Development of a New Training System for the Improvement of Equilibrium Sense

Tae Kyu Kwon*, Yong Gun Park**, Mi Yu**, Seong Hyun Kim**, Chul Un Hong* and Nam Gyun Kim*

*Dept. of Biomedical Engineering, Division of Bionics and Bioinformatics, Chonbuk National University, Jeonju, Korea (Tel : +82-63-270-4066; E-mail: kwon10, cuhong, ngkim@chonbuk.ac.kr)
**Department of Biomedical Engineering, Chonbuk National University, Jeonju, Korea (Tel : +82-63-270-2246, E-mail: yjpiao, yum391, winsomesh@hotmail.com)

Abstract: This paper proposes a new training system for equilibrium sense using unstable platform. This training system for equilibrium sense consists of an unstable platform, a computer interface circuit and software program. Postural instability changes the weighting of different types of sensory information and the state of the equilibrium maintenance system. In order to improve the equilibrium sense, we developed software program such as a block game, sine curve training (SCT) and pingpong game using Visual C++. Using this system and training programs, we performed an experiment to train the equilibrium sense of a subject. To evaluate the effects of balance training, the time maintained on the target and the moving time to the target are measured. As a result, the moving time to the target and time to maintain cursor on the target improved through repeating equilibrium sense training. It was concluded that this system was reliable in the evaluation of equilibrium sense. We expect that this system might be applied to clinical use as an effective balance training system.

Keywords: equilibrium sense, unstable platform, biofeedback, center of pressure, vestibular

1. INTRODUCTION

One of the most significant issues associated with aging is falling, which leads to a lot of problems such as fractures, decreased mobility, debilitating fears of future falls and even death. Although the human body seems to be in a static condition when it is standing up (or not moving), human posture is a continuous process and is constantly controlled or adjusted so that the center of gravity of the body can be maintained on a stable base. The sense of equilibrium in humans is formed by the sensory integration of the visual, the vestibular, and the somatosensory systems [1].

Past studies have reported that the sense of equilibrium is apparently affected by visual stimulation [2]. It is well known that the position of the center-of-gravity (CG) as well as the geometrical configuration of body segments is accurately controlled relative to the feet and to the direction of gravity [3,4,5]. In recent reports, 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 a measurement of functional performance abilities. Equilibrium sense provides orientation with respect to gravity and as humans we integrate vision, somatic sensation and equilibrium sense to maintain balance of the human body. Studies by Kim, et. al. [6,7,8]  have also focused on performance evaluation and development using a virtual reality bike simulator.

The conventional rehabilitation systems for improvement of the equilibrium sense for fall prevention bored the subjects and could not provide information for multiple stimuli [9-16]. Therefore, the development of an effective training device for improving equilibrium sense is required.

In this paper, we propose a new training system for the improvement of equilibrium sense using an unstable platform. This system is to evaluate and compare the balance ability at different conditions on an unstable platform. This is a biofeedback system using a movable multidirectional platform which the subject stands on and controls balance while watching the screen of a training program.

2. SYSTEM CONFIGURATION

2.1 Hardware design

Quantitative evaluation of equilibrium sense in equilibrium sense disabled patients is necessary. Therefore, we developed a new training system in order to conduct an assessment and analysis of static and dynamic conditions for both normal and affected patients. Figure 1 shows the training system for the improvement of equilibrium sense.

Fig. 1 Training system for improvement of equilibrium sense
This training system of equilibrium sense consists of an unstable platform, a computer interface circuits and software program.

Figure 2 shows the training system using unstable platform for the improvement of equilibrium sense. This is an elliptical-type platform which includes a tilt sensor, wireless RF module and a power supply. The horizontal length of the unstable platform is 520mm, vertical length is 390.25mm, the height is 108mm, and the radius of curvature is 20cm. Fig. 3 shows the block diagram interface between the PC and the unstable platform.

2.2 Software design

In order to improve the equilibrium sense, we developed software programs such as a block game, pingpong game and SCT (sine curve training) using the Visual C++ and LabVIEW (National Instrument Co.) commercial program. Figure 4 shows the software configurations of the training system for equilibrium sense. This software consists of an evaluation menu, training menu, patient management and analysis menu. This system performs the evaluation of the static equilibrium of the static COP, weight distribution and dynamic equilibrium of the sine curve trace, and dynamic circle in the evaluation menu. Table 1 represents the evaluation items on the postural equilibrium.

Table 1 Evaluation item on the postural equilibrium

<table>
<thead>
<tr>
<th>Evaluation mode</th>
<th>Evaluation</th>
<th>Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static equilibrium evaluation</td>
<td>Static COP</td>
<td>Free standing</td>
</tr>
<tr>
<td>Weight distribution</td>
<td>Initial evaluation</td>
<td>Adaptation</td>
</tr>
<tr>
<td>Dynamic equilibrium evaluation</td>
<td>Sine curve trace</td>
<td>Sine curve COP</td>
</tr>
<tr>
<td>Dynamic evaluation</td>
<td>Anterior</td>
<td>Posterior left</td>
</tr>
<tr>
<td></td>
<td>Posterior</td>
<td>Left</td>
</tr>
<tr>
<td></td>
<td>Left</td>
<td>Right</td>
</tr>
<tr>
<td></td>
<td>Anterior-left</td>
<td>Posterior-left</td>
</tr>
<tr>
<td></td>
<td>Posterior-right</td>
<td>Posterior-right</td>
</tr>
</tbody>
</table>

3. EXPERIMENTAL METHOD

3.1 Subjects

To evaluate the effect of balance training, we measured the parameters such as the moving time to the target, and time to maintain the cursor in the target of screen. Twenty healthy subjects participated to test the training effect for the improvement of equilibrium sense.

Balance training was carried out for two weeks and we classified the subjects into three groups according to the training program. The first group was trained through repeating SCT and the block game, the second one used only the pingpong game and the third one used only the block game.

Table 2 Subject group

<table>
<thead>
<tr>
<th>Group 1</th>
<th>Left-Right</th>
<th>SCT, Block game</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 2</td>
<td>Anterior-Posterior</td>
<td>Pingpong game</td>
</tr>
<tr>
<td>Group 3</td>
<td>Left-Right</td>
<td>Block game</td>
</tr>
</tbody>
</table>
3.2 Measurement of the EMG and FASTRAK signal

Figure 5 shows the measurement position of the EMG and 3SPACE FASTRAK position signal. The FASTRAK tracking system uses electro-magnetic fields to measure the position and orientation of a remote object. The signal of EMG and from 3SPACE FASTRAK were measured to confirm the action of the muscles and joints that were used mainly for postural balance on an unstable platform. The FASTRAK system (Polhemus Co.) was used for the measurement of the subject’s head position and the center of gravity position.

The accuracy of the position measurement of the 3SPACE FASTRAK system was 0.8mm. A remote receiver detects a display of up to 350 cm with resolution of a 0.0005 cm/cm when the distance from the transmitter to the receiver was within 78 cm, the sampling frequency was set a 35Hz.

Data was transmitted through a standard RS232 serial port to the computer and the data from the EMG signal through the A/D board was stored in the host computer. In the coordination of the system, the right of the X-axis and the back of the Y-axis of the subjects show the positive axes.

Figure 6 shows the experimental procedure of a training system for the improvement of equilibrium sense. Before the experiments, the subject knew well an outline of the experiment and all of the systems, and trained for 5 minutes on the unstable platform for the correct training of postural balance. The entirely experimental procedure of training system for the improvement of equilibrium sense is represented in Fig. 6. The evaluation was divided into 3 phases and the subjects exercised 3 times every week. Postural balance training was performed more than 20 minutes per day, 5 times a week for 2 weeks. The rest time for each evaluation was 3 minutes and we stopped the evaluation when the subject fatigued. The DC evaluation training effect was used DC evaluation because it was difficult to apply appropriate evaluation for the learning effect using the SCT evaluation program. DC evaluation was measured repetitively for 30 seconds in each direction.

4. RESULTS AND DISCUSSION

4.1 Results of the EMG and FASTRAK

The EMG and FASTRAK signal recorded the motion of the muscle and joint of the subject on an unstable platform. The EMG electrode was attached to the left leg. FASTRAK recorded the motion of the right leg. Figure 7 recorded the muscle’s activity when the unstable platform tilted on the left-right side. It was found that tibialis anterior and rectus femoris were activated at the same time when tilting on the left side; the gastrocnemius was activated when tilting on the right side. Figure 8 represents the muscle’s activity when the unstable platform tilted to the anterior-posterior side. On the posterior side, the tibialis anterior was activated. The gastrocnemius and the rectus femoris were activated on the anterior side.

Fig. 5 Measurement position of EMG and FASTRAK

Initial Evaluation

Training (20 min)

Middle Evaluation

Training (20 min)

Final Evaluation

Free Training ➔ Evaluation

Free Training ➔ Evaluation

Free Training ➔ Evaluation

Fig. 6 Experimental procedure of a training system for the improvement of equilibrium sense

Fig. 7 EMG signal when tilting to the left-right side of the unstable platform
4.2 Moving time of COP

In these studies, the movement of the center of pressure (COP), also called the body sway, was recorded during dynamic training on an unstable platform and was quantified. To evaluate the effect of balance training, we measured the parameters such as the moving time to the target, and the time to maintain the cursor on the target on the screen.

Figure 9 shows the variation of COP moving time to the target for the dynamic circle evaluation. In this figure, the horizontal line represents the target position of dynamic circle and the vertical line is the moving time of the target. As a result, the moving time to the target and time to maintain the cursor on the target improved through equilibrium sense training using the training program sine curve trace (SCT) and the block game. In particular, the moving time of COP of the third group represents the distribution of the largest time in the anterior-left side and posterior-left side.

4.3 Maintaining time of COP

Figure 10 shows the variation of time to maintain the cursor on the target for the dynamic circle evaluation. In this figure, the horizontal line represents the target position of dynamic training and the vertical line is the maintaining time of the target. As a result, the duration to maintain cursor on the target was improved through repeating equilibrium sense training. The maintaining time of COP on the target after experiments is longer than that before experiments. The maintaining time of COP for the left-right side is longer than that of anterior-posterior generally. The visual feedback was effective on improving the dynamic equilibrium sense of the subject when the biofeedback training used SCT and the pingpong game program.
The results show that this system could improve the equilibrium sense and balance ability of subjects.

5. CONCLUSION

The purpose of this paper was to analyze the effect of balance exercise using an unstable platform for postural control and the somatosensory pathway.

1) The moving time to the target and time to maintain cursor in the target improved through equilibrium sense training using the training program sine curve trace (SCT) and the block game.

2) Visual feedback was effective in improving the dynamic equilibrium sense of subjects on biofeedback training using a game program and proved that SCT and the pingpong game have an effect on equilibrium sense training.

The results and analysis of this experiment have aided us in finding a significant training method for the equilibrium sense subjects. It was concluded that this system might be applied to clinical use as an effective balance training system.

ACKNOWLEDGMENTS

The paper was supported by a grant of the Major R&D program; Ministry of Science & Technology, Republic of Korea.

REFERENCES


