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Original Article

Effects of a walking program in patients with chronic unilateral vestibular hypofunction

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Abstract. [Purpose] Patients with chronic unilateral vestibular hypofunction show decreased postural stability and low levels of physical activity and also experience much anxiety. Physical activity is known to improve these symptoms; however, no study has reported any positive effects of physical activity, such as symptom reduction or improvement in function in these patients. In this study, we investigated the role of a walking program in improvement of dizziness, anxiety, and postural stability in this patient population. [Participants and Methods] This study included 21 patients with unilateral vestibular hypofunction and chronic dizziness. Patients were instructed to walk 30 min daily for 3 months. Physical activity levels and questionnaires for clinical symptoms, anxiety, and postural stability were evaluated before and after intervention. [Results] We observed significant differences in the amount of moderate-to-vigorous physical activity, clinical symptoms, and self-perceived handicap before and after the intervention. Additionally, anxiety levels were significantly reduced and postural stability was significantly improved in these patients. [Conclusion] A walking program improved physical activity levels, clinical symptoms, and postural stability and reduced self-perceived handicap and anxiety in patients with chronic unilateral vestibular hypofunction. These results highlight the effectiveness of a walking program for these patients and emphasize its role as a complementary vestibular rehabilitation strategy.

Key words: Walking program, Postural stability, Vestibular rehabilitation

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INTRODUCTION

Peripheral vestibular dysfunction refers to the impairment of vestibular function due to peripheral tissue damage. Stimuli from the vestibular system are projected to the oculomotor nerve nuclei, spinal cord, and the thalamus, and the body's equilibrium is maintained by inputting visual, somatosensory, reticular, and cerebellar stimuli to the left and right vestibular nerve nuclei. However, when unilateral vestibular dysfunction occurs for some reason, the neural activity of the vestibular nuclei differs from side to side, resulting in nystagmus, oscillatory vision, and postural instability. In particular, dizziness is one of

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the most common symptoms[1], and it interacts with decreased postural stability[2, 3], anxiety[4, 5], and decreased activity[6–8] to adversely affect recovery from dizziness[9–16].

Vestibular rehabilitation was first reported by Cawthorne and Cooksey in 1940, and there is evidence that it is effective in reducing symptoms and restoring function in patients with unilateral vestibular dysfunction[17, 18]. Vestibular rehabilitation restores vestibular function through vestibular adaptation exercise, habituation exercise, and substitution exercise that alter neural activity in the vestibular nucleus and cerebellum[19]. However, when unilateral vestibular dysfunction occurs for some reason, the neural activity of the vestibular nuclei differs from side to side, resulting in nystagmus, oscillatory vision, and postural instability.

Previous studies have shown that physical activity is necessary for vestibular compensation[20], and it has been reported to be effective in reducing anxiety[21–25] and improving postural stability[26, 27]. Furthermore, moderate physical activity has been reported to be involved in the reduction of anxiety, improvement of postural stability, and improvement of vestibular function in elderly people without vestibular symptoms[28, 29]. However, there are no reports on the effects of moderate physical activity on patients with unilateral vestibular dysfunction. Therefore, the purpose of this study was to determine the effect of physical activity management through a walking program on the improvement of vertigo symptoms and functional recovery in patients with chronic unilateral vestibular dysfunction. Our hypothesis was that a walking program would improve physical activity and postural stability in daily life, as well as reduce anxiety and dizziness in patients suffering from this disorder.

PARTICIPANTS AND METHODS

Twenty-one patients with unilateral vestibular hypofunction participated (mean age: 60.9 ± 13.7 years old, mean weight: 55.4 ± 8.2 kg, mean height: 158.4 ± 7.0 cm) in the study. Patients were recruited from the Department of Otolaryngology at Nagoya City University Hospital. Inclusion criteria were patients with unilateral vestibular hypofunction and chronic dizziness that had persisted for more than three months. Vestibular function was measured by electronystagmography recordings during hot and cold air caloric testing, and unilateral vestibular hypofunction was defined as more than twenty-five percent asymmetry of vestibular function (Canal Paresis; CP)[17, 30]. Exclusion criteria were patients with other causes affecting dizziness, lightheadedness, and balance disorder such as cerebrovascular disease, neuromuscular disease, musculoskeletal disease, and psychiatric disease. Informed consent was obtained from all patients in accordance with the Nihon Fukushi University.

The protocol of the Institutional Review Board (review board registration number 16-08) was reviewed prior to the start of the study. Patients were instructed to walk approximately thirty minutes per day for three months. No clear criteria were set for walking intensity, except for walking for 30 minutes daily. In this experiment, the timing of implementation differed depending on the target patients, but all data were integrated at the time of analysis. The effects of the different timing were ignored in the analysis. Their general condition including questions on physical activity, dizziness, and postural stability were evaluated accordingly, and physical therapists provided feedback about the general condition of these patients once a month. No rehabilitation services were provided at the hospital. Physical activity was measured with the ActiGraph™ ActiSleep BT Monitor (ActiGraph LLC, Pensacola, FL, USA)[31, 32]. The tool contains a tri-axis accelerometer that provides a count of a dimensionless physical activity score summarizing a sixty second period (epoch) at a sampling rate of 30 Hz. All patients were instructed to wear the device on their wrist of the non-dominant side for the first and last seven days of the experimental period[33]. And remove it only during water-based activities (e.g., showering, bathing). Data were analyzed using the ActiLife™ software (version 6.11.8; ActiGraph LLC). Each minute of activity was categorized using intensity threshold values of counts per minute (cpm). The activity counts and the metabolic equivalents (METs) are highly correlated[31]. Data were classified by the following cut points. Sedentary behavior (SB) was defined as an activity below 100 cpm (<1–1.5 METs), that corresponds with activities such as sitting or watching TV. Light physical activity (LPA) was defined as an activity between 100–1,951 cpm (1.5–3 METs), that corresponds with activities such as very slow walking, and driving. Moderate to vigorous physical activity (MVPA) was defined as an activity ≥1,952 cpm (≥3 METs) that corresponds with activities such as walking or house cleaning[2, 10, 30, 34]. Total physical activity (TPA) was defined as LPA plus MVPA. The daily activity time was calculated excluding non-wear and sleep time.

Handicap-related dizziness was assessed using the Japanese version of the Dizziness Handicap Inventory (DHI)[35], the most frequently used questionnaire[36, 37]. It has been demonstrated to be valid and reliable with the English version[35, 38]. The DHI is a twenty-five question and three responses assessment of the impact of dizziness on one's quality of life. The questions are divided into three subscales: physical, emotional, and functional respectively[38]. The frequency of dizziness, lightheadedness, and concurrent autonomic and anxiety symptoms in the past month was assessed using the Japanese version on Vertigo Symptom Scale short form (VSS-sf)[39]. It consists of fifteen questions and four responses and is divided into two subscales: vestibular balance and autonomic anxiety. The validity and reliability of the Japanese version of the VSS-sf have been demonstrated in literature. Anxiety was assessed using the Japanese version on State-Trait Anxiety Inventory (STAI)[40, 41], which is the most commonly used instrument. The state subscale measures anxiety at the present time, while the trait subscale measures the tendency of a relatively stable individual[42]. Postural stability was measured using a Computerized Dynamic Posturography (CDP) system (Balance Master®, NeuroCom, Clackamas, OR, USA). The validity and reliability of the CDP system have been demonstrated previously[43, 44]. Patients stood on the CDP force plate in four different conditions; firm surface with eyes open (Condition 1), firm surface with eyes closed (Condition 2), foam surface with eyes open (Condition 3) and foam surface with eyes closed (Condition 4). Three trials of twenty seconds each were conducted, and the average velocity of body movement per second was calculated. To determine the effect of intervention, physical activity, patient reported outcome of symptoms (DHI, VSS-sf), STAI, and CDP were calculated before and after the walking program. The effect of these variables including physical activity, VSS-sf and STAI was evaluated using a one-way repeated measures analysis of variance (RM-ANOVA). To evaluate the difference of condition, the effect of variables such as DHI and CDP was evaluated using a two-way RM-ANOVA, with condition (physical, emotional, functional, total as DHI and condition 1, 2, 3, and 4 as CDP) as a between-participants factor and time (pre- and post-) as a within-participants factor. The Greenhouse-Geisser method was used to correct for non-sphericity. If the effect was significant, a *post hoc* t-test was performed on the data. The relationships of DHI emotional and STAI was investigated by Spearman's rank correlation coefficient. All analyses were performed using IBM SPSS ver. 17.0 (IBM, Armonk, NY, USA), and statistical significance was defined as $p<0.05$.

RESULTS

Characteristics of patients including gender, age, height, weight, body mass index (BMI), duration of symptom, and CP are shown in Table 1. Regarding physical activity, a one-way RM-ANOVA demonstrated significantly increased time of moderate activity (MVPA) (*$p<0.05$) after the intervention. In contrast, there was no significant change in sedentary behavior (SB) ($p>0.05$), light (LPA) ($p>0.05$) or total physical activities (TPA) ($p>0.05$) (Table 2). In the Questionnaire of Clinical Symptoms, VSS-sf, a one-way RM-ANOVA demonstrated that the total score had significantly decreased after the intervention (*$p<0.05$).

DHI was a significant effect of time (*$p<0.001$) and time × condition interaction (*$p<0.001$). Thus, further analysis was performed on each condition. For emotional, functional, and total score, post hoc analysis demonstrated that post-intervention scores were significantly improved compared to pre-intervention scores (*$p<0.05$ on emotional, *$p<0.001$ on functional and *$p<0.05$ on total). In contrast, there was no significant improvement in the physical scores ($p>0.05$).

Regarding anxiety, a one-way RM-ANOVA demonstrated that the scores of STAI-state and trait scale had significantly increased after the intervention (*$p<0.05$ on state scale and *$p<0.05$ on trait scale), suggesting that anxiety had significantly improved after the intervention.

Regarding the CDP, there was a significant effect of time (*$p<0.05$) and time ×condition interaction (*$p<0.05$). In conditions 3 and 4, emotional, functional, and total score, post hoc analysis demonstrated that post-intervention scores were significantly improved compared to pre-intervention scores (*$p<0.05$ on condition 3 and *$p<0.05$ on condition 4), suggesting that postural stability relating to the peripheral sensory feedback had significantly improved after the intervention. In contrast, there was no significant improvement in the score of condition 1 or 2 ($p>0.05$ on condition 1 and $p>0.05$ on condition 2).

To evaluate the relationship between self-perceived handicap and clinical symptom or anxiety, we examined the correlation between DHI emotional and STAI or VSS-sf by the scores in pre-intervention and in the subtraction of pre- and post- intervention. In all the participants, there were no correlations between DHI emotional and STAI or VSS-sf by the scores in pre-intervention and in the subtraction of pre- and post-intervention. However, when limited to female participants (N=15), the DHI emotional in pre-intervention was positively correlated with the STAI-1 and -2 in pre-intervention (*$p<0.05$ on STAI-1 and *$p<0.05$ on STAI-2). Moreover, the subtracted value of DHI emotional was positively correlated with the subtracted value of VSS-sf by intervention (*$p<0.05$).

Table 1. Characteristics of patients

	Patients (n=21)
Gender (Male:Female)	6:15
Age (years)	60.9 ± 13.7
Height (cm)	158.4 ± 7.0
Weight (kg)	55.4 ± 8.2
BMI (kg/m^2)	22.1 ± 3.7
Duration of symptom (months)	17.9 ± 14.2
CP (%)	52.0 ± 18.9

Values are mean ± SD.
BMI: body mass index; CP: canal paresis; SD: standard deviation.

Table 2. Comparison of physical activity, Dizziness Handicap Inventory (DHI), Vertigo Symptom Scale (VSS), State-Trait Anxiety Inventory (STAI) and Computerized Dynamic Posturography (CDP) before and after three month walking program

	Pre-intervention	Post-intervention
Physical activity (minutes)		
SB	340.8 ± 87.7	330.9 ± 76.2
LPA	251.8 ± 42.9	256.7 ± 39.7
MVPA	124.8 ± 46.5	140.6 ± 49.0*
TPA	376.6 ± 62.5	397.4 ± 59.6
Questionnaire of clinical symptoms (points)		
VSS-sf Total (points)	16.1 ± 9.0	10.8 ± 6.7
Anxiety (points)		
STAI State (points)	45.8 ± 8.6	38.2 ± 10.4***
STAI Trait (points)	48.7 ± 11.2	39.2 ± 10.0***
Self-perceived handicap (points)		
DHI Physical	14.9 ± 6.1	10.4 ± 5.4
DHI Emotional	13.0 ± 7.8	6.2 ± 5.1*
DHI Functional	16.6 ± 7.7	7.0 ± 4.9***
DHI Total	44.4 ± 18.6	23.6 ± 12.4**
Postural stability CDP (degrees/second)		
Condition 1	0.3 ± 0.2	0.3 ± 0.1
Condition 2	0.6 ± 0.4	0.5 ± 0.3
Condition 3	1.0 ± 0.5	0.8 ± 0.3**
Condition 4	3.7 ± 1.7	2.6 ± 1.4**

SB: sedentary behavior; LPA: light physical activity; MVPA: moderate to vigorous physical activity; TPA: total physical activity; DHI: dizziness handicap inventory; VSS: vertigo symptom scale; STAI: state-trait anxiety inventory; CDP: computerized dynamic posturography; SD: standard deviation. *$p<0.05$, **$p<0.01$, ***$p<0.001$.

DISCUSSION

Patients with chronic unilateral vestibular hypofunction present various symptoms such as dizziness, anxiety, and low physical activity. Although it has been reported that light physical activity is useful for the improvement of these symptoms, the effect of walking remains unclear. In this study, we applied thirty minutes walking program for 3 months to patients with chronic unilateral vestibular hypofunction. After the program, the time of moderate to vigorous level of physical activity (≥3 METs) and clinical symptoms including vertigo and self-perceived handicap significantly improved in these patients. In addition, anxiety level and postural stability related to the peripheral sensory feedback were also significantly improved after the program. These findings suggest that a thirty minutes walking program increases the moderate level of physical activity in daily life, which causes a relief of clinical symptoms and improvement in postural stability in patients with chronic vestibular hypofunction.

Recovery of vestibular function from vestibular injury requires vestibular compensation, which is an alteration of neural activity in the vestibular nuclei and cerebellum[19]. In patients with unilateral vestibular dysfunction, abnormal vestibulo-ocular reflexes cause impaired eye movements during head movements. In such vestibular disorders, it has been reported that input of visual information and head movement can lead to recovery[45]. It has been reported that restricting movement in baboons after vestibular neurectomy causes reduced vestibular compensation compared to unrestrained baboons[20]. Among previous reports of studies conducted on humans, several meta-analyses mention that physical activity can positively affect deduction of not only anxiety[21–25], but balance function[26–29] and vestibular function, too[28, 29]. Head movements that elicit dizziness symptoms based on these findings, moderate level of physical activity is required in order for vestibular compensation to occur. In the present study, patients were not given vestibular rehabilitation; rather, they were prescribed a thirty-minute daily walking program for three months to increase their physical activity. As a result, walking for thirty minutes a day increased their chances of going out, which might have increased their input of visual information and neck movements. This may have increased stimulation of the cerebellum and vestibular nuclei, leading to vestibular adaptation, which in turn may have reduced vertigo symptoms. In other words, increase in physical activity level induced by reduction of vertigo symptoms occurred after the three-month walking program and it might have caused the compensation of vestibular function in these patients.

In addition, patients with unilateral vestibular dysfunction tend to be less active due to the fear of falling on account of their postural instability caused by neck movement owing to an impaired vestibulo-ocular reflex. In animal studies, it has been reported that unilateral vestibular dysfunction delays the recovery of postural stability due to darkness[46] and limitation of body movement[20]. In the present study, we hypothesized that the vestibulo-ocular reflex function was improved by controlling the opportunity to go out, and that vestibular adaptation was enhanced by increasing somatosensory input through walking and compensating for vestibular function with visual information.

Compared to vestibular rehabilitation, the advantage of thirty minutes walking program is the good adherence of patients. Yardley and Kirby[47] report that patients with good adherence to vestibular rehabilitation had significantly better outcomes than those with poor adherence[47]. The primary reason for poor adherence was that the rehabilitation aggravated patient symptoms[47]. Vestibular rehabilitation requires regular and consistent repetition for vestibular adaptation to occur; thus, adherence to the home exercise program is a critical factor for improving a patient's dizziness. A systematic review recommends several strategies for improving vestibular rehabilitation home exercise program adherence[48]. As described above, walking is an effective and safe exercise[21–25], and walking is also an acceptable intervention with high levels of adherence[22]. Thus, a walking program could be prescribed as a complimentary or supplemental strategy for patients who are not compliant with vestibular rehabilitation.

There were several limitations in this study. This study was designed as a pilot study, and the significance of walking program for the patients was limited due to the small sample size and the lack of a control group. Further research with a larger sample size and control group is therefore needed to support and expand upon these findings. Moreover, the amount of physical activity in daily living for these patients was objectively measured by the accelerometer placed on their wrists. There are reports that patients with dizziness tend to move slowly[49] and they decrease their head movements while they are in motion[50]. Thus, the patients in the present study may have learned to modify their head movement strategies to reduce symptom provocation, and they may have used their hands without head movements in their daily living. Moreover, the details of physical activity such as daily variation or patterns were not measured in this study. More details of physical activity for these patients in their daily living were also not clear in this study. Therefore, further investigation is needed accordingly in this direction.

The present investigation revealed a novel finding that a three-month walking program for patients with chronic unilateral vestibular hypofunction may be beneficial. Our finding may be important evidence for clinicians who are managing patients with chronic unilateral vestibular hypofunction as an effective and complimentary vestibular rehabilitation strategy.

Conflicts of interest

The authors declare that there are no conflicts of interests in this study.

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