

Effect of Mental Training on the Balance Control Ability of Healthy Subjects

JIN HO CHOI, PhD, PT¹), YONG WON CHOI, MS, PT²), KI SEOK NAM, MS, PT³),
IN SUL CHO, PhD³), YOON TAE HWANG, PhD, PT⁴), YONG HYUN KWON, PhD, PT³)

¹)Department of Physical Therapy, College of Health and Therapy, Daegu Haany University

²)Department of Physical Therapy, College of Rehabilitation Science, Daegu University

³)Department of Physical Therapy, Yeungnam College of Science & Technology: 1737,
Daemyung 7-Dong, Namgu, Daegu, 705-703, Republic of Korea. TEL: +82 53-650-9702,
FAX: +82 53-629-5048, E-mail: kwonpt@hanmail.net

⁴)Department of Physical Therapy, Gangneung Yeongdong College

Abstract. [Purpose] This study investigated the effect of physical training with visual feedback and mental training with motor imagery on balance control ability. [Subjects] Twenty-one healthy adults (male/female: 7/14, mean age: 19.8 ± 0.1 years) with no history of neurological or orthopedic problems were enrolled in this study. The subjects were randomly divided into a physical training group (PTG), a mental training group (MTG), and a control group (CG). [Methods] PTG and MTG performed a dynamic balance task with physical and mental training, respectively, in a 30-minute training session, 5 days a week for 3 weeks. The CG did not receive any training. The outcomes of postural balance were evaluated in terms of the performance time and sway length measured by a force platform. [Results] In the baseline test, the three groups showed similar demographic data, performance time, and sway length. The PTG and MTG showed a significant decrease in performance time, but neither group showed any significant change in sway length. There was no significant difference in the CG. [Conclusion] Our findings indicate that physical balance training with visual feedback as well as mental balance training with motor imagery is effective. Therefore, mental training could contribute to improving dynamic balance ability in a cost-effective home-based training program.

Key words: Balance control ability, Mental training with motor imagery, Physical training

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INTRODUCTION

Balance is defined as the ability to maintain the center of body mass within a stability limit¹). Standing balance involves a continuous stabilization process that requires the integration of visual, vestibular and somatosensory inputs from all over the body to assess the position and motion of the body in space²). In particular, in the case of the elderly and patients with neurological impairment, balance is an essential part of all functions in daily living, because such subjects have impaired balance

and an increased risk of falling^{3,4}). Balance-related problems lead to considerable health problems and social incur services costs, because of the patient's dependence on basic functional activities⁵). In order to improve balance ability, many studies have adopted a wide range of training methods involving balance training with visual feedback, muscle strength training, plyometric, virtual reality, and mental training⁶⁻¹⁰).

Recently, mental training has been used in a range of fields (e.g. sports psychology, cognitive psychology, medical science) as a motor learning



Fig. 1. Schema of postural balance performance.

method for acquiring and enhancing motor skills^{11, 12}. Mental training with motor imagery is a technique by which physical skills can be cognitively rehearsed in safety, unaccompanied by overt body movements¹³. Many prior studies have suggested that mental training could be used effectively to enhance motor skill or task performance, due to the lower energy consumption than physical training for individuals who fatigue easily^{10, 14-16}. However, less attention has been paid to how mental training is related to balance control ability. We believed that it may be worthy to establish scientific evidence on the effectiveness of mental balance training with motor imagery for healthy adults. Consequently, the aim of the present study was to compare the effects of physical balance training with visual feedback and mental balance training with mental training on the balance control ability of healthy subjects.

SUBJECTS AND METHODS

Twenty-one healthy volunteers (male/female: 7/14; mean age: 19.8 ± 0.1 years) were recruited for this study. The subjects were selected according to the following criteria: 1) no neurological disorders, 2) no history of balance problems, 3) no orthopedic disorders within 3 years in the ankle, knee or hip joint, and 4) no medication within 7 days. All subjects were asked to refrain from alcohol for at least 48 hours before the test. The subjects were explained the purpose of this study, and signed written, informed consent forms before

participating in the experiment. They were assigned randomly and equally to the physical training group (PTG), the mental training group (MTG), or the control group (CG).

The postural balance (dynamic balance) was assessed using a force platform, as a measure of balance, and as training equipment. The Good Balance system (Metitur, Finland) consists of a portable equilateral triangular force platform (800 mm \times 800 mm \times 800 mm) with strain gauge transducers connected to a three-channel DC amplifier and a 12-byte analogue-to-digital (A/D) converter connected to a computer. The amplified analogue signals were digitized with a sampling frequency of $f_s = 50$ Hz and transmitted to the computer through a serial port. All filtering and data processing were carried out in digital form using the Good Balance software. Data filtering was performed for each channel separately. Two different filters were used; a median filter with a window length of seven data points, and a low-pass infinite impulse response filter with a cut-off frequency of $f_c = 20$ Hz. The use of a median filter has the advantage that it effectively removes or strongly reduces impulse noise. High frequency noise from the measurement system and A/D-conversion was reduced by low-pass filtering. After all of the measurement points were taken, the medio-lateral (x) and antero-posterior (y) coordinates of the center of pressure (COP) were calculated based on the vertical force signals. The error in the calculated X and Y coordinates of the COP was less than 1.0 mm when the mass of the subjects was at least 40 kg. The device was recalibrated weekly.

In the postural balance tests, the subjects were asked to stand barefoot on the force platform in a relaxed posture, and look at a monitor placed at eye level. The monitor for visual feedback was on a table directly in front of the subject. Nine boxes, which consisted of the eight peripheral targets and one central target, were shown on the monitor. The subject shifted their weight forward toward the target when one of the peripheral targets was presented randomly, and then back to the central target. After demonstrating the tests, the subjects were allowed to practice a preliminary test once before the measurements were taken. Each subject carried out the preliminary test three times. At the beginning of each trial, the examiner checked that the subject stood symmetrically on both legs and

Table 1. General characteristics of subjects at the baseline (Mean \pm SD)

Characteristics	Sex (M/F)	Age (years)	Body weight (kg)	Body height(cm)
PTG	2/5	19.9 \pm 0.4	58.4 \pm 6.5	164.3 \pm 8.9
MTG	3/4	19.7 \pm 0.5	60.0 \pm 8.9	166.4 \pm 6.4
CG	2/5	19.9 \pm 0.4	56.0 \pm 7.4	165.9 \pm 8.4

PTG: physical training group, MTG: mental training group, CG: control group.

Table 2. The performance time and the sway length at pre- and post-intervention in the physical training group, the mental training group, and the control group (Mean \pm SD)

	performance (second)			sway length (mm)		
	pre	post	Δ	pre	post	Δ
PTG	30.24 \pm 3.51	21.67 \pm 2.22	8.57 \pm 1.72	2949.08 \pm 543.11	2644.92 \pm 670.51	304.15 \pm 400.27
MTG	29.64 \pm 3.41	25.40 \pm 3.94	4.23 \pm 1.18	2614.40 \pm 265.37	2519.36 \pm 282.22	95.03 \pm 120.91
CG	31.36 \pm 4.21	30.26 \pm 3.81	1.09 \pm 2.09	3060.05 \pm 381.20	3030.72 \pm 392.54	29.33 \pm 78.62

PTG: physical training group, MTG: mental training group, CG: control group, *: $p < 0.05$

did not lean backwards or forwards. The subject was instructed to reach the targets as quickly and accurately as possible, and avoid unnecessary and uneconomic movements. The performance time (the time in seconds taken to complete the test) and performance distance (the distance mm traveled by the COP path during the test) were measured.

The PTG performed the physical balance training session on the force platform for 30 minutes, 5 times a week for three weeks. Physical training was carried out by providing visual feedback regarding the trajectory of the subject's COP. The goal of the training was to control the trajectory of their COP during dynamic weight-shifting. The MTG was trained to mentally image the shift in their weight forward toward the target. Mental training was performed 30 minutes, 5 times a week, for three weeks in a quiet treatment room so that the participants could concentrate on the task. The subjects were asked to stand on a bare floor in a relaxed posture with their gaze fixed on the wall at eye level. The subjects rehearsed dynamic weight-shifting and imagined COP movement on the wall. The CG did not undergo any training.

The Chi-square test was used to analyze the differences in gender ratio in the three groups. A Kruskal-Wallis test was performed to verify that the demographic data (i.e. age, body weight, and body height) was similar in the three groups, and to compare the group differences at pre-training and the changes in the performance time and the sway

length of the groups between pre- and post-intervention. Comparison between the pre- and post-training test data (performance time and sway length) within each group were analyzed using a Wilcoxon signed-rank test. Mann-Whitney U tests were performed to determine which of the variables were different between the groups. A post hoc Bonferroni correction was applied to statistics and p values < 0.0167 were considered significant, to reduce the type 1 error. Otherwise, $p < 0.05$ was adopted as the criterion for statistical significance.

RESULTS

Demographic data were not significantly different among the three groups, in terms of sex ratio, age, body height and weight (Table 1).

At the baseline, there were no differences in the performance time ($p = .610$) and sway length ($p = .087$) among the three groups. At the post-training test, the performance time was significantly improved in PTG and MTG, compared to the pre-training test. The CG did not show any significant differences. The sway length tended to improve in the PTG and MTG, compared to the pre-training tests, but without statistical significance. The CG showed no significant difference (Table 2).

Among the groups, there was a significant difference in the change of the performance time ($p = .000$). The PTG showed a significant improvement in the performance time, compared to

the MTG ($p=.002$) and the CG ($p=.001$). In addition, the MTG showed a significant improvement in the performance time compared to the CG ($p=.011$). However, there was no significant difference in the sway length ($p=.078$).

DISCUSSION

This study was designed to investigate the effect of postural balance training with physical and mental practice on healthy subjects. The performance time and sway length were used as dependent variables to assess the improvement of balance performance after both training modes, because of the high reliability and prevalence shown in prior balance experiments¹⁷⁻¹⁹). In addition, normal healthy participants were the subjects in order to exclude high heterogeneity and its related erroneous interpretation in patients with neurological disorders. Three weeks of physical and mental balance training resulted in significant improvement of balance ability in terms of the performance time. A comparison of both training groups showed that actual balance training with visual feedback was more effective than mental balance training with motor imagery. However, the control patients did not show any improvement. Concerning the better outcome of physical balance training, we postulated that the additional visual information might make subjects more aware of their body's displacement and orientation in space. These results were accordance with several prior studies, indicating that mental training produces significant improvement of isometric muscular strength, upper extremity function and ADL activity^{16,20,21}). Therefore, our findings support the fact that postural balance training with motor imagery is an effective therapeutic method for improving the balance control ability of healthy subjects.

There may be two possible explanations for this outcome. First, a physiological mechanism similar to actual movement may occur during mental training. Several previous studies have suggested that mental training of a specific action without a corresponding motor output has mechanisms similar to underlying movement preparation and execution^{22,23}). According to Guillot et al.⁹), when subjects imaged various different type of muscle contraction, a corresponding muscle activation pattern was detected on electromyography. Second,

the effect of mental training may be explained by cerebral and cerebellar plasticity. Neuroimaging studies using positron emission tomography have shown that the neural areas concerned with actual motor function, such as the supplementary motor area, premotor areas, and cerebellum, are activated during motor imagery²⁴⁻²⁶). Therefore, we assume that the effect of motor imagery might involve a mechanism similar to physical movement as well as utilization of the neural substrates related to the actual motor function. However, there was no significant difference in the sway length between the PTG and MTG, even though there was a slight decrease. We think that the increase of performance speed might have raised the probability of error in movement, as the performance time was decreased.

Postural balance control is one of the most important factors in performing functional activities in daily life. In addition, successful performance of balance is essential for establishing a comprehensive strategy for overcoming the challenges to intrinsic, environmental, and behavioral factors^{27,28}). On the account of necessity of such multiple factors, the physical impairment of musculoskeletal/neural structures can increase the risk of subsequent fall and injuries^{27,29}). In particular, balance dysfunction is a very important issue in the elderly. Numerous therapeutic interventions have been attempted in order to improve the postural control ability of elderly adults and various types of patients^{6,8,9,30}). Our findings show that mental practice with motor imagery can provide an effective and safe training method for individuals with balance dysfunction. We acknowledge that our results cannot be generalized due to the small sample size, and that the amount of mental practice required was not evaluated. Therefore, future studies will be required to address these issues.

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