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# Dominant foot could affect the postural control in vestibular neuritis perceived by dynamic body balance

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## ABSTRACT

During attacks of vestibular neuritis (VN), patients typically lose postural balance, with resultant postural inclination, gait deviation toward the lesion side, and tendency to fall. In this study, we examined and analyzed static and dynamic postural control during attacks of VN to characterize differences in postural control between right and left VN. Subjects were patients diagnosed with VN at the Department of Otolaryngology, Toho University Sakura Medical Center, and underwent in-patient treatment. Twenty-five patients who had spontaneous nystagmus were assessed within 3 days after the onset; all were right-foot dominant. Right VN was detected in nine patients (men: 4, women: 5; mean age: 57.6 ± 17.08 years [range: 23–82]) and left VN in 16 patients (men: 10, women: 6; mean age: 58.4 ± 14.08 years [range: 23–85 years]); the percentages of canal paresis of right and left VN were 86.88 ± 18.1% and 86.02 ± 15.0%, respectively. Statistical comparisons were conducted using the independent *t*-test. In stabilometry, with eyes opened, no significant differences were found between patients with right and left VN. However, with eyes closed, the center of horizontal movement significantly shifted ipsilateral ($p < 0.01$). The differences in the lateral and anteroposterior body tracking test (BTT) were statistically significant ($p = 0.0039$ and $p = 0.0376$, respectively), with greater changes in cases with right VN. Thus, the dominant foot might contribute to the postural control mechanism.

## 1. Introduction

Key signs and symptoms of vestibular neuritis include acute onset of rotatory vertigo lasting several days, horizontal spontaneous nystagmus (mostly with a rotatory component) toward the unaffected ear, a deviation of the subjective visual vertical toward the affected ear, postural imbalance with a tendency to fall toward the affected side of the ear, and nausea [1].

A definitive diagnosis of VN should be made by demonstrating canal paresis or paralysis on caloric testing.

During stabilometry, patients with VN show a significantly greater outer circumferential area with eyes open than that in healthy individuals [2]. Values of total length of the movement and outer circumferential area increased in our results of stabilometry, suggesting the importance of visual information to stabilize balance. Gagey analyzed body balance function in patients with VN by measuring the sway of the center of gravity, and demonstrated that the sway distance and area in patients with VN was significantly greater than that of healthy individuals and that the horizontal center of gravity deviated more when compared to healthy individuals [3]. It has been reported that, during attacks, patients with VN showed ipsilateral deviation of their center of gravity with eyes closed [4]. Angunsri et al. conducted gait analysis to assess dynamic body balance function in 92 patients, which included patients with VN [5]. As for integrated plantar pressure, in most cases with VN, it increases in the ipsilateral foot, suggesting that the body's center of gravity could shift ipsilaterally during gait, as well. All of the reports have supported Fukuda's deviation phenomenon.

The righting reflex test is a fundamental test to examine postural control. Both dynamic and static body balance function tests have been introduced for the clinical evaluation of functional body balance. Stabilometry is used to examine and evaluate the static postural reflex. Dynamic body balance tests include Fukuda's stepping test, the vertical writing test with eyes closed, the walking test, the tandem gait test, and others [6], and these are used in the clinical setting to primarily evaluate the deviation phenomenon and changes of plantar pressure and foot kinematics during the stance when walking [5].

During these attacks, patients typically lose postural balance, with resultant postural inclination, ipsilateral gait shift, and tendency to fall. We used equipment that applied both stabilometry and the body tracking test (BTT), a novel examination system, for the assessment of static and dynamic body balance function in patients with VN [7]. This system records and analyzes, in detail, center of pressure (COP)

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movements initiated while the subject tracks the movement of a visual target that moves on a screen at a constant speed in the vertical plane (anteroposterior [AP] BTT) or lateral direction (lateral BTT). BTT has been applied to estimate the overall dynamic postural control function using visual tracking and a spinal postural control system [7]. Few studies have explored procedures for assessing dynamic body balance function using moving visual stimuli and COP assessment. Therefore, in this study, we analyzed static and dynamic postural control during attacks of VN to characterize differences in posture control characteristics between right and left VN and the correlation with the patient's dominant foot.

Therefore, in this study, we examined and analyzed static and dynamic postural control during attacks of VN to compare the differences in posture control characteristics between right and left VN.

## 2. Subjects and methods

### 2.1. Participants

This retrospective study included patients who were diagnosed with VN and underwent inpatient treatment at a university medical center. Of the 102 patients with VN who were examined between May 2011 and September 2016, we investigated 25 patients who had spontaneous nystagmus and were assessed within 3 days of VN onset.

All patients were right-foot dominant; the dominant foot was determined by interviewing subjects to confirm which foot was used to kick a ball [8].

Right VN was observed in nine patients (men: 4, women: 5; mean age: 57.6 ± 17.08 years [range: 23–82 years]) and left VN in 16 patients (men: 10, women: 6; mean age: 58.4 ± 14.08 years [range: 23–85 years]). The percentages of canal paresis (CP%) of right and left VN were 86.88 ± 18.1% and 86.02 ± 15.0%, respectively. The study protocol was approved by the ethics committee of our university (#S16044).

We provided information to the patients on how to opt out of the research through our medical center's website. For this type of study, formal consent was not required.

### 2.2. Evaluation

In patients with VN, stabilometry was conducted with eyes open and closed, and BTT was conducted with eyes open.

The method for BTT has been reported previously [7]. Briefly, the BTT equipment, as shown in Fig. 1, is composed of a stabilometer (ANIMA-G620, ANIMA Co. Tokyo, Japan) and a visual stimulus monitor. Although various recording conditions can be set for conducting a detailed examination, in the present study, we only applied the BTT to evaluate body tracking function in the AP and lateral directions.

On the monitor screen, the moving visual stimulus was shown in green, whereas the position of the subject's COP was shown in red. The moving visual stimulus and the subject's COP appeared side-by-side on the display (Fig. 1, left figure). Each patient was asked to move his/her COP in accordance with the movement of the visually moving target, and the position of each movement was assessed. An upward movement on the AP BTT monitor reflected a forward direction of the COP, whereas a downward movement reflected a posterior direction.

In the lateral BTT, right and left movements on the display reflected the same corresponding movements of the COP. Visual stimulation was administered at a constant frequency of 0.125 Hz, determined from previous experimental reports [9]. The analog/digital (A/D) converter recorded samples every 50 ms (20 Hz), and the AP BTT and lateral BTT were recorded for 60 s each. The distance between the target and the subject was set at 100 cm, and subjects stood with their feet closed parallel, while maintaining an upright posture. These test conditions are recommended by the Japan Society for Equilibrium Research (Kyoto, Japan) [10]. Gain of the COP movement displayed on the screen is two times greater than the actual COP movement value according to past research [11]. Subjects were instructed to set their COP at the center of the coordinate, maintain foot position, and track the target in an upright posture. The actual recording was started 8 s after beginning the exercise.

### 2.3. Analysis

#### 2.3.1. Stabilometry

We checked the total length of the movement (cm), outer circumference area (enveloped area; $cm^2$), locus length per unit area (1/$cm^2$), center of left-to-right movement (cm), and center of anteroposterior movement (cm).

#### 2.3.2. BTT

In the AP BTT and lateral BTT, the tracking of the visual stimulus for movement was displayed on a straight line, and the subjects tried to control their COP so COP movement was tracked in accordance with the movement of the target. Two-dimensional coordinates of the COP ($x$-axis: lateral direction, and $y$-axis: AP direction) sampled in each experimental session were analyzed using principal component analysis. The main axis of the tracking performance was evaluated as an eigenvector corresponding to the first principal component. In the lateral BTT, the subject's tilt during the task was expressed as a displacement angle of the main axis from the $x$-axis, with clockwise tilt considered to be positive and counterclockwise tilt considered to be negative (Fig. 1, right figure). In the AP BTT, the subject's tilt during the task was expressed as a displacement angle of the main axis from the $y$-axis, with clockwise and counterclockwise tilts considered to be positive and negative, respectively (Fig. 2).

### 2.4. Statistical analysis

Statistical comparisons were conducted using the independent $t$-test (Ekuseru–Toukei 2015, Social Survey Research Information Co., Ltd Tokyo, Japan). A $p$-value of $< 0.05$ was considered to be statistically significant.

## 3. Results

### 3.1. Stabilometry

The results are shown in Table 1. With eyes open, no significant differences were detected between right and left VN with respect to the total length of the movement (cm), outer circumference area (enveloped area; $cm^2$), locus length per unit area (l/cm), center of left-to-right movement (cm), and center of anteroposterior movement (cm). With eyes closed, significant differences in inclination were found with respect to the center of left-to-right movement (cm) on the ipsilateral side in patients with right or left VN ($p < 0.01$). Deviation was seen toward the affected side in stabilometry.

### 3.2. BTT

Lateral BTT in the left VN group presented a clockwise tilt with a mean displacement angle of 2.6° ± 8.37°, whereas the group with right VN presented a somewhat counterclockwise tilt, with a mean displacement angle of −12.0° ± 10.2°; Fig. 3. This difference was found statistically significant with the independent $t$-test ($p = 0.0039$). However, the AP BTT in the left VN group presented a clockwise tilt with a mean displacement angle of 7.7° ± 9.6° whereas the group with right VN presented a somewhat counterclockwise tilt, with a mean displacement angle of −2.2° ± 9.5°; Fig. 4. This difference was statistically significant when evaluated with the independent $t$-test ($p = 0.0376$).