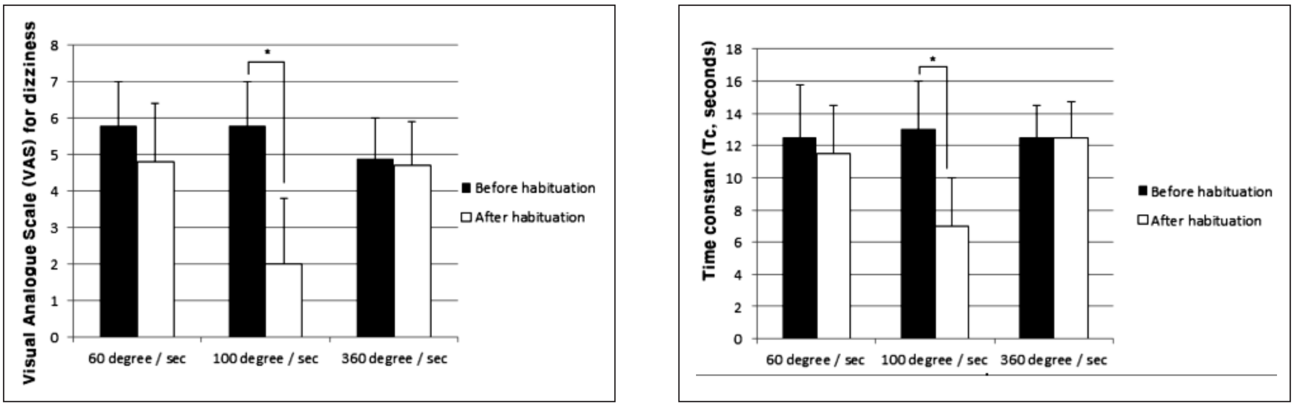

Figure 2. (a) The subjective dizziness evaluated by Visual Analog Scale (VAS) questionnaire and **(b)** time constant (Tc) induced by 100°/sec rotatory movement, before and after vestibular habituation protocol using different angular velocity. After 7-day habituation training using 100°/sec angular velocity, VAS score and Tc were significantly decreased when exposed to same angular velocity (Wilcoxon Signed Rank Test, *: p<0.05)

significant differences of VAS scores or Tcs before and after rotatory training (p>0.05, Figure 2).

Discussion

Collins and researchers emphasized the importance of visual input when they observed decreased dizziness and nystagmus after visual fixation technique in figure skaters [3-5]. Tokita and researchers also reported that the nystagmus after rotatory movement was significantly decreased by visual fixation [18]. From subsequent studies of several researchers, it had been proved that visual fixation technique improved subjective dizziness [1-5,16,19]. However, there had still been no study about the quantitative analysis of the effect of visual fixation during repeated rotation.

In our study, visual fixation after the rotatory stimulus significantly reduced dizziness and Tc after rotatory period. However, visual fixation during the rotatory stimulus had no effect on post-rotatory dizziness. It could be explained by the fact, that dizziness after rotation is caused by the inertial flow of endolymph in the opposite direction when the rotatory movement stopped. Therefore, visual fixation 'during' the rotation could not have an influence on the inertial endolymphatic flow 'after' the rotation. Meanwhile, visual fixation 'after' the rotatory stimulus have an inhibitory effect on the post-rotatory dizziness through the inhibition of post-rotatory nystagmus.

There had been several experimental studies which suggested that repetitive stimulation of vestibular apparatus could have an effect on VOR [11,14,17]. Robinson suggested that repeated rotatory stimulus caused a reduced Tc, and proposed that this phenomenon was due to the habituation of the vestibular organ [20]. After then, several researchers argued that vestibular habituation was caused by the adaptation of the central velocity storage mechanisms, not by mechanical or histologic changes of the peripheral vestibular organ [15, 21]. Tanguy insisted that, as vestibular habituation is induced by repeated rotatory stimulation, otolithic input during rotatory movement is effectively interpreted (suppressed) as in professional rotators such as figure skaters (and dervishes) compared to ordinary people [6]. However, the optimal angular velocity of rotatory movement that could speed and maximize the process of vestibular habituation was not studied before.

From our results, we could find that after habituation with 100°/sec of angular velocity, participants felt less dizzy when they were exposed to a rotatory movement of the same angular velocity (100°/sec). However, habituation using different angular velocities (60°/sec or 360°/sec) had no effect on the 100°/sec rotatory movement. In other words, we could suppose that vestibular habituation was 'angular velocity-specific'; And this result has several meaningful implications. In professional rotators such as ballet dancers, sufi dervishes or figure skaters, vestibular habituation training according to their own rotatory angular velocity could yield more rapid and optimal extent of habituation. And, in patients who had suffered from vestibular disorders such as vestibular neuritis**;** vestibular rehabilitation could be more effective using the angular velocity of rotation which is frequently observed in the patients' everyday life. To confirm this result, further studies with larger populations and various angular velocities should be performed in the future.

Clement claimed that even if habituation is formed over a short time period, it could be maintained for a long time [8,9]. However, we think that a pitfall of our study is the relatively short time of the experiment period. Therefore, we could not evaluate the duration of vestibular habituation induced by 7-day training. Since another disadvantage of our study is smaller number of the study population, subsequent studies with larger groups and longer follow up periods may yield more meaningful conclusion.

In conclusion, we showed that visual fixation technique after the rotatory stimulus is more effective in reducing post-rotatory dizziness. Process of vestibular habituation may be induced relatively over a short-time period, and may be induced for a specific angular velocity which was used during the habituation training. More studies are needed to establish these findings and investigate the physiologic mechanisms underlying these phenomena.

Conflict of Interest: None.

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