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Original Article

Role of Comprehensive Vestibular Rehabilitation Based on Virtual Reality Technology in Residual Symptoms After Canalith Repositioning Procedure

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BACKGROUND: We aimed to explore the role of comprehensive vestibular rehabilitation based on virtual reality (VR) technology in residual symptoms after canalith repositioning procedure.

METHODS: A total of 124 patients, who were diagnosed with benign paroxysmal positional vertigo from September 2020 to July 2023 and had residual symptoms 24 hours after the canalith repositioning procedure, were selected as the subjects. They were randomly divided into a normal control (NC) group, a Cawthorne–Cooksey exercise group (n = 41), a Brandt–Daroff exercise group (n = 41), and a VR group (n = 42). The NC group received no intervention, the Cawthorne–Cooksey exercise group underwent Cawthorne–Cooksey exercise, the Brandt–Daroff exercise group was subjected to Brandt–Daroff exercise, and the VR group was given comprehensive vestibular rehabilitation based on VR technology.

RESULTS: After treatment, the Dizziness Handicap Inventory (DHI) and vestibular symptom index (VSI) scores of the virtual reality (VR), Cawthorne–Cooksey exercise, and Brandt–Daroff exercise groups were significantly lower than those of the NC group ($P < .05$). The scores of the VR group were lower than those of the Cawthorne–Cooksey exercise and Brandt–Daroff exercise groups ($P < .05$). The abnormality rates of ocular vestibular evoked myogenic potentials (oVEMP) and cervical vestibular evoked myogenic potentials (cVEMP) in VR, Cawthorne–Cooksey exercise, and Brandt–Daroff exercise groups were lower than those of the NC group ($P < .05$). The rates of the VR group were lower than those of the Cawthorne–Cooksey exercise and Brandt–Daroff exercise groups ($P < .05$).

CONCLUSION: Comprehensive vestibular rehabilitation based on VR technology can cure the residual symptoms after the canalith repositioning procedure, reduce the abnormality rates of oVEMP and cVEMP, and reconstruct the balance ability.

KEYWORDS: Otolith, residual symptom, vestibular rehabilitation, virtual reality

INTRODUCTION

Otolith disease, also known as benign paroxysmal positional vertigo (BPPV), is a mechanical problem of the peripheral vestibular system caused by the translocation of the otolith to the semicircular canal, becoming a common vestibular disease.[1] Primary otolith disease has a high incidence rate, for which the canalith repositioning procedure is the most effective therapeutic method to significantly relieve vertigo symptoms in patients.[2] However, some patients still have residual symptoms after a successful canalith repositioning procedure, typically including giddy feeling, floating feeling, instability during walking, and even nausea and vomiting.[3,4] If these residual symptoms persist for a long time, they will increase the risk of adverse events such as mental disorders and falling injuries, thereby affecting patients' quality of life.[5] Therefore, efficacious therapeutic intervention with vestibular rehabilitation is of important significance for alleviating the residual symptoms after the canalith repositioning procedure and improving the survival function of patients. Cawthorne–Cooksey exercise and Brandt–Daroff exercise are both common vestibular rehabilitation methods at present.[6] Specifically, Cawthorne–Cooksey exercise mainly takes advantage of neural plasticity to compensate for vestibular function while restoring vestibulo-ocular reflex and mitigating the symptoms of dizziness, vertigo, and balance disturbance using adaptation, acclimatization, and substitution mechanisms.[7] Brandt–Daroff exercise can alleviate the symptoms of dizziness and vertigo by cracking and expelling particles in the semicircular canal.[8] However, conventional vestibular rehabilitation therapy is not only uninteresting, monotonous, and repetitive, but also extremely prone to inducing adverse

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psychological emotions.[9] Therefore, conventional vestibular rehabilitation therapy often fails to achieve ideal effects. Currently, with the constant advancement of contemporary medical science and technology, virtual reality (VR) technology has been gradually applied to assist in various clinical rehabilitation therapies.[10] This technology has multiple functions, such as real-time simulation, interaction, and gaming during application, which can better help patients accomplish vestibular rehabilitation exercises on the basis of routine vestibular rehabilitation exercises.[11]

In this study, VR technology was used for the instruction of vestibular rehabilitation. The application effect of comprehensive vestibular rehabilitation based on VR technology on the residual symptoms after the canalith repositioning procedure was investigated, aiming to provide a reference for clinical treatment.

MATERIAL AND METHODS

Subjects

A total of 124 patients, who were diagnosed with BPPV in Beijing Haidian Hospital from September 2020 to July 2023 and had residual symptoms at 24 hours after the canalith repositioning procedure, were selected as the subjects and then divided into 4 groups using a random number table: the normal control (NC) group, the Cawthorne–Cooksey exercise group, the Brandt–Daroff exercise group, and the VR group (n = 31). The patients and their families were informed of the study and signed the informed consent form, and the study was approved by the Ethics Committee of Beijing Haidian Hospital (Approval No: BHH202009008, Date: September 4, 2020), and written informed consent was obtained from all patients.

Diagnostic Criteria

Otolith disease had residual symptoms after the canalith repositioning procedure and was diagnosed based on the following criteria:[12] 1) paroxysmal and recurrent vertigo or dizziness after changing the head position relative to the gravity direction; 2) vertigo as well as characteristic and positional nystagmus during positioning test; 3) vertigo caused by vestibular neuritis or vestibular migraine excluded; and 4) disappearance of vertigo after successful repositioning, but giddy feeling, floating feeling, instability during walking, and even nausea and vomiting.

Inclusion and Exclusion Criteria

The inclusion criteria included: (1) patients who met the diagnostic criteria of otolith disease and had residual symptoms after the canalith repositioning procedure and had undergone successful treatment with the canalith repositioning procedure; (2) those with normal comprehension and communication ability, and who were able to cooperate in all examinations; and (3) those who voluntarily participated in the study.

The exclusion criteria were set as follows: (1) patients with severe infectious diseases; (2) those complicated with central nervous system diseases; (3) those with mental anomalies or visual or auditory abnormalities; (4) those receiving intervention with vestibular suppressants within the past 3 days; (5) those with recurrent or multiple otolith diseases; (6) pregnant or lactating women; (7) those with a history of head trauma or head surgery; or (8) those with a history of positional vestibular vertigo.

Treatment Methods

The NC group received no intervention, the Cawthorne–Cooksey exercise group underwent Cawthorne–Cooksey vestibular rehabilitation training, the Brandt–Daroff exercise group was subjected to Brandt–Daroff exercises, and the VR group was provided with comprehensive vestibular rehabilitation based on VR technology.

As for Cawthorne–Cooksey exercise, (1) the patients were trained for eye movement and head movement in the sitting position or by lying on the bed. i) Eye movement: the patients moved their eyes slowly first and then rapidly, upward and downward, as well as to the left and right. Finally, they fixed both eyes on the finger in front, and the finger was moved from 60 cm to 30 cm in front. ii) Head movement: eye opening, eye closing, anteflexion, retroextension, left head turning, and right head turning were performed slowly first and then quickly. (2) Sitting exercise was conducted in an open space, where the patients circled their shoulder joints forward and backward and then bent to pick up objects on the ground. (3) Standing exercises in an open space included: i) raising exercise (transition from the sitting position to the standing position; followed by eye opening and eye closing); ii) ball throwing with 1 hand and ball catching with the other hand (the ball passed above the eyes and then below the knees); and iii) transition from the sitting position to the standing position and rotation for 360° in place (360° from the left side and 360° from the right side between 2 chairs or 2 tables in the open space for 4 consecutive weeks, 10 min/time, twice a day). The patients could rest in the case of severe dizziness symptoms during exercise.

In the Brandt–Daroff exercise, the patient sat on the edge of the sofa or bed, lay down in the left lateral position with the head turned 45° to the right side, looked 45° upward for more than 30 seconds, and sat up for 30 seconds. After that, the patient laid down on the right side in the same way. The whole movement was practiced 5 times for 4 consecutive weeks.

Comprehensive vestibular rehabilitation based on VR technology was performed as follows: A VR vestibular rehabilitation training system was employed, where the patients were assisted to wear a head-mounted display, instructed in the usage of the handle and system software, and able to understand and independently complete the instructions of each scene. The rehabilitation training included 15 built-in scenes at the entry and adaptation level and 21 built-in scenes at the consolidation and improvement level. With Cawthorne–Cooksey exercise and Brandt–Daroff exercise as the basis of rehabilitation training, the 15 built-in scenes at the entry and adaptation level were performed in the sitting position in week 1 and week 2, and the 21 built-in scenes at the consolidation and improvement

MAIN POINTS

- Comprehensive vestibular rehabilitation based on VR technology can cure the residual symptoms after canalith repositioning procedure.
- It can reduce the abnormality rates of oVEMP and cVEMP.
- It can also reconstruct the balance ability.

level were accomplished in the standing position in week 3 and week 4. The rehabilitation training was executed for 4 consecutive weeks, 15-20 minutes per time, twice a day.

Evaluation of Severity of Vertigo and Residual Symptoms

The severity of vertigo and residual symptoms was evaluated using the Dizziness Handicap Inventory (DHI) Scale[13] and Vestibular Symptom Index (VSI),[14] respectively, before treatment and at 4 weeks after treatment. The DHI scale was composed of physical, emotional, and functional sub-dimensions containing 25 items in total, with a total score of 100 points, and higher scores indicated more severe vertigo in patients. VSI involved such symptoms as balance, vertigo, dizziness, nausea, visual sensitivity, and headache. Each item was scored 0-10 points, and higher scores suggested more serious residual symptoms in patients.

Detection of Vestibular Evoked Myogenic Potentials

Vestibular evoked myogenic potentials (VEMPs), including ocular VEMP (oVEMP) and cervical anterior VEMP (cVEMP), in patients were detected before treatment and at 4 weeks after treatment using the Eclipse Evoked Response Detector (Interacoustics, Denmark), and the failure to elicit reproducible waveforms during 3 consecutive sessions of monitoring under acoustic stimulation at 95 dBnHL or an asymmetry ratio of bilateral amplitude >21% was set as the criterion for oVEMP and cVEMP abnormalities. Electromyographic activity was continuously monitored at an intensity interval of 50-200 μV.

Evaluation of Balance Ability and Psychological Emotions

Before treatment and at 4 weeks after treatment, the balance ability, psychological anxiety, and depression were assessed through the Berg Balance Scale (BBS),[15] the Self-rating Anxiety Scale (SAS), and the Self-rating Depression Scale (SDS),[16] respectively. Specifically, BBS consisted of 14 items scored 0-4 points for each, with a total score of 0-56 points, and the higher the BBS score was, the better the balance function of the patients would be. Both SAS and SDS were composed of 20 items, with 1-4 points for each item. The SAS score of ≥50 points and the SDS score of ≥53 points signified the presence of anxiety and depression in patients.

Statistical Analysis

Statistical Package for Social Science Statistics software, version 25.0 (IBM SPSS Corp.; Armonk, NY, USA), was used for statistical analysis. The count data (e.g., number of reductions) were described by the case number, and the χ^2 test was performed for comparisons between the residual group and the normal group. The measurement data (e.g., homocysteine, 25(OH)D_3, and course of disease) were described by ($-x \pm s$), and the *t*-test was performed for comparisons between 2 groups. Seven factors, such as diabetes mellitus, number of reductions, gender, and type of onset, were incorporated in multivariate logistic regression analysis, and risk factors including age, diabetes mellitus, number of reductions, anxiety state, hypertension, and course of disease were introduced into R software to construct a nomogram prediction model for residual symptoms. The efficacy of the model for predicting the postcure residual symptoms in BPPV patients was evaluated using calibration curves, receiver operating characteristic curves, and the Hosmer-Lemeshow test, respectively. $P < .05$ was considered statistically significant.

RESULTS

General Data on Patients

The NC group included 16 males and 15 females aged 35-65 years old, with a course of disease of 1-14 days. The Cawthorne–Cooksey exercise group consisted of 18 males and 13 females aged 32-66 years old, with a course of disease of 1-15 days. There were 17 males and 14 females aged 35-67 years old in the Brandt–Daroff exercise group, with a course of disease of 1-16 days. The VR group included 15 males and 16 females, with an age range of 35-64 years old and a course of disease of 1-15 days. The differences in gender, age, course of disease, and affected semicircular canals were not statistically significant among the 4 groups of patients ($P > .05$) (Table 1).

Dizziness Handicap Inventory and Vestibular Symptom Index Scores

There were no statistically significant differences in DHI and VSI scores among the 4 groups before treatment ($P > .05$). After treatment, the DHI and VSI scores of the VR, Cawthorne–Cooksey exercise and Brandt–Daroff exercise groups were significantly lower than those of the NC group ($P < .05$). The scores of the VR group were lower than those of the Cawthorne–Cooksey exercise and Brandt–Daroff exercise groups ($P < .05$). Moreover, no statistically significant differences in DHI and VSI scores were observed between the Cawthorne–Cooksey exercise group and the Brandt–Daroff exercise group after treatment ($P > .05$) (Table 2).

Vestibular Evoked Myogenic Potential Results

The abnormality rates of oVEMP and cVEMP were not significantly different among the 4 groups of patients before treatment ($P > .05$). The abnormality rates of oVEMP and cVEMP of VR, Cawthorne–Cooksey exercise, and Brandt–Daroff exercise groups were lower than those of the NC group ($P < .05$). The rates of the VR group were lower than those of the Cawthorne–Cooksey exercise and Brandt–Daroff exercise

Table 1. General Data on Patients

Group	n	Gender (Male/Female)	Average Age (Year)	Mean Duration of Disease (d)	Affected Semicircular Canal (Posterior/Horizontal)
NC	31	16/15	54.62 ± 3.89	8.12 ± 0.52	22/9
Cawthorne–Cooksey exercise	31	18/13	54.87 ± 3.24	8.34 ± 0.45	24/7
Brandt–Daroff exercise	31	17/14	55.11 ± 4.26	7.89 ± 0.43	23/8
VR	31	15/16	54.55 ± 3.67	7.93 ± 0.46	21/10
χ^2/F		0.691	0.110	2.286	0.811
P		.875	.628	.089	.847

NC, normal control; VR, virtual reality.

Table 2. Dizziness Handicap Inventory and Vestibular Symptom Index Scores [(x ± s), point]

Group	n	DHI Score		VSI Score	
		Before Treatment	After Treatment	Before Treatment	After Treatment
NC	31	45.32 ± 5.12	44.35 ± 3.24	32.23 ± 2.12	31.98 ± 2.13
Cawthorne–Cooksey exercise	31	46.13 ± 4.35	27.75 ± 2.11*	31.89 ± 2.31	14.42 ± 1.42*
Brandt–Daroff exercise	31	45.98 ± 3.76	26.12 ± 1.89*	31.77 ± 2.36	13.98 ± 1.45*
VR	31	45.27 ± 3.42	12.35 ± 1.87*#&	32.25 ± 2.15*#&	7.56 ± 0.35*#&

DHI, Dizziness Handicap Inventory; NC, normal control; VR, virtual reality; VSI, vestibular symptom index.
*$P < .05$ vs. NC group. #$P < .05$ vs. Cawthorne–Cooksey exercise group. &$P < .05$ vs. Brandt–Daroff exercise group.

Table 3. Vestibular Evoked Myogenic Potential Results [n (%)]

Group	n	oVEMP Abnormality Rate		cVEMP Abnormality Rate	
		Before Treatment	After Treatment	Before Treatment	After Treatment
NC	31	29 (93.54)	27 (87.10)	20 (64.52)	19 (61.29)
Cawthorne–Cooksey exercise	31	26 (83.87)	18 (58.06)*	19 (61.29)	9 (29.03)*
Brandt–Daroff exercise	31	27 (87.10)	17 (54.84)*	17 (54.84)	8 (25.81)*
VR	31	28 (90.32)	3 (9.68)*#&	18 (58.06)	2 (6.45)*#&

cVEMP, Cervical anterior vestibular evoked myogenic potential; NC, normal control; oVEMP, ocular vestibular evoked myogenic potential.
*$P < .05$ vs. NC group. #$P < .05$ vs. Cawthorne–Cooksey exercise group. &$P < .05$ vs. Brandt–Daroff exercise group.

groups ($P < .05$). After treatment, the abnormality rates of oVEMP and cVEMP showed no statistically significant differences between the Cawthorne–Cooksey exercise group and the Brandt–Daroff exercise group ($P > .05$) (Table 3).

Balance Ability

No statistically significant differences in BBS score were observed among the 4 groups of patients before treatment ($P > .05$). The BBS scores for balance ability of the VR, Cawthorne–Cooksey exercise, and Brandt–Daroff exercise groups were higher than those of the NC group ($P < .05$). The score of the VR group was higher than those of the Cawthorne–Cooksey exercise and Brandt–Daroff exercise groups ($P < .05$). The BBS scores showed no statistically significant differences between the Cawthorne–Cooksey exercise group, and the Brandt–Daroff exercise group after treatment ($P > .05$) (Table 4).

Table 4. Balance ability [(x ± s), point]

Group	n	BBS score	
		Before treatment	After treatment
NC	31	28.92 ± 3.25	29.09 ± 2.12
Cawthorne–Cooksey exercise	31	29.12 ± 2.14	35.26 ± 2.23*
Brandt–Daroff exercise	31	28.77 ± 3.33	34.53 ± 3.41*
VR	31	28.96 ± 2.89	43.54 ± 4.26*#&

BBS, Berg Balance Scale; NC, normal control; VR, virtual reality.
*$P < .05$ vs. NC group. #$P < .05$ vs. Cawthorne–Cooksey exercise group. &$P < .05$ vs. Brandt–Daroff exercise group.

Psychological Emotions

No statistically significant differences in SAS or SDS scores were observed among the 4 groups of patients before treatment ($P > .05$). In virtual reality, Cawthorne–Cooksey exercise and Brandt–Daroff exercise groups had lower SAS and SDS scores for psychological emotions than those of the NC group ($P < .05$). However, there were no significant differences in these scores between the VR, Cawthorne–Cooksey exercise, and Brandt–Daroff exercise groups ($P > .05$) (Table 5).

DISCUSSION

Residual symptoms after the canalith repositioning procedure are generally manifested as persistent dizziness and/or instability without positional nystagmus and vertigo. Although the specific mechanism of the residual symptoms remains unknown, it may be related to the following aspects: (1) Functional degradation of macula utriculi

Table 5. Psychological Emotions [(x ± s), Point]

Group	n	SAS Score		SDS Score	
		Before Treatment	After Treatment	Before Treatment	After Treatment
NC	31	55.46 ± 4.35	54.53 ± 3.24	50.34 ± 4.35	49.90 ± 3.42
Cawthorne–Cooksey exercise	31	55.12 ± 3.98	22.42 ± 2.12*	49.89 ± 3.51	24.76 ± 2.34*
Brandt–Daroff exercise	31	55.28 ± 5.34	21.25 ± 1.89*	50.28 ± 2.56	23.41 ± 2.11*
VR	31	55.76 ± 4.36	20.94 ± 1.22*	50.41 ± 4.56	22.31 ± 2.45*

NC, normal control; SAS, Self-rating Anxiety Scale; SDS, Self-rating Depression Scale; VR, virtual reality.
*$P < .05$ vs. NC group.

and otolithic membranes occurs, during which asymmetric function of bilateral macula utriculi due to massive otolith shedding leads to dizziness symptoms.[17] (2) Bilateral vestibular tone is altered after the onset of otolith disease, which induces a new self-adaptive process of the central nervous system, and such a self-adaptive process is stably established along with the prolonged existence of otolith masses in the endolymphatic fluid. However, the previously formed self-adaptive process of the central nervous system starts again in patients following the canalith repositioning procedure, which is extremely prone to trigger residual dizziness symptoms.[18] (3) During repositioning, the remaining tiny otolith fragments in the semicircular canal or ampulla of the semicircular canal cannot be restored, resulting in residual symptoms in the majority of patients after changing their postures.[19] (4) The otoliths falling into the vestibular cistern can alter the utriculus sensitivity or lead to neuronal degeneration, thus easily inducing residual symptoms such as dizziness.[20] (5) Mental factors, including stress and anxiety, also increase the risk of residual symptoms.[21] A previous study indicated that about 30% of patients with otolith disease have residual symptoms after the canalith repositioning procedure,[22] which may persist for a long time and subsequently cause psychological stress, panic, insomnia, *etc.*, and the patients have a poor quality of life under the influence of residual symptoms. In this study, patients with residual symptoms after canalith repositioning procedures were selected as subjects to analyze the effects of different rehabilitation methods on them so as to promote the elimination of residual symptoms.

As a receptor for gravity and accelerated head movement, the vestibule is also a posture-related neurological tool controlling the perception of self-movement state, vertical orientation, stabilization of head position, and control of the center of gravity, which has currently been applied in treatments for ameliorating residual symptoms after the canalith repositioning procedure, including drug therapy, psychological treatment, and vestibular rehabilitation training.[23] Among them, vestibular rehabilitation training covers traditional vestibular rehabilitation exercises such as Cawthorne–Cooksey exercise and the Brandt–Daroff exercise. To be specific, Cawthorne–Cooksey exercise relies on the plasticity and compensation of the vestibular system and central nervous system to train the human visual sense through eye-tracking exercise, vestibular sense via vestibulo-ocular reflex, and proprioceptive sense by head or neck exercise, thereby enhancing the compensation of the central nervous system and relieving or eliminating the residual symptoms.[24-26] In terms of the mechanism of Brandt–Daroff exercise in treating the residual symptoms after the canalith repositioning procedure, the mechanical force generated during postural change facilitates the dissolution of otolith fragments and enhances the compensation of the central vestibular system, thus mitigating the residual symptoms.[27,28] Currently, Cawthorne–Cooksey exercise, Brandt–Daroff exercise, and other vestibular rehabilitation training have been widely utilized in clinical intervention therapies for residual symptoms after canalith repositioning procedure, proven to be effective in improving the residual symptoms. However, it has been found through clinical practice that vestibular rehabilitation training alone tends to be boring, during which the patients often have attenuated compliance, and the residual symptoms can only be thoroughly eliminated through long-term training due to the limitations of accessibility and time investment, which is time-consuming. Recently described as a favorable tool for vestibular rehabilitation, VR technology can avoid the defects of conventional vestibular rehabilitation training.[29] In the process of rehabilitation training based on VR technology, VR technology is integrated with Cawthorne–Cooksey exercise, Brandt–Daroff exercise, and other vestibular rehabilitation training. The patients are exposed to a dynamic VR environment by changing different scenes, as well as the auditory sense and stereoscopic vision formed by sound and light feedback, and more ideal results can be obtained by immersive VR technology.[30] During comprehensive vestibular rehabilitation training based on VR technology, patients are instructed to accomplish coordination exercises of the eyes, head, and waist according to the prompts of the head-mounted display, thereby strengthening the adaptability of the vestibular and balance systems of patients with vestibular dysfunction and improving posture stability. Meanwhile, the training is intensified step by step to increase the efficacy of vestibular rehabilitation training.[31] The results of this study revealed that different vestibular rehabilitation training methods were all able to reduce the severity of vertigo, ameliorate the residual symptoms, and reconstruct the balance ability of patients compared to the NC group. Additionally, comprehensive vestibular rehabilitation based on VR technology presented a more significant improvement effect than conventional Cawthorne–Cooksey exercise and Brandt–Daroff exercise, demonstrating the feasibility of VR technology in vestibular rehabilitation.

The occurrence of residual symptoms after the canalith repositioning procedure is closely associated with vestibular dysfunction. In particular, the functional impairment of otolith-favored macula utriculi is affected by otolith shedding, which triggers such residual symptoms as dizziness.[32,33] VEMPs are crucial means commonly employed to evaluate the function of macula utriculi and sacculi, and oVEMP and cVEMP can reflect the functional status of otolith and vestibular nerves.[34] In the present study, the abnormality rates of oVEMP and cVEMP in patients were compared before and after treatment to analyze the functional status of macula utriculi and sacculi in patients before and after rehabilitation therapy. It was found that the patients had various degrees of abnormal functional status of macula utriculi and sacculi before treatment, while the abnormality rates of oVEMP and cVEMP were remarkably lowered after treatment, and the improvement in patients receiving intervention with comprehensive vestibular rehabilitation based on VR technology was more significant. Therefore, it was speculated that the application of VR technology is more conducive to eliminating the residual symptoms and that its combination with vestibular rehabilitation may perform the function by repairing the functional impairment of the macula utriculi.

Furthermore, the effects of diverse vestibular rehabilitation methods on the psychological emotions of patients were analyzed in this study, and the results showed that the 3 methods all prominently ameliorated the negative psychological emotions compared with those of the NC group. These results imply that comprehensive vestibular rehabilitation based on VR technology can also alleviate the negative psychological emotions of patients. Possibly, a progressive scheme can be formulated according to the disease conditions of patients during rehabilitation without causing psychological frustration to the patients, and such a rehabilitation training system can be operated privately, avoiding the uncomfortable and uneasy emotions due to the influence and the presence of other people.

In conclusion, comprehensive vestibular rehabilitation based on VR technology can cure the residual symptoms after the canalith repositioning procedure, reduce the abnormality rates of oVEMP and cVEMP, and reconstruct the balance ability. Nevertheless, this study is limited; the sample size is small, and the follow-up time is short. Further studies with larger sample sizes and longer follow-up times are needed to verify the findings.

Ethics Committee Approval: This study was approved by the Ethics Committee of Beijing Haidian Hospital (Approval No: BHH202009008, Date: September 4, 2020).

Informed Consent: Informed consent was obtained from the patients who agreed to take part in the study.

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Declaration of Interests: The authors have no conflicts of interest to declare.

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