Possibility of Using the Wii Balance Board in Stabilometry

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Stabilometry is useful for understanding overall equilibrium function, and is applied as one test of body equilibrium function. It is a simple test in which 60-second recording starts when body sway stabilizes. Objective evaluation is possible by computer analysis of the speed and direction of the sway, enabling diagnosis of a patient's condition. However, conventional stabilometer are very expensive. Attempts have therefore been made to develop a method of stabilometry using a Wii Balance Board. Wii Balance Boards are available at much lower cost than conventional stabilometers. As an application of stabilometry using the Wii Balance Board, we conducted a stabilometry test with subjects viewing 3D images. In this study, we examined the possibility of stabilometry using a Wii Balance Board. We also examined the effect on equilibrium function of stabilometry done with subjects viewing 3D images. We compared conventional stabilometry and the Wii Balance Board. Among the four types of analysis index, a very high correlation was seen in total locus length between the two instruments. Total locus length was the only analysis index for which a strongly correlation was seen with conventional stabilometer. Therefore, it may be possible to use a Wii Balance Board in place of a conventional stabilometer using total locus length. We also performed stabilometry with subjects viewing a 3D image. The results of stabilometry performed with subjects viewing stereoscopic images suggest that the total locus length may be helpful in visually induced motion sickness.

Key words: Stabilometry, Stabilograms, Romberg's Posture, Stereoscopic Image

1. Introduction

Stabilometry as a test of equilibrium is useful in investigating overall equilibrium function. Stabilometry methods are presented in the standards of the Japan Society for Equilibrium Research (Japan Society for Equilibrium Research, 1983) and international standards (Kaptyen *et al.*, 1983). In Japan, devices to measure body sway are defined by Japanese Industrial Standards (JIS). Stabilometry is a simple test in which 60-second recording starts when body sway stabilizes. Objective evaluation is possible by computer analysis of the speed and direction of the sway, enabling diagnosis of a patient's condition (Hase and Ohta, 2006).

However, the stabilometers in general clinical use are expensive. Moreover, stabilometers are mostly found only medical and research institutes, so there are few places where a test can be had simply. Attempts have therefore been made to develop a method of stabilometry using a Wii Balance Board. Wii Balance Boards are available at much lower cost than conventional stabilometers.

Although studies have compared the Wii Balance Board with conventional stabilometers (Kawaida *et al.*, 2009), these comparisons only use weight. Moreover, these studies do not compare analysis indicators that are used as diagnostic standards in the medical field.

In this study, stabilometry was conducted using both the Wii Balance Board and a conventional stabilometer. Conventional analysis indices were computed and the possibility of stabilometry using the Wii Balance Board was examined.

As an application of stabilometry using the Wii Balance Board, we conducted a stabilometry test with subjects viewing 3D images. Viewing stereoscopic images may have adverse effects, such as asthenopia or visually induced motion sickness (VIMS) (International Standard Organization, 2005), on some individuals. While the symptoms of general motion sickness include dizziness and vomiting, the phenomenon of VIMS is not fully understood (Yano and Ide, 2001; Yano *et al.*, 2003). At present, VIMS is explained by the sensory conflict theory (Reason and Brand, 1975). The human equilibrium system receives information input from the visual, vestibular, and somatosensory systems. The sensory conflict theory states that when the combination of information is inconsistent with previously established human experience, spatial localization of self becomes unstable and produces discomfort. Visual input enters the brainstem from the visual and somatosensory systems and the cerebellum (Barmack, 2003), in addition to the vestibular system, suggesting that the nuclei physiologically integrate this sensory information. Researchers generally agree that there is a close relationship between the vestibular and autonomic nervous systems both anatomically and electrophysiologically (Balaban and Porter, 1998), which strongly indicates

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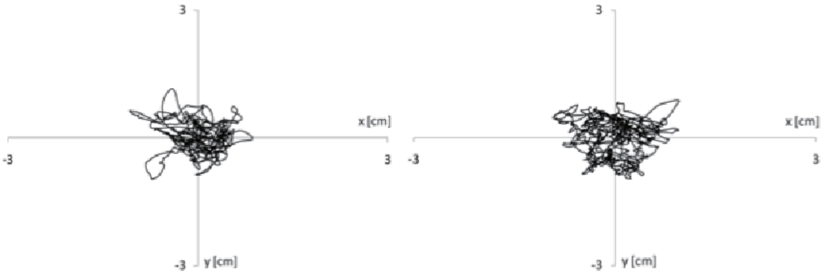


(a) GS3000 (b) Wii Balance Board

Fig. 1. Typical stabilogram.

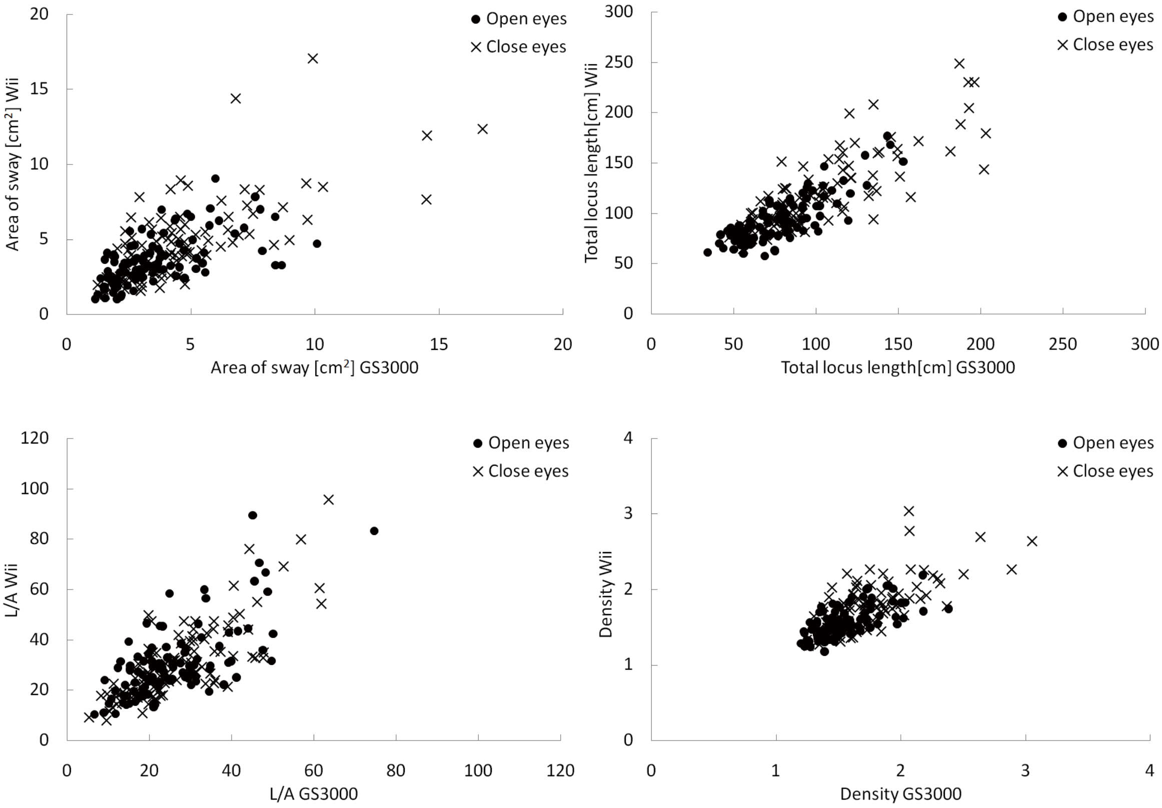


Fig. 2. The scatter diagram of the indices obtained from GS3000 and Wii Balance Board.

that the equilibrium system is associated with the symptoms of motion sickness. This provides a basis to quantitatively evaluate motion sickness based on body sway, an output of the equilibrium system.

In this study, we examined the possibility of stabilometry using the Wii Balance Board. We also examined the effect on equilibrium function of stabilometry done with subjects viewing 3D images.

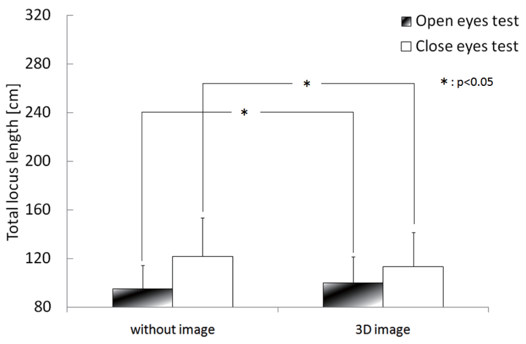
2. Material and Methods

2.1 Experiment 1

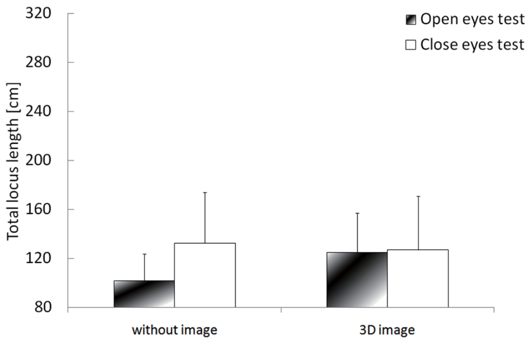
The subjects were 102 persons between the ages of 18 and 85 years with no past medical history of ear or nervous system diseases. The experiment was explained to all subjects and written informed consent was obtained in advance. The study was approved by the Ethical Review Board of the Graduate School of Information Science at Nagoya University.

Two kinds of stabilometer were used in this experiment. The first device was a Gravicorder GS3000 (ANIMA Corp.), generally used as a medical device. The second device was a Wii Balance Board (Nintendo). The subjects stood upright on each of the devices in Romberg's posture. After resting for 30 seconds in a standing posture, the body sway was measured for one minute each with open and closed eyes consecutively. In tests with open eyes, a gazing point was placed 2 meters in front of the subjects at eye level, and the subjects gazed at it. The sampling frequency of Gravicorder is 20 Hz, and the sampling frequency of the Wii Balance board is 100 Hz. Therefore we resampled the Wii Balance Board at 20 Hz.

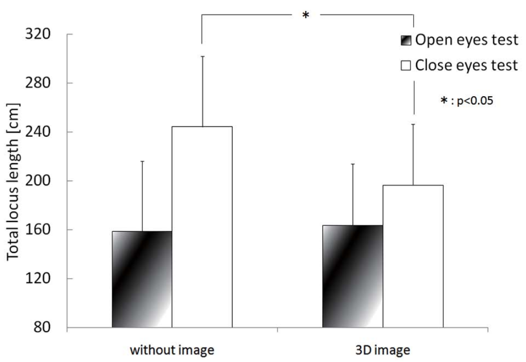
The x-y coordinates were recorded at each sampling



(a) Young subjects



(b) Middle subjects



(c) Eldery subjects

Fig. 3. Result of the total locus length while viewing 3D image.

time-point in tests with open and closed eyes, and the indices were calculated. The data were converted to time series of the position of the center of gravity in the x (right direction is designated as positive) and y (anterior direction is designated as positive) directions in each test with open and closed eyes, and the area of sway, total locus length, locus length per unit area, and density were evaluated. Four indices were calculated from identical data. The definitions are shown below.

- Area of sway: Area of a region surrounded (enveloped) by the circumferential line of sway on the x-y coordinates. An increase in the value represents more unstable sway.
- Total locus length: Total extended distance of movement of the center of gravity within the measurement time. An increase in the value represents more unstable sway.
- Locus length per unit area: Value calculated by dividing the total locus length by the area of sway. A decrease in the value represents more unstable sway.
- Density: Frequency of passage by the center of foot pressure in each fraction established by dividing the stabilogram into squares. The value gets closer to 1 when sway is small, i.e., in a region with a high local density. Inversely, the value increases when sway is scattered.

We calculated the correlation coefficients between the four analysis indices with the two devices.

2.2 Experiment 2

The subjects included 64 young people, 45 middle-aged people and 23 elderly people with no past medical history of ear or nervous diseases. We obtained informed consent from all subjects and approval from the Ethical Review of the Graduate School of Information Science at the Nagoya University.

In this study, stabilometry was performed as subjects viewed 3D images. A Wii Balance Board was used for the stabilometer. After resting for 30 seconds, the body sway of each subject was measured for one minute with opened and closed eyes consecutively. The measurements were performed in Romberg's posture. The image was shown on a display 2 meters from the subject. The 3D display method used was a naked eye system. A TOSHIBA 55-inch display (Model 55X3) was used as the playback device with a Panasonic Blu-ray player. In the image used in the experiment, spheres were fixed to the four corners while another sphere moved around the screen. That sphere moved reciprocally back and forth at different depths, going up and down and left and right. Measurements were made for one minute while the subject viewed the image (open eye test). Then the subject closed his or her eyes and measurements were made again for one minute (closed eye test). The closed eye test was performed to observe the effect from interruption of visual information. A comparison was then made with subjects asked to simply to gaze at a point 2 meters in front of them at eye level with no image.

The experiments were carried out in random order and subjects were allowed sufficient rest during the experiment.

We compared the total locus length with and without the subjects viewing 3D images to see whether there was a difference. Statistical tests were done using the t test.

3. Result

Typical stabilograms with the Gravicorder GS3000 and Wii Balance Board are shown in Fig. 1. This is the open eye test in the same subject. A scatter diagram with the analysis indices obtained from the Gravicorder GS3000 on the horizontal axis and the analysis indices obtained from the Wii Balance Board on the vertical axis is shown in Fig. 2. The graph shows the results of the open eye test with solid black circles and the results of the closed eyes test with × symbols. Figure 2(a) shows the results for the area of sway. The correlation coefficient of the open eye test is 0.61 and that of the closed eye test is 0.71. Figure 2(b) shows the total locus length. The correlation coefficient of the open eye test is 0.82 and that of the closed eyes test is 0.85. Figure 2(c) shows the locus length per unit area. The correlation coefficient of the open eye test is 0.69 and that of the closed eye test is 0.78. Figure 2(d) shows the density. The correlation coefficient of the open eye test is 0.65 and that of the closed eye test is 0.71. Each of the above correlation coefficients was statistically significant ($p < 0.05$).

Figure 3 shows the results for total locus length (mean ± standard deviation) without subjects viewing an image and while they were viewing a 3D image. In the open eye test, the total locus length was significantly greater for young people when they viewed 3D images than when there was no image ($p < 0.05$). In the closed eye test, the total locus length was significantly greater for young and elderly people after they had not viewed an image than after they had viewed 3D images ($p < 0.05$).

4. Discussion

In this study, we compared conventional stabilometry and the Wii Balance Board. We also performed stabilometry with subjects viewing a 3D image.

4.1 Experiment 1

First, we discuss Experiment 1. In the results of the analyses of the four indices with the two devices, the correlation coefficients for total locus length were very high at about 0.8. High tendencies of 0.6 or more were also shown with other indices. Guilford shows that there is very high correlation with a correlation coefficient 0.8 (Guilford, 1956). Therefore, the Wii Balance Board may be suitable as a replacement for conventional stabilometers. However, the strong correlation was limited to the total locus length.

Previous comparisons of the Wii Balance Board and conventional stabilometers were performed using weight. Moreover, only the stabilograms were compared; there were no comparisons of practical analysis indices. Furthermore, none of the previous studies had a large number of subjects like this study. Thus, the present findings are novel. In order to determine whether a Wii Balance Board can be used as a substitute for a stabilometer, it is important to conduct experiments not only with weights but with humans. It is also important to compare the results including the actual analysis indices. Measures so that stabilometry can be performed with analysis indices other than the total locus length need to be considered.

4.2 Experiment 2

Next, we discuss Experiment 2. In the open eye test, the total locus length was significantly greater for young people when they viewed the 3D image than when there was no image. This means that sway increased with viewing of an image. The total locus length is a value that represents the sway of small vibrations. The image that was used in this experiment moved in a complex, spherical pattern. When the sphere moved around, the body moved in connection with it. The motion may have appeared in the form of the total locus length.

Several previous studies on motion sickness using stabilometry have been conducted, and there are some reports that sway increases. However, analysis indices related to VIMS are not yet resolved. In this study it was found that the total locus length increased. The relevance of the increase in total locus length and VIMS needs to be considered in the future.

5. Conclusion

In this study, we compared conventional stabilometry and the Wii Balance Board. Among the four types of analysis index, a very high correlation was seen in total locus length between the two instruments. Total locus length was the only analysis index for which there was a strong correlation with conventional stabilometer. Therefore, it may be possible to use a Wii Balance Board in place of a conventional stabilometer using total locus length.

We also performed stabilometry with subjects viewing a 3D image. In the open eye test, the total locus length was significantly greater for young people when they viewed the 3D image than when there was no image. The results of stabilometry performed with subjects viewing stereoscopic images suggest that the total locus length may be helpful in preventing VIMS.

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