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The Effects of Balance Training Frequency on the Balance Ability in Healthy Young Adults

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ABSTRACT

Huang HN, Yamamoto T. The Effects of Balance Training Frequency on the Balance Ability in Healthy Young Adults. **JEPonline** 2013;16(1):86-94. Despite widespread use of balance training, the effects of day(s) per week (frequency) as one of the three training components (intensity, duration, and frequency) on the balance ability are as yet unclear. This study investigated the effects of different frequencies of balance training on the balance ability using a seesaw-like platform. In total, 35 of 40 healthy male subjects aged 20 to 22 yrs completed the study. The subjects were assigned to the following subgroups: (a) 1 $d \cdot wk^{-1}$ training group (W1; n = 9); (b) 2 $d \cdot wk^{-1}$ training (W2; n = 10); (c) 3 $d \cdot wk^{-1}$ training (W3; n = 7); and (d) a control group without training (Control; n = 9). No significant difference in baseline of balance keeping time (BKT) among the four groups was confirmed. The training period was 8 wks. The subjects maintained balance as long as possible at each trial, and the BKT was determined by recording the platform movement and head acceleration for postural control. This trial was repeated 10 times a day consisting of a 1-day training session. After an 8-wk training period, absolute changes in BKT from baseline (ΔBKT) in W2 and W3 were significantly larger than in W1 ($P<0.01$ and $P<0.05$, respectively). Moreover, pre-post comparison of ΔBKT within W1 showed no significant training effect as well as the non-training control group. These findings indicate that balance training frequencies of more than 2 $d \cdot wk^{-1}$ for at least 8 wks with 10 consecutive trials are effective in the improvement of balance ability.

Key Words: Dynamic Balance, Postural Control, Training Frequency

INTRODUCTION

The ability to keep balance on an unstable support surface is very important for many people in their daily life and sports. For example, people find themselves standing in moving trains, surfboarding, skiing, gymnastics, and many other sports. However, regardless of the wide recognition of the importance of balance ability not only in the field of sports but also in the preventing falls in the elderly, only a few studies have dealt with the effects of balance training frequency on balance ability.

In 1992, Balogun et al. (1) reported that a 6-wk training program using a wobble board exercise system resulted in a significant increase in balance performance and muscular strength of the lower limbs in young healthy subjects. However, the training frequency was fixed at 3 times a week, and thereafter, a 10-min training session was increased to a 20-min session. So, it is unclear how training frequency influenced the training effects. Additionally, Toulotte et al. (10) reported that both static balance and walking parameters improved when the elderly fallers and non-fallers were trained 2 times a week for 3 months with 1-hr mixed exercise sessions consisting of several kinds of physical activities for developing muscular strength, flexibility, static and dynamic balance. It is interesting that while training frequency was fixed at 3 times a week in the Balogun et al. study (1), it was fixed at 2 times a week in the Toulotte et al. study (10). This consideration plus the latter study's use of physical activities as training stimuli makes it difficult to clarify what kind of exercise was more effective in increasing balance ability.

The purpose of this study was to investigate the effects of different frequencies of balance training on the balance ability expressed as performance while recording the changes in the seesaw-like platform movements and head acceleration in the control of postural stability. The finding should be helpful for developing balance ability.

METHODS

Subjects

The subjects who participated in the present study were male students in the 3rd or 4th grade of the same faculty at the School of Health and Sport Sciences of Chukyo University in Japan. They were healthy and free from any balancing disorders and/or injuries. Forty students volunteered to participate in this study. The training group was divided into three different subgroups: W1, W2, and W3 with respect to the number of training days per week. Thirty of the 40 subjects were randomly assigned to these three training groups. Ten subjects served as the control group without balance training. Thus, 10 subjects were assigned to each group. However, during the course of the study, 5 subjects were unable to carry out the balancing task due to either injuries in the physical education classes (2 subjects) or scheduling problems (3 subjects). Their data were eliminated from the statistical analyses. As a result, 35 subjects completed all the training programs. The experimental protocol was approved by the Ethics Committee at Chukyo University Graduate School of Health and Sport Sciences in Japan. Prior to participation in the study and after the subjects were informed of the advantages and possible risks, they signed a written consent form.

Measurement of Balance Performance

The subjects were required to stand barefoot on a custom-built seesaw-like platform consisting of a 40 cm x 40 cm aluminum-steel plate (2 cm in thickness) fixed on a base frame (50 cm x 50 cm steel-iron plate and 5 cm in height) with a pivot bearing. The platform was designed to rotate around the pitch-axis in both directions of toes-up and toes-down. Its maximum inclination was set at an angle of 25° to horizontal plane, which was in agreement with the findings of Hukuda (7) who reported that a healthy individual could maintain his standing position on the platform tilted gradually about 25° to 30°

in any direction. This maximum degree of platform inclination was confirmed to be sufficient to cause imbalance and get down the platform in all subjects in advance. In order to record the changes in platform angular rotation during balancing, an electrogoniometer was installed on the tip of the horizontal pivot.

At first, the subjects were instructed to stand upright with the long axes of the feet at right angles to the pivot of the platform. Thereafter, the subjects kept a light hold on the start button with the right hand. As soon as the subjects' right hand was released from the button, a timer (Model 413, Takei-kiki, Japan) started to record the balance time. When the subjects lost balance, the edge of a platform contacted with the base plate produced an electric pulse for stopping the timer. Hence, balance time was determined as the duration from the starting signal to the finishing one (Figure 1). The subjects were instructed to do their best to maintain the standing posture on the unstable platform as long as possible while simultaneously looking at a fixed eye-level cross mark (size: 10 cm x 10 cm) at a distance of ~3 m. The subjects were tested for one session that consisted of 10 successive trials of balancing per day. The mean time of their balance keeping time (BKT) was calculated and adopted as balance ability.

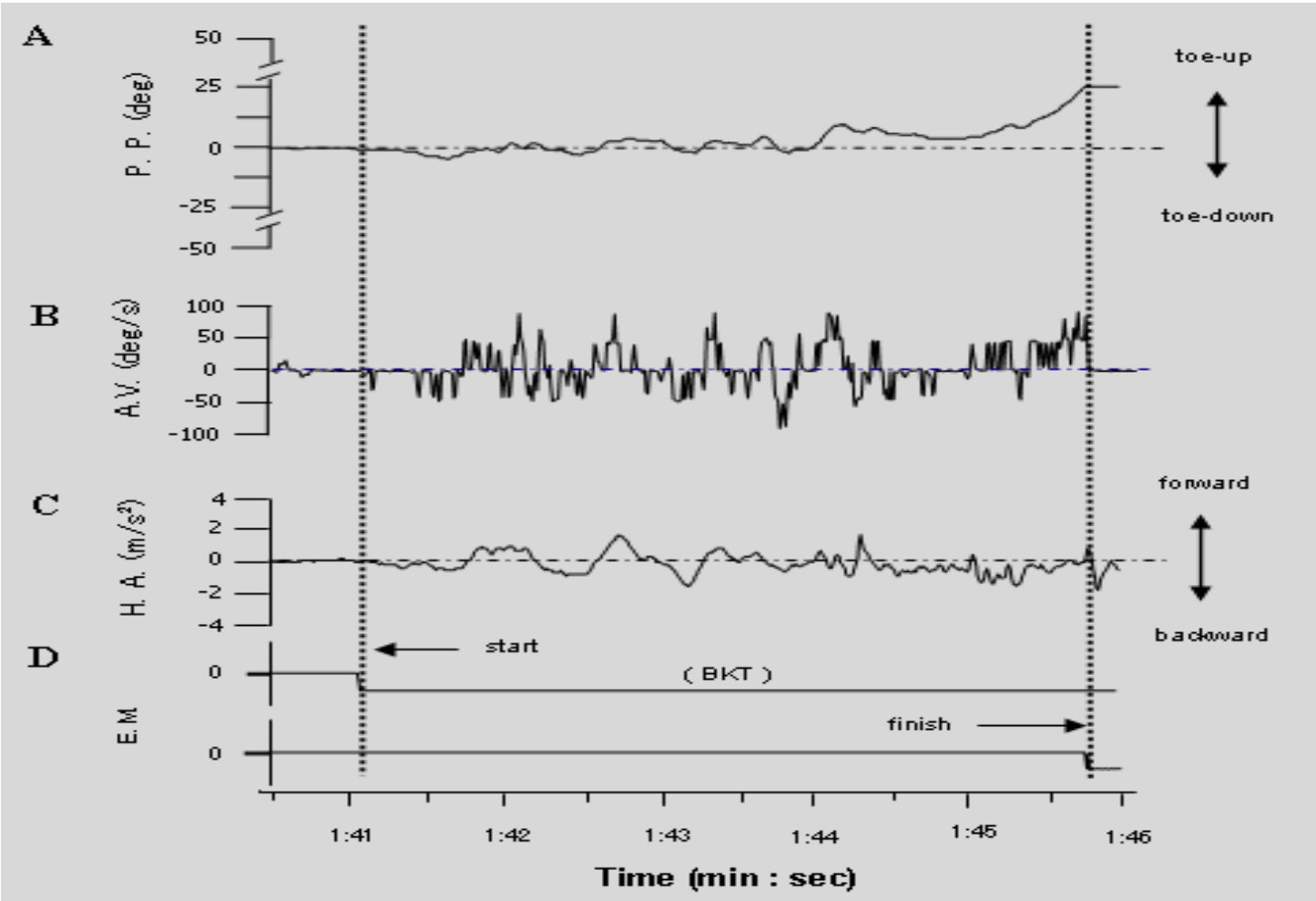

Figure 1. Representative recordings from one subject keeping balance on the seesaw-like platform. **Panel A:** platform position (P.P.); **Panel B:** angular velocity (A.V.) of the platform position; **Panel C:** head acceleration (H.A.); **Panel D:** event marks (E.M.) showing start and finish points of keeping balance. Balance keeping time (BKT) is 4.8 sec.

Balance Training Programs

Before training, the subjects' BKT was measured as baseline level. The subjects were then assigned to the following subgroups: (a) 1 $d \cdot wk^{-1}$ training group (W1; n = 9); (b) 2 $d \cdot wk^{-1}$ training (W2; n = 10); and (c) 3 $d \cdot wk^{-1}$ training (W3; n = 7). A 1-day training session consisted of 10 successive trials of balancing. Each subject took an appropriate rest among the trials to prevent fatigue. The training period was 8 wks in all groups, and the BKT was recorded on all trials.

Signal Recording and Analyzing System

All the signals from both the timer and the platform system were collected simultaneously into the Universal Data Recorder (Model A-69, Sony Magnescale, Japan) as a backup device through amplifiers (Model NS901, San-ei, Japan) without working any filters. The signals were led to the data acquisition system (PowerLab 8/30, ADInstruments Japan Inc.) for signal recording and for further processing and analysis (PowerLab Chart ver.5 software package) in combination with a personal computer (IBM, Taiwan).

Figure 1 shows a sample record of: (a) angular changes in the platform position; (b) the angular velocity of the platform obtained by the derivative, which provided offline calculation of first order derivatives of platform movement; (c) the output from the accelerometer (BAH-10G, Shinko, Japan) attached to the forehead of the subject; and (d) start and stop signals from the button operated by the subject and from the platform contact switch, respectively. Root mean squares (RMS) of both the angular velocity of the platform and acceleration of the head movement were calculated and, then, adopted them as indices of platform and head movements, respectively. All the signals were recorded at a sampling frequency of 100 Hz.

Statistical Analyses

All the values were expressed as means ± standard deviations (SD). Statistical analyses were performed using both the statistical software packages SPSS version 11.0 for Windows XP (SPSS Inc., Japan) and statistical analysis add-in software (Statcel 2, SSRI Inc., Japan) for Excel 2002. After confirming normality of distribution (Shapiro-Wilk's test), and equality of variance (Levene's test), data were studied by using paired-samples t test for analyzing pre-post comparisons within each group. In addition, a one-way analysis of variance (ANOVA) was used of which if it was significant, the differences among the groups were then determined using the Tukey's post-hoc test.

The level of statistical significance was set at $P<0.05$, while P-values ≤ 0.1 were conventionally reported to indicate trends. The sample size was calculated by statistical power analysis in agreement with Faul et al. (3). By referring to standard mean difference in the previous balance training studies reviewed by Zech et al. (11), the recommendation of minimum sample size by an *a priori* power analysis was five subjects per group for detecting significant difference between pre-post within each group in our study, provided that $\alpha = 0.05$ and a statistical power ($1- \beta$) of 0.80 recommended by Cohen (2). We calculated *a posteriori* statistical power to detect the significant group-differences in training effects, and also used 95% confidence intervals (95% CI) for assessing mean differences.

RESULTS

Table 1 presents the physical characteristics of the subjects at baseline measurements. There was no significant difference in each variable between the four groups except for age.

Table 1. Physical Characteristics of the Subjects at Baseline Measurements.

Variables	Training Groups			Non-Training Group
	W1 (n = 9)	W2 (n = 10)	W3 (n = 7)	Control (n = 9)
Age (yrs)	21.4 ± 0.7	20.9 ± 0.1	20.7 ± 0.1*	21.5 ± 0.1
Height (cm)	172.8 ± 2.0	173.0 ± 1.3	174.6 ± 2.1	175.1 ± 2.1
Weight (kg)	66.2 ± 1.3	66.2 ± 2.0	65.3 ± 2.9	71.2 ± 2.9
BMI ($kg \cdot m^{-2}$)	22.2 ± 0.4	22.2 ± 0.6	22.1 ± 0.5	23.1 ± 0.3
Pre BKT (sec)	3.10 ± 0.71	3.19 ± 1.39	2.90 ± 0.74	2.21 ± 0.42

Values are means ± SD; **W1:** 1 $d \cdot wk^{-1}$ training group, **W2:** 2 $d \cdot wk^{-1}$ training group, **W3:** 3 $d \cdot wk^{-1}$ training group; *P<0.05 versus **NTG:** control group.

Training Effects on Balance Performance

The BKTs (sec) after post-training were 3.48 ± 0.59 in W1, 5.40 ± 1.63 in W2, and 4.90 ± 1.39 in W3 groups, and 2.68 ± 0.79 in the control group. Pre-post comparisons of ΔBKT within each group using the paired t test showed significant differences in W2 (P<0.01, Effect size (ES): d = 2.17, power (1- β) = 0.99) and W3 (P<0.01, ES (d) = 1.93, power = 0.99) groups. No significant changes were found within W1 and control groups. Moreover, inter-group differences in ΔBKT after training were compared using a one-way ANOVA (F (3, 31) = 9.01, P<0.001, ES (f) = 0.93, power = 0.99) followed by Tukey's post hoc test (Figure 2). ΔBKT for the W2 group after training was significantly larger than that of W1 and control groups (P<0.01, mean difference and 95% CI = 1.81 (0.61 to 3.02); P<0.01, mean difference and 95% CI = 1.74 (0.53 to 2.94), respectively). Furthermore, ΔBKT of the W3 group was significantly larger than that of W1 and control groups (P<0.05, mean difference and 95% CI = 1.60 (0.28 to 2.92); P<0.05, mean difference and 95% CI = 1.52 (0.20 to 2.85), respectively). However, there was no significant difference between W2 and W3 groups.

Changes in Platform Movement and Head Acceleration during Training

Figures 2B and 2C show the changes in ΔRMS angular velocity of the platform movement and ΔRMS head acceleration during balance training, respectively. A one-way ANOVA (F (3, 31) = 2.42, P=0.08, ES (f) = 0.48, power = 0.60) followed by the Tukey's post hoc test revealed no significant group differences in ΔRMS angular velocity; however, ΔRMS angular velocity in the W2 group has a tendency of decrease compared with those of the W1 group after training (P = 0.10). On the other hand, as shown in Figure 2C, a one-way ANOVA (F (3, 31) = 3.47, P < 0.05, ES (f) = 0.57, power = 0.77) followed by Tukey's post hoc test revealed that ΔRMS head acceleration in the W2 group was significantly larger than that of the control group after training (P<0.05, mean difference and 95% CI = 0.32 (0.03 to 0.61).

DISCUSSION

Pre-Post Comparisons of Balance Performance

No significant training effects were found between W1 and control. The training effects were larger in W2 and W3 versus W1 and control. The results indicate that training frequency influenced the subjects' balance ability. The subjects made maximum efforts to maintain balance at every trial, which has also been used in the research field of muscular strength training (5). In short, the balance training frequencies of more than 2 $d \cdot wk^{-1}$ for at least 8 wks with 10 consecutive trials are effective in the improvement of balance ability.

The sum of average BKT during all the training periods including pre-training in W1, W2, and W3 groups was approximately 317, 760, and 1090 sec, namely, 1.00 to 2.40 to 3.44 times in ratio, respectively. These total values of BKT are considered to work as total training stimuli and, therefore, to cause different training effects. On the other hand, ΔBKT as training effects in W1, W2, and W3 groups at post-training were 0.390, 2.208, and 1.995 sec, that is, 1.00 to 5.66 to 5.12 times in ratio, respectively. The training stimuli in the W2 group almost equal to 2.40 times the value of the W1 group brought approximately not 2.40 but 5.66 times the training effects of the W1 group. These discrepancies between the ratios of training stimuli and training effects in W1, W2, and W3 groups may suggest that training frequency more than twice a week is qualitatively different from once a week (i.e., the former may bring the development of balance ability while the latter may not).

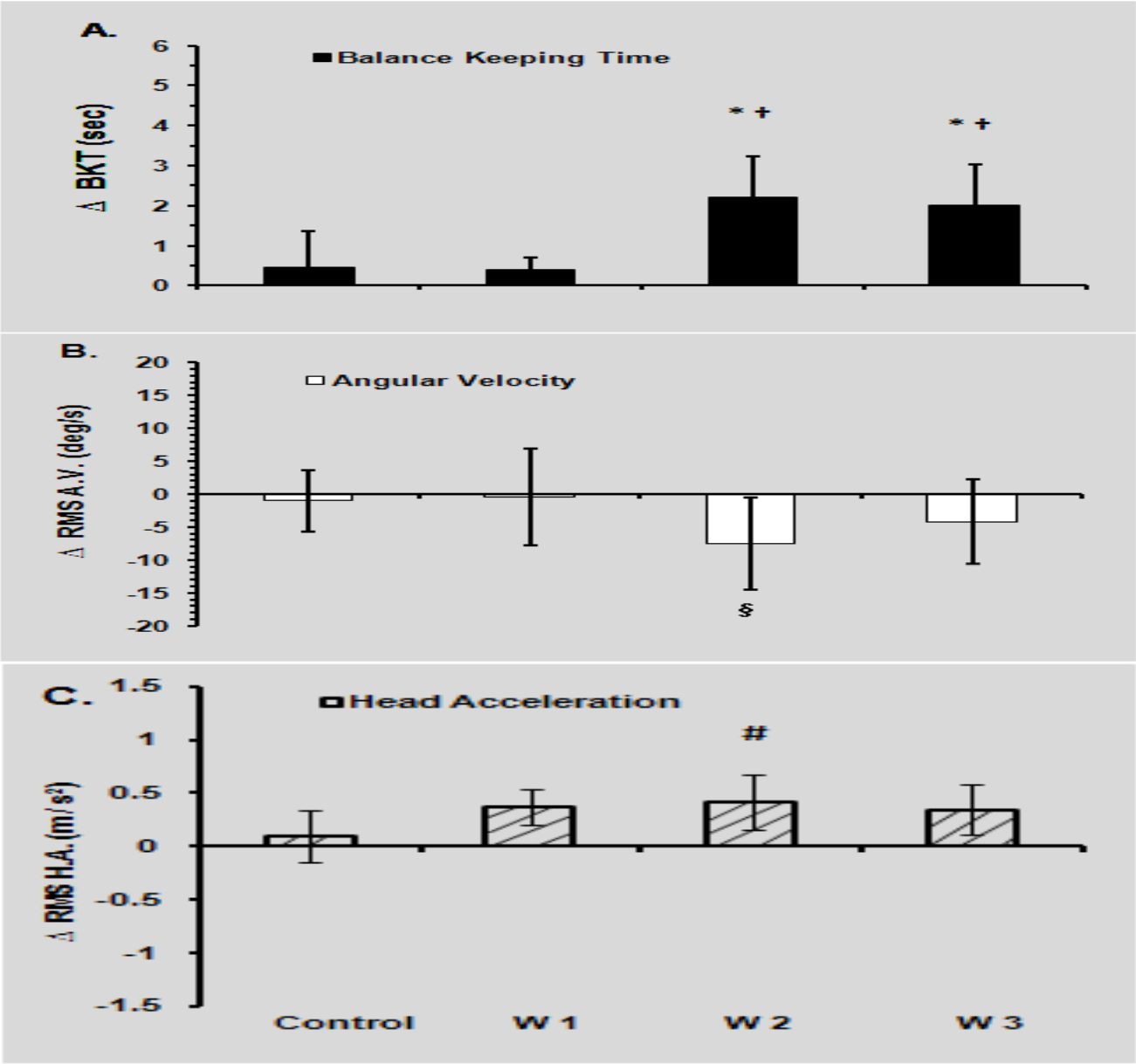

Figure 2. Comparisons among four groups (W1, W2, W3, and Control) in each variable (ΔBKTs (**Panel A**), ΔRMS angular velocity (A.V.) (**Panel B**) and ΔRMS head acceleration (H.A.) (**Panel C**) immediately after 8 wks of training (post-training)). Values are means ± SD. In panel **A** (ΔBKTs), *: significantly different at P<0.01, W2 versus W1 and Control; †: significantly different at P<0.05, W3 versus W1 and Control. In **Panel B** (ΔRMS angular velocity (A.V.)), §: a trend (P=0.10) of a more decrease in W2 than W1 groups. In **Panel C** (ΔRMS head acceleration (H.A.)), #: P<0.05, W2 versus Control.

It is apparent that when the subjects worked to maintain balance on the unstable platform, many organ responses were functionally related. This is true for both voluntary and reflex movements. One of the important organs in this case is the proprioceptors, as pointed out by Balogun et al. (1). During balancing, joints of the lower extremity function irregularly, which implies that relevant muscles contract and relax swiftly responding to the efferent impulses from the spinal motoneurons where both afferent impulses arise from proprioceptors in peripheral organs and efferent ones descending from the supraspinal motor centers are integrated. Based on this neurophysiological background, balance training has been widely applied to the rehabilitation of lower limb injuries in athletes with proprioceptive deficits. This role of balance training as proprioceptive training was advocated by Irrgang et al. (8) who suggested a stronger relationship between training effects of balance training and an improvement of proprioreceptor functions.

Another point of importance is neural plasticity within central nervous system accompanying balance training. The achievement of a significant increase in balance performance with balance training leads to the consideration of changes in the function of the supraspinal system. One likelihood for change is within the cerebellum that associates with repeated skillful movements, as pointed out by Ito (9). He proposed the idea that when a motor skill is practiced, it is done so unskillfully at first and, then, with continued practice, the execution of the skill becomes easier as new neural connections between cerebellum nuclei and other neurons of the brain are reinforced.

Changes in the Platform Movement and Head Movement Acceleration

Given the musculoskeletal design of lower limb joints, movements are more easily performed in the forward and backward directions than from side to side. In the present study, we used a seesaw-like platform that allowed by recording balance performance as time in seconds and also, by using an electrogoniometer, to record the direct rotation of a platform. The latter recording is considered to be closely related to the ankle joint angular rotation. In advance of this experiment, we hypothesized that the decrease in the ankle and head movements would be accompanied by the positive training effects in the balance performance. In support of this expectation, we recorded the changes in both the platform movements and the head acceleration before and after training. After the data were processed, a trend towards a lower RMS magnitude of platform movement in the W2 group was detected versus the W1 group ($P = 0.10$). Although the change was not significant, the head acceleration in the W2 group significantly increased when compared to the control group. Thus, the question is, “How should this trend be interpreted?

To our knowledge, very few data are available in the literature that deals with the training-dependent changes in postural control during prolonged balance training. Our data show not only a trend towards a decrease in platform movements after training, but also a significant increase in head acceleration in the W2 group. This suggests that post-training subjects who are standing on an unstable platform may try to keep equilibrium in response to sagittal plane movements of the platform mainly by swinging the upper part of the body forward or backward around the hip joints, that is to say, by hip strategy rather than ankle strategy as proposed and termed by Horak and Nashner (6). Interestingly, a related study, Haguenauer et al. (4) investigated the influence of constraining the ankle joint by wearing figure skating skates on interjoint co-ordinations. They demonstrated that the restriction of ankle joint movement significantly limited the knee joint while the hip angular motion was not affected and, therefore, they proposed that constraining the distal joint induces a reorganization of interjoint co-ordinations.

CONCLUSIONS

Our results indicate that ΔBKTs for the W2 and W3 groups during an 8-wk balance training program were significantly larger than those of the W1 and control groups. However, there were no significant differences in ΔBKT between W1 and the control group. Therefore, training frequencies of more than 2 $d \cdot wk^{-1}$ are more effective than 1 $d \cdot wk^{-1}$, provided that one training session per day consists of 10 successive trials of balancing. In addition, no significant difference in ΔRMS angular velocity was found. But, although limited in the W2 group, a trend for ΔRMS angular velocity to decrease and significant increase in ΔRMS head acceleration may imply partial changes in postural control. These findings might be helpful in developing balance ability through balance exercise prescription.

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