Effects of Y-balance and aero-step training on balance ability and muscle activity in young adults

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Abstract

Background/Objectives*: The Y-Balance test has been used in several studies to evaluate the training effects, performance enhancement, and postural control in athletes. In the present study, we aimed to investigate the effects of a training program, which includes the Y-Balance test and aero-step, on balance ability and lower limb muscle activity in young adults.*

Methods/Statistical analysis*: We recruited 24 healthy adults: 12 assigned to the Y-Balance training group (YBTG) and 12 assigned to the aero-step training group (ATG). We analyzed the balancing ability and the activation of the tibialis anterior and peroneus longus muscles before and after training within and between each intervention group. The respective training programs were conducted for 5 weeks, 3 sessions per week, 40 minutes per session.*

Findings*: In YBTG, the subjects' ability to balance was significantly increased ($p<.05$), and muscle activation increased significantly in the tibialis anterior and peroneus longus muscles ($p<.05$). In ATG, the activation of the peroneus longus and gastrocnemius muscles significantly increased ($p<.05$).*

Improvements/Applications*: The findings of this study suggest that Y-Balance training can be used to collect data regarding ankle strategy in patients with ankle disorders or balance impairment.*

Keywords: *Y-Balance test, aero-step, ankle exercise, EMG, balance ability*

1. INTRODUCTION

Balance is the ability of an individual to maintain the body's center of gravity over its base of support, while also maintaining the proper postural alignment of the body[1]. Laughton et al. identified lower limb muscle weakness as a main cause of balance impairment. To prevent balance impairment and impairment-related injury, there are various balance-improving rehabilitation methods including muscle-strengthening exercises, gait training, drug therapy, and prevention education[2].

Balance is a highly complex function in the human body involving functional elements of both the nervous and musculoskeletal systems to maintain posture. An accurate perception of the surrounding environment and an appropriate response strategy to perturbations are required for proper balance[3,4]. Traditional rehabilitation methods include lower limb muscle strengthening and proprioception training using both visual feedback and biofeedback. Exercises performed on unstable support surfaces involve identifying the center of balance and maintaining posture or shifting the weight on slings, Swiss balls, tilt-boards, balance balls, and balance pads[5]. In addition, aero-step exercise is a useful at-home balance exercise because it is both safe and easy to perform[6].

Functional movement screen (FMS) and Y-Balance test (YBT) are two representative tools for assessing balance. Both tools were developed by Gray Cook, an American physical therapist[7]. YBT is a simple test that can evaluate an athlete's neuromuscular control on-site, including dynamic balance. Several studies have used it to evaluate training effects, performance enhancement, and postural control in athletes[8-10]. As YBT can predict the risk of falls by assessing body movements, researchers have used it in fall-prevention exercise programs to obtain basic data from participants[8,11,12]. Moreover, Lee et al. studied the relationship between dynamic balance and lower limb muscular strength using YBT. They reported that in elderly women, dynamic balance training increases balance ability by increasing muscular strength in the lower limbs[13].

However, the effectiveness of YBT in balance training has been inadequately studied. This study thus aimed to investigate the effects of an integrated training program, combining aero-step exercise and YBT, on balance and lower limb muscle activation in young adults aged 20–29.

2. Materials And Methods

2.1. *Subjects*

We selected 24 students attending the N University in Cheonan-si. Subjects agreed to participate in this study after they were explained about the study's purpose and methods. Participating subjects were all required to read and sign a consent form approved by the Namseoul University Ethics Committee for Human Investigations prior to commencing the study. The inclusion criteria were as follows: (1) no musculoskeletal disease, (2) no previous history of general surgery or neurological disorders, (3) no ongoing pain in the back or lower limbs, and (4) no decline in condition due to overwork or disease. The exclusion criteria were as follows: (1) surgery or treatment for fracture or other musculoskeletal diseases within the past year, (2) overtraining or special training programs involving the lower limbs or trunk. The 24 subjects were randomly assigned to either the Y-Balance training group (YBTG; 12 subjects) or the Aero-step training group (ATG; 12 subjects) as shown Table 1. During preliminary testing, we measured all subjects' balance abilities using a balance assessment device, and also measured the levels of activation in the tibialis anterior and peroneus longus muscles using surface electromyography (sEMG). Both groups received one 40-minute training session per day, three times per week, for five weeks. After the respective training programs, we once again measured the subjects' balance and lower limb muscle activation.

Table 1: General features of the research subjects

Variables	YBTG (M±SD)	ATG (M±SD)	P
Age [yr]	21.35±2.07	20.49±2.77	.486
Height [㎝]	169.56±9.27	170.03±7.24	.814
Weight [㎏]	72.43±20.80	68.68±12.84	.201
Gender(male/famale)	6/6	7/5	-

YBTG: Y-balance training group, ATG: Aero-step training group

2.2. *Measurements*

2.2.1. Balance ability test

To evaluate subjects' balance abilities, we used a balance measurement device (BT-4 Hur Labs, Karla in Finland)[14].

We used the "limit of stability" testing method included in a software program (Smart Suite 1.4). The subjects took their shoes off and positioned their feet so that the heels were 2 cm apart and each foot faced outward by 15°. Both hands were placed naturally at the bottom line of the subjects' pants[15].

After placing both feet on the balance platform while standing straight, participants were asked to sway their bodies as much as possible in four directions: forward, backward, left, and right, holding each position for 8 s. Balance ability was measured as the maximum range of sway in the anteroposterior and mediolateral directions[16].

2.2.2 EMG measurements

To measure the activation level in the tibialis anterior, peroneus longus, and gastrocnemius muscles, we connected sEMG electrodes to the subjects as described. For the tibialis anterior muscle, we placed electrodes at the one-fourth to one-third point between the tip of the patella and lateral malleolus along the lateral side of the tibia. For the gastrocnemius muscle, we placed electrodes at the upper one-fourth point of the line connecting the inner knee joint and the calcaneus. For the peroneus longus muscle, we placed the electrodes 5–7 cm from the head of the fibula along the lateral side[17,18].

We used the Ag-AgCl-type adhesive electrodes with a 2.5-cm diameter for the entire electrode area and those with a 1.5-cm diameter for the measurement area. The inter-electrode distance for Channel 1 was set to 1 (inside)–2.5 (outside) cm. EMG signals were obtained using the electrodes and were immediately amplified tenfold using an amplifier that reduced noise and interference. The signals were transferred along a cable to reach the patient unit and immediately converted to digital data using a 16-bit A/D converter. Data collected from the patient unit were transmitted to a computer through Wi-Fi and to access pointer through a LAN cable immediately after acquisition. We then processed and displayed the raw data using MYOLAB software (BTS, Italy) and the Free-EMG system.

To normalize our surface electrode positioning and EMG data, we measured the maximal voluntary isometric contraction (MVIC) for each muscle. We used the conventional handgrip strength measurement method, adding additional manual resistance as necessary[19,20]. We applied manual resistance in a graded manner until the maximum contraction was reached, after which the contraction was held for 5 seconds. Measurements were repeated three times for each muscle, with a 30-s resting period between measurements. The peak torque value was then recorded21. We verified proper electrode placement by monitoring the EMG signal amplitude during manual resistance testing. During the MVIC for each muscle, the maximum EMG signal amplitude was considered to indicate 100% muscle activation. The level of muscle activation recorded during movement was therefore displayed as the normalized %MVIC value, obtained by dividing the MVIC value by 100.20. The raw EMG recordings were monitored during data acquisition, and the EMG signals were full-wave rectified and computed to root mean square (RMS) values. For EMG recording, we used a sampling rate of 1 kHz, a low-pass filter of 500 Hz and a high-pass filter of 20 Hz.

2.3. *Interventions*

2.3.1 Y-Balance training program

We modified the well-known Y-Balance test as previously described as shown Table 2 [22].

Table 2: Y-balance training program

Session		Exercise	Repetition/ sets	time (minute)
Warm-up		Hamstring, Calf, Ankle stretching		5
main	1week	• Move in 6 directions* while standing on one leg • 30 seconds break in each direction	6/3	25
	2-3 week	• Added balance pad • Move in 6 directions while standing on one leg • 30 seconds break in each direction	6/3	25
	4-week	• Move in 6 directions while standing on one leg • 30 seconds break in each direction	6/3	25
	all week	• Do the following performance on the aero step. - Hold for stand on 30 seconds - Close your eyes and stand on 30 seconds - Hold for 30 seconds on one leg standing(each legs) - Hold 30 seconds of squat posture in eyes open(each legs) - Hold 30 seconds of squat posture in eyes close(each legs)	1/1	5
Cool-down		Hamstring, Calf, Ankle stretching		5

*6 directions: anterior, anterolateral, anteromedial, posterior, posterolateral, posteromedial

2.3.2. Aero-step training program

For the balance training program used in this study, we used an aero-step composed of a soft rubber material and two air spaces within the equipment (Aero-Step, TOGU, Germany) as shown Table 3 [13,23].

Table 3: Aero-step exercise program

Session	Exercise	sets	time (minute)
Warm-up	Hamstring, Calf, Ankle stretching		5

main	1-5 week	• Do the following performance on the aero step. - Hold for stand on 30 seconds - Close your eyes and stand on 30 seconds - Hold for 30 seconds on one leg standing(each legs) - Hold 30 seconds of squat posture in eyes open(each legs) - Hold 30 seconds of squat posture in eyes close(each legs) - Give and receive balls while standing 15 times • 10 seconds break every 30 seconds	3	30
Cool-down	Hamstring, Calf, Ankle stretching			5

2.4. Statistical analyses

All statistical analyses were performed with the SPSS (version 20.0). Data normality was determined using the Shapiro–Wilk test. The general characteristics of the subjects and the homogeneity test of the pre-measured dependent variables of each group were performed by one-way ANOVA. Paired t-test was performed to compare intra-group dependent variables, and inter-group dependent variables were compared by independent t-test. All variables were expressed as mean ± SD. The significance level was set to α=0.05.

3. Results And Discussion

3.1. Balance ability (Limits of stability, LOS)

Table 4: Comparisons balance ability between before and after intervention

variables	YBTG pre (M±SD)	YBTG post (M±SD)	*p*	ATG pre (M±SD)	ATG post (M±SD)	*p*	*Bp*
Forward	5.64±1.41	6.80±1.22	0.03*	3.87±1.32	3.99±1.51	0.82	0.13
Reward	4.31±1.32	5.54±.89	0.00*	5.50±1.43	6.41±1.00	0.15	0.63
Left	7.42±.97	7.72±.74	0.23	6.97±1.42	7.34±1.62	0.38	0.87
Right	7.45±.79	8.03±.64	0.02*	7.05±1.56	7.51±1.41	0.39	0.83

*p<0.05, BP: Between group p value, YBTG: Y-balance training group, ATG: Aero-step training group, BO: both leg/open-eyes, BC: both leg/closed-eyes

We found a significant increase in subjects' forward-backward movement range following YBT training relative to their pre-training movement range in Table 4 (p<0.05). We found no significant post-training change in forward-backward movement range for the ATG group or any increased left-right movement range after training as shown Table 4. There was no significant difference in post-intervention movement range change between YBTG and ATG groups as shown Table 4.

Balance is the ability of an individual to maintain the body at equilibrium, which is crucial for all daily movements. Balance ability refers to the ability to maintain one's center of gravity (COG) over one's base of support (BOS) with minimal postural sway while standing, moving voluntarily, or moving in response to an external force[24]. We analyzed the change in the limit of stability as measured by balance testing before and after the two training regimens. We found that in the group receiving Y-Balance training, there was a significant increase in the forward-backward and rightward directions relative to the maximum forward-backward and left-right excursions (p<.05). There was no significant difference between pre- and post-training movement ranges in ATG (p>.05).

YBT is a tool for assessing balance. Ryu et al.[8] used YBT to assess the degree of recovery in professional baseball players with ankle injuries[25], while Lisman et al. used YBT to assess the risk of damage in high school athletes[26]. Other studies have used YBT to evaluate ability of the ankle and lower limbs to balance[27,28]. As such, YBT is closely linked to balance and lower limb function. We believe that a significant increase in balance was observed in this study because we trained subjects using a modified version of the YBT.

3.2. Muscle activity (EMG)

Table 5: Comparisons muscle activity between before and after intervention

variables [unit: ㎷]	YBTG			ATG			
	pre 0(M±SD)	post (M±SD)	*p*	pre (M±SD)	post (M±SD)	*p*	*Bp*
TA	196.46±65.81	262.27±75.52	0.01*	159.66±80.18	214.59±75.40	0.10	0.84
PL	102.17±31.10	143.20±40.43	0.01*	72.98±40.95	103.55±43.89	0.00*	0.96
GCM	145.10±49.67	161.91±64.59	0.32	123.54±47.69	170.28±69.71	0.01*	0.14

*p<0.05, BP: Between group p value, YBTG: Y-balance training group, ATG: Aero-step training group, TA: tibialis anterior, PL: peroneus longus, GCM: gastrocnemius

We found that the activation level of the tibialis anterior and peroneus longus muscles significantly increased following YBT training relative to the pre-training activation as shown Table 5 (p<0.05). We also found that the activation of peroneus longus and gastrocnemius muscles significantly increased following ATG training relative to pre-training activation as shown Table 5 (p<.05). There was no significant difference between YBTG and ATG in terms of the change in the tibialis anterior, peroneus longus, or gastrocnemius muscle activation after training in Table 5.

Because a human's center of gravity rests above and immediately anterior to the ankle joint, the muscles surrounding the ankle (including the gastrocnemius muscle and soleus muscles) are activated during normal balance. The tibialis anterior muscle activates when the body sways backwards, whereas the gastrocnemius becomes active when the body shifts forward[29-31]. During balance control in healthy adults, the activation of the lower limb muscles depends on various conditions. During dynamic movement, the activity of both the gastrocnemius and tibialis anterior muscles is increased when various proprioceptive feedback is provided for balance[31,32]. In this study, activation of the tibialis anterior and peroneus longus muscles significantly increased post-training because the YBT included dynamic movements such as bending the knees. However, aero-step training included mostly static movements, and thus, gastrocnemius muscle activation was increased in the ATG [33,34].

limitation of this study is that the results cannot be generalized to all age groups because the study was conducted on students aged 20–29 at N University in Cheonan-si. Additionally, this study had a limited sample size of 24 patients, and the training intervention was relatively short term (5 weeks). Furthermore, as the study was conducted among healthy adults, it cannot be applied to patients with ankle or lower limb problems. We suggest that future research should include subjects with impaired ability to balance with their ankles.

4. Conclusion

In this study, balance ability was significantly increased (p<.05) after YBTG, and there was a significant increase in the activation of the tibialis anterior and peroneus longus muscles (p<.05). On the other hand, there was a significant increase in the activation of the peroneus longus and gastrocnemius muscles after ATG (p<.05). The results of the Y-Balance training in this study suggest that YBT can be used in future studies to analyze the balance ability at the ankle in patients with ankle disorders or balance impairment.

Acknowledgment

Funding for this paper was provided by Namseoul University

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