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The effectiveness of wedge shoes in patients with insufficient vestibular compensation

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Abstract

Objectives: Patients who fail to achieve sufficient vestibular compensation after acute vestibular deafferentation show a tendency to deviate toward the affected side. This study evaluated the effectiveness of wedge shoes specially manufactured with a 4 mm inclination on the affected side to patients with chronic vestibular insufficiency.
Methods: Subjects comprised 13 patients with chronic vestibular insufficiency for >6 months after acute unilateral vestibular dysfunction and 9 healthy volunteers. Subjects underwent vestibular tests wearing wedge shoes and regular shoes. Differences in results were compared.
Results: Patients showed significant improvements in the straight gait test ($p < 0.01$), Unterberger–Fukuda stepping test ($p < 0.01$) and posturography test ($p = 0.015$) when wearing wedge shoes compared with wearing regular shoes.
Conclusion: Our results suggested that raising the lateral sole of shoes on the affected side could effectively ameliorate the effects of chronic vestibular insufficiency.

Keywords: Vestibular insufficiency; Disequilibrium; Vestibular compensation; Wedge shoes

1. Introduction

A unique feature of the central nervous system is the capacity for compensation of asymmetries in bilateral peripheral vestibular afferent activity. However, some patients display incomplete compensation. Patients who have previously suffered from an acute peripheral insult such as vestibular neuritis often complain of feeling dizzy or being unable to walk immediately due to "whirling" sensations [1].

For patients with chronic vestibular insufficiency, vestibular rehabilitation therapy (VRT) was developed and introduced in the 1990s based on an original principle [2,3]. VRT is indicated for almost all cases in which compensation is insufficient, even for patients with multifactorial balance disorders such as those seen in the elderly [3]. However, some patients fail to obtain sufficient results from VRT. We therefore attempted to mitigate unsteadiness in patients using wedge shoes.

Wedge shoes are a kind of medical footwear in which the outer side of the sole is raised. The use of wedge shoes has been reported for patients with osteoarthritis of the knee, as shoe correction is considered to improve pain [4–7]. In addition, Surdyk et al. reported that shoes with raised heels enabled patients with Parkinson's disease to walk without falling backward [8]. However, no reports have described the effects of wedge shoes on patients with chronic vestibular insufficiency. The purpose of this study was to evaluate the effectiveness of using wedge shoes for chronic vestibular insufficiency.

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2. Subjects and methods

2.1. Subjects

Subjects comprised 9 healthy volunteers (3 men and 6 women) with a mean age of 51.7 years (range, 37–62 years) and no history of dizziness or vertigo and 13 patients (6 men and 7 women) with a mean age of 73.3 years (range, 32–90 years). Patients were composed of nine individuals with vestibular neuritis and four individuals with nonspecific vestibulopathy. Patients met the following criteria:

(1) History of attacks of vertigo or dizziness more than 6 months before testing and chronic dizziness lasting until the time of testing.
(2) Canal paresis (CP) in caloric tests $\geq$20%.
Caloric stimulus was delivered into external auditory canal using 20 °C cold water and/or 4 °C ice water. Nystagmus induced by caloric irrigation were analyzed by measuring the slow phase eye velocity using electronystagmography.
(3) Constant deviation to the affected side, which was judged using the straight gait test and Unterberger–Fukuda's step test as described in Methods. When a patient had abnormal results on both tests, the patient was regarded as having constant deviation. The criteria of these tests were described in Methods.

Each participant gave informed consents. All experimental procedures were performed in accordance to the principles of the Declaration of Helsinki.

2.2. Methods

Each subject underwent testing using two types of running shoes. One type of shoes was available on the market (regular shoes made in Japan), and the other was created by a specialist in medical clothing (wedge shoes). The outer side of the wedge shoes on the affected side was raised 4 mm (Fig. 1).

Subjects underwent the following tests wearing regular and wedge shoes. The order of wearing regular and wedge shoes was randomized.

(1) Straight gait test (10 m with eyes closed).
(2) Unterberger–Fukuda's step test [9,10] (50 steps with eyes closed).
(3) Posturography test (for 1 min with the eyes closed).
(4) Subjective evaluation of wedge shoes into four grades: excellent, good, average and bad.

(1) In the straight gait test, patients and volunteers were requested to walk with regular and wedge shoes at a comfortable walking speed and style for 10 m with the eyes closed on a straight line three times. Average distance from the straight line (midline) was calculated.

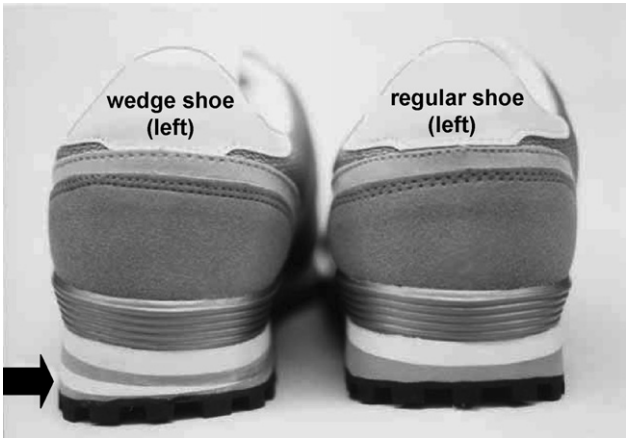

Fig. 1. Shoes used in this study. A wedge shoe for the left foot and a regular shoe for the left foot. A white wedge pointed by black arrow is the part raising 4 mm on the affected side.

(2) In Unterberger–Fukuda's step test [9,10], subjects were requested to march 50 steps with regular and wedge shoes in place with the eyes closed and arms placed straight out in front at shoulder height. Angle of deviation from the midline was measured.
(3) In the posturography test, subjects were requested to stand with regular and wedge shoes for 1 min with the eyes closed, both feet together and arms at the sides. Rectangular area of oscillation was measured.

In each test, the examiner reassured the subject that they would be close by and would not let the patient fall. In the straight gait and Unterberger–Fukuda's step tests, the extents of deviation from the midline were compared between wearing wedge shoes and wearing regular shoes. In the posturography test, rectangular area of oscillation was also compared between wearing wedge shoes and wearing regular shoes. Results of patients and healthy volunteers wearing wedge shoes were compared with those wearing regular shoes using the Wilcoxon signed rank test on Sigma Stat statistical software (Jandel; SPSS, Chicago, IL, USA). Results of patients with wedge shoes and healthy volunteers with regular shoes were compared using the Mann–Whitney rank sum test on Sigma Stat statistical software.
(4) Finally, patients were asked whether wedge shoes improved symptoms or not. Subjective evaluation of wedge shoes was made using four grades: excellent, good, average and bad.

3. Results

In the straight gait test, distances from the midline with wedge shoes were decreased in 10 of the 13 patients (77%) and 4 of the 9 volunteers (44%) in comparison with those with regular shoes. Deviations from the midline were significantly smaller in patients with wedge shoes than with

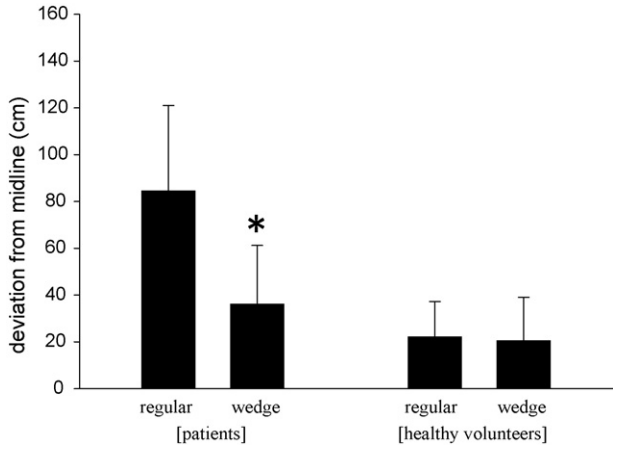

Fig. 2. Mean and standard error of the mean for deviations from midline when wearing regular and wedge shoes in the straight gait test. Differences in patients between regular and wedge shoes during straight gait are significant ($p < 0.05$). No significant differences were noted between patients with wedge shoes and healthy volunteers with regular shoes ($p = 0.152$).

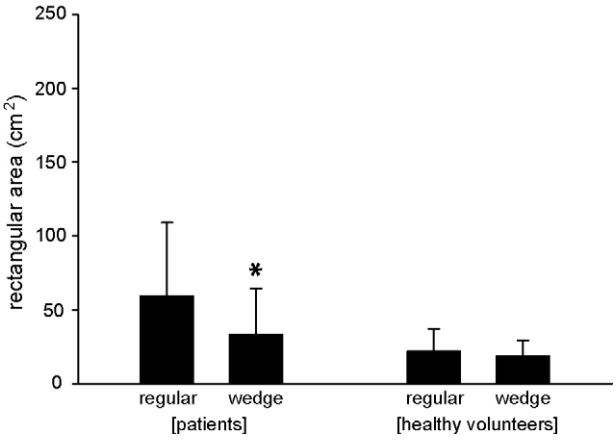

Fig. 4. Mean and standard error of the mean for rectangular area of oscillation when wearing regular and wedge shoes in posturography test. Differences in patients between posturography tests with regular and wedge shoes are significant ($p = 0.015$). No significant difference was seen between patients with wedge shoes and healthy volunteers with regular shoes ($p = 0.595$).

regular shoes ($p < 0.01$), but such significant difference was not seen in healthy volunteers ($p = 0.861$). No significant differences were noted between patients with wedge shoes and healthy volunteers with regular ($p = 0.152$)/wedge ($p = 0.171$) shoes (Fig. 2).

In Unterberger–Fukuda's step test [9,10], decreases in deviations from the midline were found in 12 of the 13 patients (92%) and 6 of the 9 volunteers (67%) wearing wedge shoes in comparison with those with regular shoes. Angles of deviation with wedge shoes were significantly smaller than those with regular shoes in patients ($p < 0.01$), while no such significant differences were noted in healthy volunteers ($p = 0.641$). Deviations from the midline were significantly larger when patients were wearing wedge shoes than when healthy volunteers were wearing regular ($p = 0.009$)/wedge ($p = 0.003$) shoes (Fig. 3).

In the posturography test, decreases in rectangular area with wedge shoes were found in 10 of the 13 patients (77%) and 6 of the 9 volunteers (67%) in comparison with those with regular shoes. Rectangular areas were significantly smaller in patients with wedge shoes than with regular shoes ($p = 0.015$), while no such significant difference was seen in healthy volunteers ($p = 0.167$). In addition, no significant difference was seen between patients with wedge shoes and healthy volunteers with regular ($p = 0.595$)/wedge ($p = 0.593$) shoes (Fig. 4).

Subjective evaluations are shown in Table 1. Patients were divided into two groups according to the results of caloric tests. Patients with CP $>$ 50% tended to give more positive evaluations of wedge shoes than those with CP $\leq$ 50%, but no significant difference was identified.

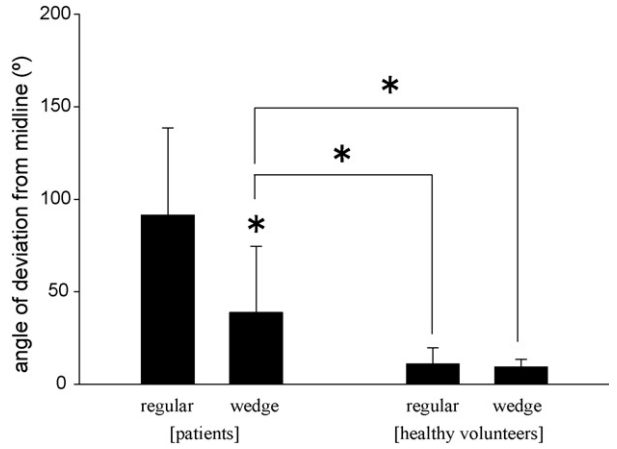

Fig. 3. Mean and standard error of the mean for angle of deviation from the midline when wearing regular and wedge shoes in Unterberger–Fukuda's step test. Differences in patients between straight gait with regular and wedge shoes are significant ($p < 0.05$). Deviations from midline were significantly larger when patients were wearing wedge shoes than when healthy volunteers were wearing regular ($p = 0.009$)/wedge ($p = 0.003$) shoes.

Table 1
Subjective evaluation of wedge shoes in four grades: excellent, good, average and bad

	Patients (CP >50)	Patients (CP ≤50)	Total
Excellent	3	1	4
Good	3	2	5
Average	0	3	3
Bad	0	1	1
Total	6	7	13

Patients were divided into two groups according to the results of caloric tests.

4. Discussion

Results for the straight gait, Unterberger–Fukuda's step [9,10] and posturography tests were improved when patients wore wedge shoes with the outer sole on the affected side raised 4 mm. Results of the straight gait and posturography tests in patients wearing wedge shoes were not significantly different from results in healthy volunteers wearing regular/wedge shoes. These results suggested that wearing wedge shoes could effectively mitigate unsteadiness.

In this study, the outer side of the wedge shoes on the affected side was raised 4 mm. There are varieties concerning the height of wedges among the reports of orthopedics [11–13]. In our preliminary study, wedge shoes with the outer side of the sole on the affected side was raised 2, 4, 7 and 10 mm were tried in several cases. On the basis of the preliminary study, we decided to use shoes in which the outer side of the shoes on the affected side was raised uniformly 4 mm. When the height of wedge was 7 and 10 mm, the patients felt the shoes unnatural and complained of difficulty in walking. When the height of wedge was 2 mm, use of wedge shoes was not effective. When we used the shoes in which the inner side on affected side or the outer side on the unaffected side in several cases, oscillation increased.

Physical training and exercise have been known since the 1940s as effective methods for accelerating recovery from equilibrium disturbances which occurred after acute vestibular deafferentation [14]. This method is based on the principle that correct balance on the earth comprises of three peripheral components: the vestibular system, the visual apparatus and the deep sensory and motor system [15,16]. VRT has been known as an effective method for improving equilibrium since the 1990s [2,3,15,16]. However, VRT may be difficult or ineffective in some patients, particularly among the elderly. These patients experience chronic vestibular insufficiency and often show decreased muscular tonus on the affected side and deviation toward this side [17]. This might imply that the gravitational vector might be deviated toward the affected side in patients with chronic vestibular insufficiency. If the vector is corrected using wedge shoes, reduction in unsteadiness of the head and trunk may be achievable.

Wedge shoes used in this study are promising to correct the deviation of the gravitational vector in patients with chronic vestibular insufficiency, leading to reduce unsteadiness of the head and trunk. Then we should think about the possibility that the use of wedge shoes might retard the development of vestibular compensation might emerge. As this concern is reasonable, the application of wedge shoes should be limited to patients who failed in vestibular compensation with the ordinary VRT.

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