Characteristics in Frequency Domain of Postural Sway of Elderly Adults Participating in the Training for Postural Control

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1. Introduction

Adequate postural control depends on the spatial and temporal integration of vestibular, visual, and somatosensory information regarding the motion of the head and body, and the generation of appropriate responses to that motion[1]. Age-related alterations in postural control strategies are well known. Many studies have reported on the increase in postural sway with advancing age. A considerable number of studies have reported on training for postural control or improving the stability of standing balance in elderly adults and patients. Various methods and instruments have been used to improve postural control and balance abilities. Various evaluation parameters have been applied to evaluate the training effects, such as the Berg balance score, timed up and go test, activities-specific balance confidence scale, COP (center of pressure) sway path, RMS (root mean square) of COP sway, COP sway path, repetition maximum strength of the muscles, limits of stability test, one-leg balance, and so on[2, 3]. The objective of this study was to analyze the difference in postural control parameters before and after training, especially the change in frequency domain in different frequency bands in different standing positions.

2. Materials and Methods

2.1 Subjects

Thirty healthy adults were enrolled in the study on a volunteer basis. The 15 volunteers were randomized into the training group (TG) (7 males and 8 females; mean age 68.43±2.44years; mean weight 64.64±9.3kg; mean height 164.36 ±8.97cm) and the remaining 15 adults were randomized to the control group (CG) (9 males and 6 females; mean age 69.93±3.71years; mean mass 59.43±8.86kg; mean height 163.07±6.03cm).

2.2 Experimental procedure

After the first evaluation, the training group took part in an 8-week course of postural training while the control group received no intervention, although the social contact was maintained. The training group participated in training 3 times weekly for 8 weeks in 1 hour sessions. After 4 weeks of training, a second evaluation was done in both groups. After 8 weeks of training, a third evaluation was done in both groups.

2.3 Evaluation

Static postural stability was measured during standing on a force plate (4060-08, Bertec Co.) for 30s periods. The sampling rate was 100Hz. The subjects were asked to stand in three different positions with theireyes open (EO) and then with their eyes closed (EC). The standing positions included (a) side by side (SBS the subject stood barefoot with the feet positioned side by side with 200mm distance between them, with the arms hanging freely at either side), (b) malleolar by malleolar (MBM the subject stood barefoot with the feet positioned malleolar by malleolar with no space between them, with the arms hanging freely at either side), and (c) the Romberg stance (RBS the subject stood barefoot with the non-dominant heel in front of the dominant toe, and the arms hanging freely at either side). Posturography was performed first with the EO, then with the EC. During the EO test, the subject looked at a monitor fixed at eye-level at a distance of approximately 80cm. The monitor displayed the COP of the subject's form on the force plate. The subject was instructed to minimize postural sway. All of the sessions were repeated 3 times.

2.4 Training

The training was performed on a training system that we developed[4]. The training program was intended to improve the postural control ability of the trainees by repeated training with instructed movement of the COP. The training sessions included COP maintenance and trace training sessions. The COP maintenance training was performed in eight directions. Subjects were to move the COP in the requested direction and maintain it in the designated target circle for 30s. This was repeated twice. The distance of the target circle away from the center was 6 cm. The rest time is 30s. The directions were anterior, posterior, left, right, anterior-left, anterior-right, posterior-left, and posterior-right. The direction was selected in random order. Afterward, the trace training was performed. The trace training required that the subject move the COP by following the target circle, which traced the designated trace pattern. The trace patterns were the circle trace, the quadrangle trace, the triangle trace, and the sine curve trace. In this study, the speed of the target circle was 0.6cm/s; the levels of 5 cm and 7 cm were selected. All of the trace patterns were selected in random order, and repeated twice. The rest time was 30s.

3. Results

3.1 Mean frequency of COP sway

Figure 1 shows the mean frequency of the COP sway in the ML and AP directions under the different visual and standing positions before and after training. The mean frequency of COP sway in the ML direction under both visual conditions and in both groups was highest in the SBS standing position and lowest in the MBM standing position. The mean frequency in the AP direction under both visual conditions and in both groups exhibited significant differences in the RBS standing position compared with the SBS and MBM standing positions. The mean frequency in the AP direction was not significantly different in the SBS and MBM standing positions. The mean frequency under both visual conditions and in both groups in the SBS standing position were significantly higher in the ML direction than in the AP direction. After training, the mean frequency in both directions and in all three standing positions was significantly increased under the EO condition in the training group, but not in the control group. There was no significant difference in the training group in the ML direction under the EC condition after training. For the AP direction, the mean frequency under the EC condition in the SBS and MBM standing positions were significantly increased in the training group after training. The mean frequency of COP sway exhibited an increasing tendency in the training group after training, but this was not observed in the control group.

3.2 Spectral energy of COP sway

In our study, the selected frequency bands included the low-frequency band (LF, 0.1 ~ Hz), the middle-frequency band (MF, 0.3~1Hz), and the high-frequency band (HF, 1~3Hz). The spectral energy of the three frequency bands was calculated to investigate the change in frequency. The spectral energy of the COP sway in the ML and AP directions under the different visual before and after training are shown in Figure 2. The spectral energy under the EO condition in both directions was significantly decreased in the low-frequency and the middle-frequency bands and increased in the high-frequency band in the training group, but not in the control group. The spectral energy under the EC condition and in the AP direction was significantly increased in the high-frequency band after training. The spectral energy of the COP sway exhibited a decreasing tendency in the low- and middle-frequency bands and an increasing tendency in the high-frequency band in the training group after the training, but not in the control group.

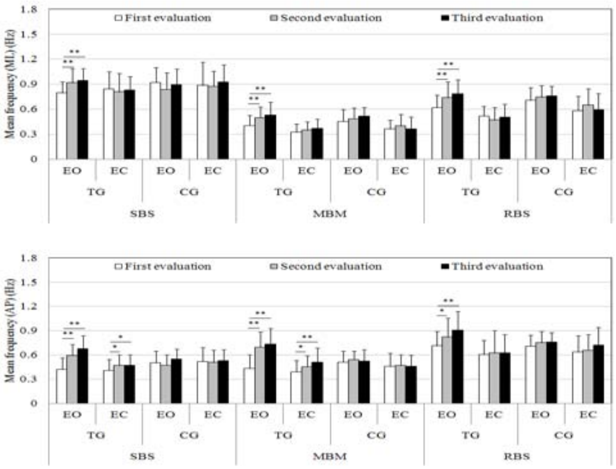

Fig. 1 Mean frequency in the different visual conditions before and after training: (a) ML direction (b) AP direction

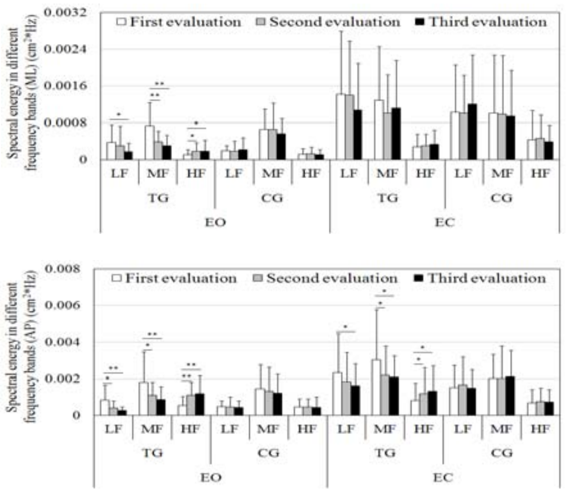

Fig. 3 Spectral energy in the different visual conditions of MBM position before and after training: (a) ML direction (b) AP direction

4. Discussions

Our experimental results showed that the mean frequency of COP sway changed in the different standing positions after training. For the MBM and RBS standing positions, the mean frequency in both directions exhibited a significant difference under the EC and EO conditions. In the SBS standing position, however, the mean frequency in both directions was not significantly different under the EC condition compared with the EO condition, but was due to the standing position. The SBS standing position was a relatively stable standing position compared with the other standing positions. Especially in the ML direction, it tended to lower the COP sway, and have a higher frequency of COP sway. Even under the EC condition, the mean frequency was not significantly different between the two groups. With regard to the MBM and RBS standing positions, the mean frequency under the EO condition in the ML and AP directions was significantly higher than that under the EC condition. Following the decrease in position stability, the mean frequency in both directions was significantly increased. After 8 weeks of training, the mean frequency under the EO condition in both directions was significantly increased in the training group. Under the EC condition, the mean frequency in the AP direction was significantly increased in the SBS and MBM standing positions. The increased frequency of the COP sway indicated that the postural control ability was enhanced by training.

To investigate the change in the frequency domain, the spectral energy of COP sway in the ML and AP directions was divided into different frequency bands. Golomer suggested that the low-frequency band is linked to visual control, the middle-frequency band is sensitive to vestibular and somatosensory information, and that the high-frequencies reflect proprioceptive control and muscle activity[5]. Our experimental results are consistent with this hypothesis. The training patterns used in this system could effectively strengthen the ankle and knee joints by using an unstable platform. Different movement patterns, directions, speeds, and the tilt angles caused different movements of the ankle and knee joints. The muscles in the lower limbs were also activated. Additionally, the ankle strategy for postural control was applied in the training. Therefore, ankle strength and the knee joints could be effectively improved. Simultaneously, the ability to keep the body balanced on the unstable platform could also be effectively improved, therefore directly affecting the frequency change of the COP sway after training. The increase in spectral energy in the high-frequency band indicated that the proprioceptive control and muscle activity was enhanced. Following training, the frequency of COP sway changed to the high frequency range. The power density spectrum of COP sway also changed to the high-frequency band. Therefore, the spectral energy in the low- and middle-frequency bands was correspondingly decreased. Our findings suggest that the higher spectral energy in the high-frequency band exhibited better performance in the postural control for elderly adults after training.

5. Conclusions

In this study, we investigated the change in frequency domains at the different frequency bands in the different standing positions. The experimental results show that the training resulted in an increase in the mean frequency of COP sway. The power density spectrum of COP sway also changed to the high-frequency band. The increased frequency and decrease in the postural sway after the training seems to reflect a change in postural strategy. The results suggest that the analysis in different frequency bands may be applied to analyze the contribution of the visual, vestibular system, and somatosensory for postural control.

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REFERENCES

1. Horak, F. B., Shupert, C. L. and Mirka, A., "Components of postural dyscontrol in the elderly: a review," Neurobiology of Aging, **10**, 727-738, 1989.
2 Morioka S. and Yagi F., "Influence of perceptual learning on standing posture balance: repeated training for hardness discrimination of foot sole," Gait and Posture, **10**, 36-40, 2004.
3 Granacher U., Gollhofer A. and Strass D., "Training induced adaptations in characteristics of postural reflexes in elderly men," Gait and Posture, **24**, 459-466, 2006.
4. Piao, Y. J., Yu, M., Kwon, T. K., Hong, C. U. and Kim, N. G., "Development of the training system for equilibrium sense using the unstable platform," Journal of the Korean Society of Precision Engineering, **22**, 192-198, 2005.
5 Nagy E., Feher-Kiss A., Barnai M., Domjan-Preszner A., Angyan L. and Horvath G., "Postural control in elderly subjects participating in balance training," Eur. J. Appl. Physiol., **100**, 97-104, 2007.