

Analysis on the Effect of a Training System for Improving Equilibrium Sense Using an Unstable Platform

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Abstract: In this paper, we analyzed the effect of a training system for improving equilibrium sense. This training system consists of an unstable platform, a force plate, a computer, and training programs. Using the system with training programs, we performed various experiments to train the equilibrium sense of fifteen subjects. To evaluate the effect of the training system, we measured the time a subject maintains a focus, the moving time to the target, and the absolute deviation of the trace. We analyzed these parameters obtained before and after the training using paired-samples T-test. The results showed that the subjects experienced a distinctive enhancement of their equilibrium senses through the training using our system.

Keywords: Equilibrium sense, Training, Unstable platform

1. INTRODUCTION

The capability of controlling his or her posture and keeping the bodily balance is very important for a person in daily activities. Adequate postural control depends on the spatial and temporal integration of vestibular, visual, and somatosensory information about the motion of the head and the body. The increased incidences of falls in the older generation suggest that one or more of these components degenerate with age. Diminished visual, vestibular, and somatosensory function and slowed down sensorimotor processing would all occur with normal aging process [1, 2]. To prevent falls and reduce the likelihood of them, balance training is very important to the elderly. In the other hand, as the volume of traffic increases, the occurrence of injuries related to traffic accident increases. These injuries can also affect or impair balance ability and the rehabilitation of balance ability is also very important to those patients.

Past studies have reported that posture control is affected by visual stimulation. It is well known that the position of the center-of-gravity (COG) as well as the geometrical configuration of body segments is accurately controlled relative to the feet and to the direction of gravity [3-5]. In recent studies, postural sway has been measured using an unstable platform and an index of stability. The measure of postural sway has been used as an index of sensory motor impediments, rather than as a measurement of functional performance ability. The conventional rehabilitation systems for improving postural control and balance ability is monotonous to patients and don't provide information for multiple stimuli [6-8]. Therefore, it is essential to develop a training system and methods for effective balance training to improve the ability of postural control.

In this paper, we present the analysis on the effects of a training system for improving equilibrium sense using an unstable platform. Using this system and the training programs which we had also developed, we performed a variety of experiments on improving the ability of equilibrium sense of subjects. Through the comparison of the posture control capabilities of the subjects before the training with that after the training, the effects of the training were evaluated and

verified. The positive outcomes indicated that this system can readily be applied to clinical rehabilitation training for improving equilibrium sense as a new balance training system.

2. SYSTEM CONFIGURATION

We developed a new training system for improving the equilibrium senses of the trainees. The training system consists of an unstable platform, a computer interface, a safety belt, a monitoring device, and a computer. Figure 1 shows the training system.

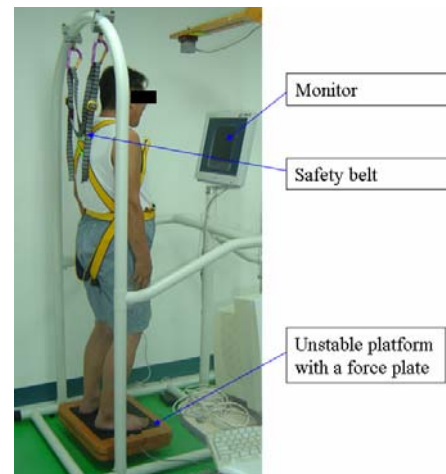


Fig.1 A training system for improving the equilibrium sense using an unstable platform.

2.1 Hardware

We designed a new training device for improving the equilibrium sense using an unstable platform with a force plate. The device is shown in Fig. 2. The dimensions of the unstable platform are 550mm long, 390mm wide and 130mm high. The curvature radius of the unstable platform is 200mm. The maximum tilt angle in left-right direction is 18°; the maximum tilt angle in anterior-posterior direction is 28°. A force plate is attached on the top of the unstable platform. There are four

load cells and an A/D converter in the force plate. Using the force plate, we can compute the center of pressure (COP) of the subject on the force plate. There are two tilt sensors installed inside of the unstable platform. Using the tilt sensors, we can measure the tilt angle of the unstable platform. The signals of the force plate and the tilt sensors were input to a computer using a PCI-6024E card of the National Instruments.

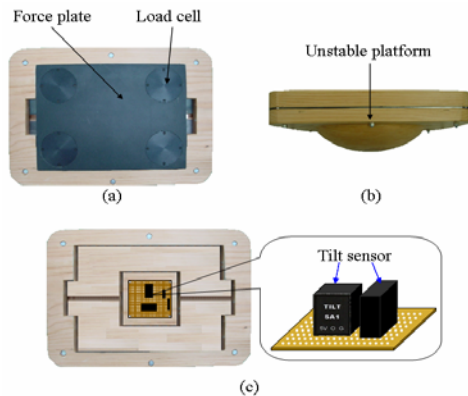


Fig. 2 An unstable platform with a force plate. (a) Top view (b) side view (c) Tilt sensor

2.2 Software

The methods for the training for improving the equilibrium sense are very important and essential to the subjects. Therefore, we developed software for the training and the evaluation of the equilibrium sense. The software consists of a training program, an evaluation program, a subject managing program, and an analysis program.

The training program is designed to improve the ability of postural control of the subjects by repeated training of moving COP. The training program consists of the COP movement training in horizontal direction, the COP movement training in vertical direction, the COP movement training in 45° direction, the COP movement training in -45° direction, the circle trace, the quadrangle trace, and the triangle trace. Using these training programs, we can train the trainee’s movement of the COP in different directions, angles, and speeds.

To evaluate the effects of the training, we also developed the evaluation program. The evaluation program consists of the dynamic circle evaluation module and the modules for the changeable triangle trace, the changeable quadrangle trace, the spiral trace, the sine curve trace in horizontal direction, and the sine curve trace in vertical direction. Using the evaluation program, the parameters such as the time a subject maintains a focus, the moving time to the target, and the mean absolute deviation of the different trace before the training and after the training were measured. Through the comparison of the parameters before the training with those after the training, we evaluated the effects of the training.

The analysis program was also developed to analyze the acquired data. The analysis program make up of the COP moving time analysis modules, the COP maintaining time analysis module, and the mean absolute deviation analysis module. Using the analysis program, we can process the measurement data at an instance.

3. METHOD

3.1 Subject

Fifteen normal subjects who volunteered for the experiment

were examined. The age of the subjects ranged from 23 to 33. Before the start of the examination, the subjects were all informed of the details of experiment and all signed consent forms.

3.2 Experimental method

We trained and evaluated equilibrium sense of the subjects using the training program and the evaluation program with the unstable platform. Initial evaluations of equilibrium sense were done before the beginning of the training. In the following two weeks, the subjects trained their equilibrium sense using the training programs with the unstable platform. After two weeks of training, the second evaluation was done. To evaluate the effects of the training, we investigated the parameters such as the time a subject maintains a focus, the moving time to the target, and the mean absolute deviation of the different trace before and after the training. Through the comparison of the parameters before the training with those after the training, we were able to evaluate the effects of the training of equilibrium sense.

4. RESULTS AND DISCUSSIONS

We performed variety of experimental trainings on improving the equilibrium senses of the subjects using this system. Through the comparison of the parameters obtained before the training with those obtained after the training, the effects of the training were assessed. The followings are the findings from our experimental results.

4.1 The COP moving time

Here, the COP moving time indicates the time it takes for a subject to move his or her COP to reach a desired target location away from the central location. The COP moving time is an important parameter in evaluating the ability in controlling the movement of the COP. In the experiment, we measured the COP moving time in eight directions. The eight directions are anterior, posterior, left, right, anterior-left, anterior-right, posterior-left, and posterior-right directions. We analyzed the time parameters obtained before the training with those obtained after the training using a paired-sample T-test in SPSS 10.0. Fig. 3 shows the COP moving time before and after the training. As shown in the figure, the COP moving times measured after the training is shorter than those before the training. The results of the paired-sample T-test analysis on the COP moving time parameters before and after the training showed that p is lower than 0.05. The comparison of the COP moving times before the training with those after training shows distinctive improvement and proves that the training system has positive effect in improving the equilibrium sense.

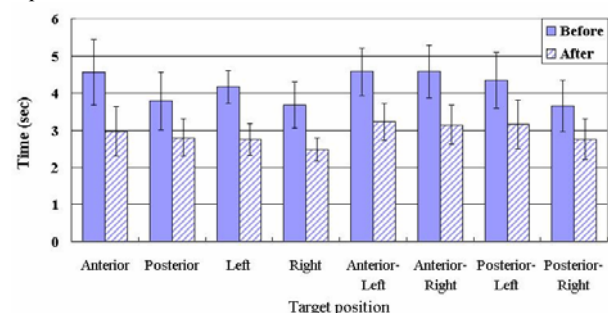


Fig. 3 The COP moving time of before and after the training.

4.2 The COP maintaining time

The COP maintaining time indicates the time a subject maintains his or her COP on a desired target. The parameter of the COP maintaining time is an important parameter in evaluating the balance maintaining ability. In our experiment, we measured the COP maintaining time in eight directions. They are anterior, posterior, left, right, anterior-left, anterior-right, posterior-left, and posterior-right direction. We analyzed the COP maintaining time obtained before and after the training using a paired-sample T-test in SPSS 10.0. Figure 4 shows the COP maintaining time before and after the training. As shown in the results, the COP maintaining time after the balance training is longer than that before the training. The result of the paired-sample T-test of the COP maintaining time before and after the training showed that p is lower than 0.05. The comparison of COP maintaining time before and after training also shows distinctive differences. These results also confirm the effectiveness of the training system in improving the ability of postural control of the trainee.

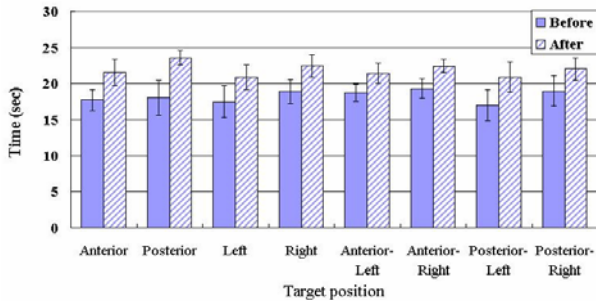


Fig. 4 The COP maintaining time of before and after the training.

4.3 The mean absolute deviation of the trace

The mean absolute deviation of the trace represents the mean absolute deviation of the tracking trace of COP when a subject moves his or her COP following a desired trace. In the experiment, we measured the mean absolute deviation for three different traces. The three traces are spiral trace, triangle trace, and quadrangle trace. Eq. (1) shows the calculation of the mean absolute deviation of the trace.

$$Mean\ absolute\ deviation = \frac{\sum(X - \bar{X})}{n} \quad (1)$$

Where X represents the location of COP in the monitoring device, \bar{X} represents the location of target in the monitoring device, and n is the number of times being measured.

In the experiment, the traces of COP movements when a subject tries to move his or her COP tracking different shapes of trace were measured before and after the training. Figure 5, 6, and 7 shows the actual traces of COP movements before and after the training. The figures show that the capability of controlling the COP movement has distinctly improved after the training. Consequently, the methods for effective balance training that utilize the spiral trace, triangle trace, and quadrangle trace seems to achieve good effect for improving the equilibrium sense.

We investigated the relation between the mean absolute deviation and the training time. Figure 8, 9, 10, and 11 shows the relation between the mean absolute deviation and the training time for different shapes of trace. The results indicated that the mean absolute deviation have decreased as the training time increased. Therefore, the training brings about an outstanding effect on improving the capability of postural control.

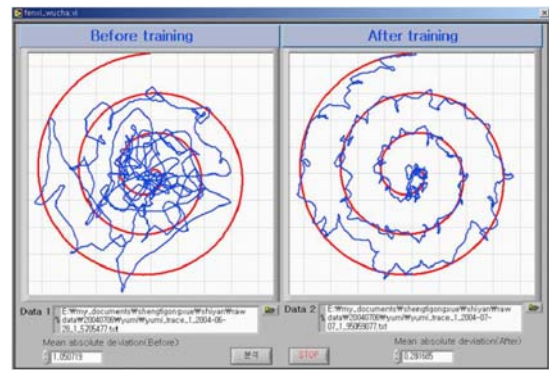


Fig. 5 Evaluation of the spiral trace before and after the training.

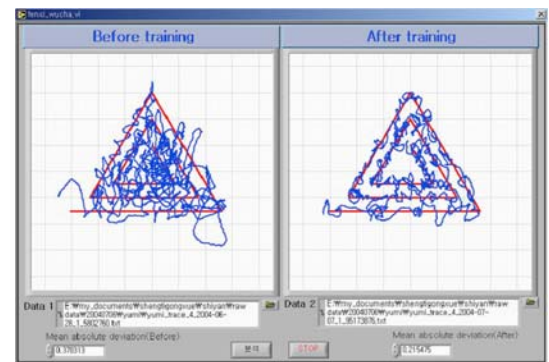


Fig. 6 Evaluation of the triangle trace before and after the training.

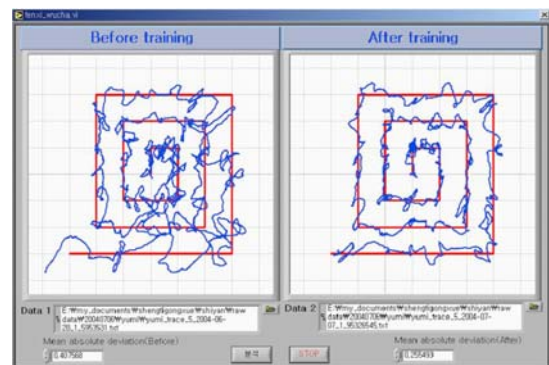


Fig. 7 Evaluation of the quadrangle trace before and after the training.

We analyzed the mean absolute deviation of the trace before and after the training using paired-sample T-test in SPSS 10.0. The results of Paired-sample T-test of the mean absolute deviation for different traces before and after the training showed that p is lower than 0.05. The mean absolute deviation of the trace before and after the training has distinctive difference. Figure 12 shows the mean absolute deviation before the training and after the training. As shown in the result, the mean absolute deviation after the training is lower than that before the training. By using different trace models, the subjects were able to train their COP moving capability at different speeds, angles, and directions. The decrease in the mean absolute deviation is another proof that the training of equilibrium sense using this training system and improving the equilibrium sense is feasible.

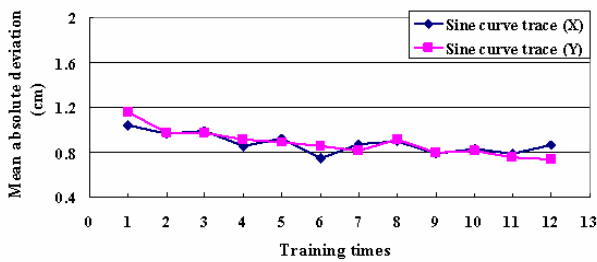


Fig. 8 Relation between the mean absolute deviation and the training time of the sine curve trace.

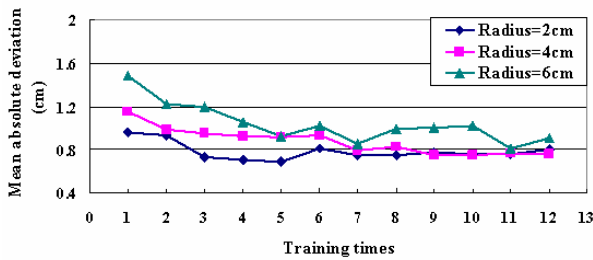


Fig. 9 Relation between the mean absolute deviation and the training time of the circle trace.

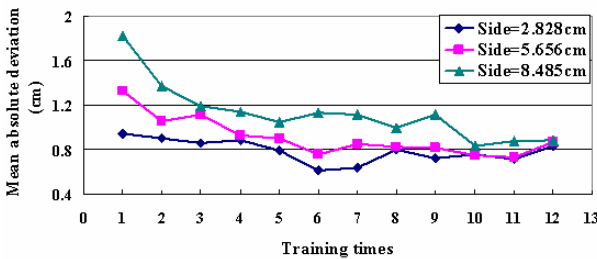


Fig. 10 Relation between the mean absolute deviation and the training time of the triangle trace.

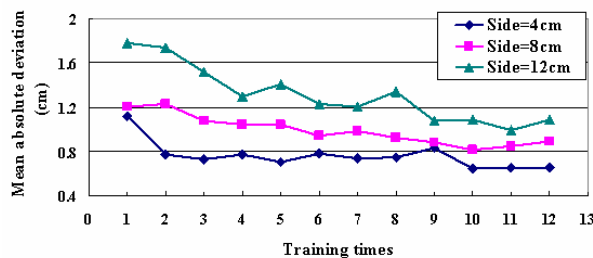


Fig. 11 Relation between the mean absolute deviation and the training time of the quadrangle trace.

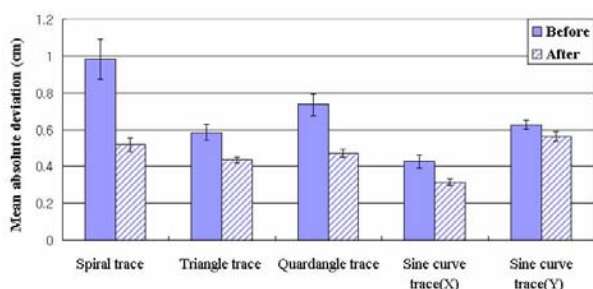


Fig. 12 The mean absolute deviation of the different trace.

5. CONCLUSIONS

In this paper, we have presented the analysis on the effects of a training system for improving equilibrium sense using an unstable platform and training programs. Using this system, the subjects trained their equilibrium senses and tested the capabilities of their equilibrium senses. The results confirm that the improvement of equilibrium sense using this system is feasible. The study also shows that this system can be applied to clinical rehabilitation training for improving equilibrium sense as a new balance training system overcoming the drawbacks of conventional training systems.

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REFERENCES

- [1] F.B. Horak, C.L. Shupert, and A. Mirka, "Components of postural dyscontrol in the elderly: a review," *Neurobiology of Aging*, Vol. 10, No. 10, pp. 727-738, 1989.
- [2] R.A. Speers, A.D. Kuo, and F.B Horak, "Contributions of altered sensation and feedback responses to changes in coordination of postural control due to aging," *Gait and Posture*, Vol. 16, pp. 20-30, 2002
- [3] V.S. Gurfinke, and I.A. Babakova, "Precision of stabilization of the projection of human center of gravity during standing," *Fiziologia Cheloveka*, Vol. 21, No. 3, pp. 65-74, 1995.
- [4] J. Massion, "Movement, posture and equilibrium: interaction and coordination," *Prog. Neurobiol.*, Vol. 38, pp. 35-56, 1992.
- [5] L.M. Nashner, and G. McCollum, "The organization of human postural movements: a formal basis and experimental synthesis," *Behav. Brain Sci.*, Vol. 8, pp. 135-172, 1985.
- [6] C.A. Lughton, M. Slavin, K. Katdare, L. Nolan, J.F. Bean, D.C. Kerrigan, E. Philips, L.A. Lipsite, and J.J. Collins, "Aging, muscle activity and balance control: physiologic changes associated with balance impairment," *Gait and Posture*, Vol. 18, pp. 101-108, 2003.
- [7] R.G. Hamman, I. Mekjavic, A.I. Mallinson, and N.S. Longride, "Training effects during repeated therapy sessions of blance training using visual feedback," *Arch. Phys. Med. Rehabil.* Vol. 73, pp. 738-744, 1992.
- [8] J.O. Lee, Y.G. Park, P.H. No, C.U. Hong, and N.G. Kim, "Development of a new training system for the improvement of equilibrium sense," *J. Biomed. Eng. Res.*, Vol. 25, No. 6, pp. 465-469, 2004.