Original Article

The effect of functional balance training on the balancing abilities of those who wear high-heeled shoes

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Abstract

Since wearing high-heeled shoes results in the increased chance of falling, it is important for people who wear high heels to do functional balance training. The aim of this study is to examine the effect of functional balance training on the balancing abilities. Nineteen participants were divided into a Control Group (CG) and a Functional Balance Training Group (FBTG). The modified Star Excursion Balance Test (mSEBT) applied with high-heeled shoes was used to study the effects of dynamic postural control, and a provocation test was used to study postural stability. The overall dynamic postural control of those in the FBTG group was significantly better (P<0.05) for both legs than it was among the participants in the CG group. Also in the CG group, postural stability was significantly reduced (P<0.05) in the sway paths. In conclusion, functional balance training leads to improved balancing abilities that may help prevent the occurrence of slipping and ankle sprains.

Keywords: functional balance training, balancing ability, high-heeled shoes

1. Introduction

High-heeled shoes are shoes with heels that are higher than the forefeet. In general, the toe areas are narrow, the heels are hard, and the curvature is on the soles of the feet, which affects foot movement. However, high heels are still among the favorite footwear choices (Bae, Ko, Park, & Lee, 2015) for women because of the demands of fashion and, in some professions, for elegance. Wearing high heels for extended periods of time can result in discomfort and muscular fatigue (Cronin, Barrett, & Carty, 1985), back pain from overuse of certain muscle functions, and increased lumbar lordorsis (Dai *et al*., 2015; Mika, Oleksy, Mika, Marchewka,

& Clark, 2012). The altered pressure on the knees that is caused by walking in high heels may predispose people to degenerative changes in their joints (Kerrigan, Todd, & Riley, 1998). In addition, wearing high-heeled shoes can lead to hallux valgus, musculoskeletal pain (Barnish & Barnish, 2016), and leg injuries at the ankles (39%) and feet (33%) (Barnish & Barnish, 2016; Moore, Lambert, Jenkins, & McGwin, 2015; Tedeschi, Dezzotti, Joviliano, Moriya, & Piccinato, 2012), and especially to ankle sprain that causes tearing of the ankle ligaments (Moore *et al.*, 2015).

High-heeled shoes also cause damage to the circulatory system by reducing the blood flow to the muscles, and as a result the veins of the legs are stimulated, which leads to risk factors for varicose veins (Tedeschi *et al.*, 2012). Furthermore, wearing high heels increases the chances of slipping and falling because the changes that are felt around the ankles affect balance (Blanchette, Brault, & Powers, 2011). Wearing

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shoes with heels that are higher than 5.08 cm (Ebbeling, Hamill, & Crussemeyer, 1994) often leads to fatigue because it is difficult for both feet to balance the weight, and results in a loss of dynamic balance, which can cause falls and ankle sprains.

It is important for those who wear regular high-heeled shoes to work out or receive training to reduce injuries (Kim *et al*., 2015). Previous studies have been conducted on the use of ankle exercises (Ebbeling *et al*., 1994; Kim *et al*., 2015) and balance exercises to help in preventing damage to the ankle joints by improving balancing abilities (Lee, Han, & Lee, 2016). Balance training should also relate to the activities in people's daily lives. Injuries most frequently occur at home (49.5%), on public property (33.1%), and on a street or highway (10.3%) (Moore *et al*., 2015). Training should therefore focus on the specific activities people do in their daily lives. Michell, Ross, Blackburn, Hirth, and Guskiewicz (2006) found that dynamic postural stability can be improved more by practicing functional balance training than through general coordination exercises (Michell *et al.*, 2006). Also, Azeem, and Zutshi (2017) found that functional balance training improved dynamic postural control and that postural control is the key to ankle rehabilitation (Azeem & Zutshi, 2017), since developing control over posture helps the ankle to become more stable (Riemann, 2002; Rozzi, Lephart, Sterner, & Kuligowski, 1999). Clearly, a functional balance training program can be applied to many groups, not only to athletes and patients, and should be used for those who wear high-heeled shoes, which requires good balancing abilities to prevent falls and ankle sprains.

Researchers are, then, interested in introducing functional balance training to those who wear high heels on a daily basis. It is expected that functional balance training will improve dynamic postural control and therefore help to prevent slipping and ankle flipping in people who wear high heels.

2. Materials and Methods

2.1 Subjects

The study involved 22 female student participants from the Kamphaeng Saen Campus, at Kasetsart University. The sample size was determined based on a previous study (Benis, Bonato, & La Torre, 2016) and the means and SDs for the parameters from that study. The calculation was performed using the online G*Power Program, Version 3.1.9, with α=0.05 and 95% power. The participants had habitually worn high heels measuring a minimum of 5 cm for not less than 20 h a week for at least one year. The body mass index (BMI) of the participants did not exceed 24.9 kg/m^2. In addition, none of the participants had experienced pain or injury or had lower extremity surgery within the previous six months, and they had no communication or cognitive impairments and no histories of neurological disorders or vertigo or problems with vision and balance. The participants were divided into two groups: the Control Group (CG, n=11) and the Functional Balance Training Group (FBTG, n=11). The participants were then divided based on ranking, lottery method, and by the composite reach distance score. All participants signed an informed consent form to participate in this study. Participants were excluded if they did not follow the

researcher's advice, had any injuries or were pregnant during the time of the program. During the experimental session one of them in the FBTG dropped out due to an accident and two participants in the CG withdrew from the study.

2.2 Methods

The leg lengths of all participants were measured from the anterior superior iliac spine to the medical malleolus, after which they stretched their leg muscles before undertaking the following test.

2.2.1 Dynamic postural control through the modified Star Excursion Balance Test (mSEBT)

All participants were tested with the mSEBT by standing with high-heeled shoes and reaching leg tap distals of the toe box in three directions (Clagg, Paterno, Hewett, & Schmitt, 2015). They also listened to a demonstration of the test method given by a researcher. The test began with the participant standing on one leg (the measurement leg), making sure that the distal part of the shoe tip was at the center of the grid (Figure 1), and placing both hands on the waist. The participant then reached, or extended, the foot that was not standing so that it was as far away as possible in the anterior, posteromedial, and posterolateral directions (Hertel, 2008; Plisky, Rauh, Kaminski, & Underwood, 2006). The participant practiced this four times in each direction, and the researcher recorded the distances in centimeters for the three trials, allowing the participant to rest for 10 sec after each trial, then to rest for 20 sec after the subsequent trials (Filipa, Byrnes, Paterno, Myer, & Hewett, 2010). The tests ended when any of the following occurred: the participants lost their balance, they did not keep their hands on their waists, the heels of the standing leg did not continuously touch the floor, the reach foot did not touch the floor during the reach, they took their weight off the reach foot on the floor, and the reach leg did not return to the starting position before the next trial.
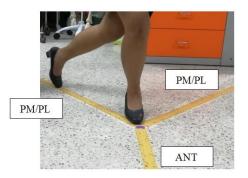

Figure 1.   The modified Star Excursion Balance Test (mSEBT) with three reach directions labeled in reference to the right stance foot.

2.2.2 Postural stability assessed by the provocation test

Postural stability was assessed using dynamic posturography (Kaut, Brenig, Marek, Allert, & Wüllner, 2016), which was performed using an experimentally standardized balance perturbation method that measured the path of medial-

lateral and anteroposterior sway using an ultrasound-based measuring system with a movable and adjustable plate (PosturoMed® device) (Haider-Bioswing, Weiden, Germany). The motions of a plate with markers were obtained by the measurement unit Zebris CMS10 (CMS10, zebris Medical GmbH, Isny im Allgäu, Germany) (Figure 2). The short name for this test is the provocation test (Boer, Mueller, Krauss, Haupt, & Horstmann, 2010; Kiss, 2011). The results of the provocation test were analyzed using Zebris WinPosture software (Holnapy & Kiss, 2013).

Briefly, the measurement unit, an ultrasound-based measuring head, was located 30 degrees to one side of the participant (Figure 2), and the movement of the plate was measured by two ultrasound-based sensors (Ultrasonic marker-big M1311) attached to the side of the plate. The plate was moved to the right relative to the medium position in the mediolateral direction and then locked in this position by the provocation unit. When the participant stood with high-heeled shoes in a double-leg stance in the middle of the platform, the stance width of the feet was standardized by the width of each participant's shoulder. The plate lock was suddenly released without warning, and the plate then swung back to its resting position. Participants were asked to counter the body's center of balance with compensatory equilibrium reactions and were instructed to look straight ahead and to balance with arm motions, without holding onto anything. The movement of the plate was measured until it came to rest, and the results were documented as the sum of all sways 5 sec after release. Five measurements were taken, and participants rested for 60-sec intervals between measurements. Trials were rejected when a participant touched the guardrail. The value for measurement was expressed as the average of two successfully completed trials, which was required. Higher values correspond to greater sway, which is an indicator of the worst clinical performance and impaired postural stability.

In each test, the non-participants performed a test of intratester reliability with the intraclass correlation coefficient (ICC). The test results showed the reliability of the repeat measurement within the test, with the dynamic postural control (mSEBT) test having an ICC value of 0.99 and the postural stability assessed by the provocation test having an ICC value of 0.99. Measurements of all variables of this study were done by blinded investigators but the participants were
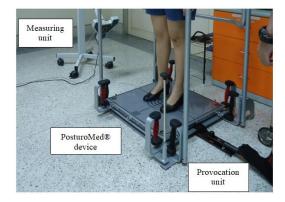

Figure 2.   Measurement arrangement of the provocation test, where the motion of the PosturoMed® device is obtained by the measurement unit and locked by the provocation unit.

not blinded to the study. During the experimental session, the CG participants were advised to perform their daily life activities but were prohibited from extra training.

2.2.3 Functional balance training program

Participants in the FBTG were trained through a functional balance training program three times a week for four weeks (Azeem & Zutshi, 2017; Michell *et al.*, 2006) (Table 1). The FBTG was trained by a group of qualified physical therapists who had more than 15 years experience in laboratory settings.

2.3 Data analysis

The composite reach distance was calculated by taking the sum of the three reach distances (anterior, posteromedial, and posterolateral), and then divided by three times the limb length, and multiplied by 100. The quantitative data including age, height, BMI, composite reach distances of the left and right composite reach distances, and the sway paths from the provocation test are presented as mean and standard deviation (SD).

The data were analyzed using the means and standard deviations calculated from the demographic data, results of dynamic postural control by the mSEBT, and postural stability assessed by the provocation test. The Shapiro-Wilk test was used to test for normal distribution. The Mann-Whitney U test was used to compare the data for weight and BMI between the two groups. The distributions for the left and right composite reach distances were found to be normal. Therefore, an independent *t*-test was used to compare the data from the two groups. Postural stability was assessed by the provocation test using the independent *t*-test for comparison of the data between the two groups. After four weeks, the independent *t*-test was used to compare the data from the two groups for both the dynamic postural control by the mSEBT and postural stability assessed by the provocation test. The level of statistical significance was calculated at $P<0.05$ for all statistical analyses.

3. Results and Discussion

The ages of the participants ranged from 20 to 22 years and the mean±SD ages of the CG and FBTG were 21.36±0.67 and 21±0.77 years, respectively. The heights ranged from 149.5 to 165.0 cm and the mean±SD heights of the CG and FBTG were 160.59±5.13 and 159±4.04 cm, respectively. The weights ranged from 41.0 to 63.3 kg and the mean±SD weights of the CG and FBTG were 50.84±4.61 and 51.21±7.33 kg, respectively. The BMIs ranged from 15.4 to 24.72 kg/m^2 and the mean±SD BMIs of the CG and FBTG were 19.69±1.86 and 20.18±3.15 kg/m^2, respectively (Table 2).

3.1 Comparison of dynamic postural control results using modified Star Excursion Balance Test (mSEBT)

A comparison of the measurements for the dynamic postural controls between the CG and the FBTG before the program showed that the composite reach distance of both

Table 1.   Functional balance training program.

Week 1	Week 2	Week 3	Week 4
Aerobic: side-to-side shuttle, high knee skipping, light running 1 min			
Static stretch: groin, hamstrings, quadriceps, calves (TA tendon) each), buttock kicks 2 min			
Dynamic stretch: leg swings (side) - 30 sec/side, leg swings (front & back), 30 sec/direction 2 min			
Lunges			
Lunges: forward and backward (reps 10/side)	Curtsy lunges (reps 10/side)	Clock lunges (reps 5/side)	Lunge forward onto BOSU ball and backwards off of BOSU ball (reps 20/side)
Squats			
Squats (reps 10)	Bipedal, chair touch (reps 10)	Bipedal on BOSU, ball facing upwards (reps 10)	Single leg (reps 10/side)
Hop			
Hop on the step bipedal (reps 5)	Hop on the step single leg hop (reps 3/side)	Hop on to BOSU: Bipedal, ball facing upwards (reps 10)	Hop on to BOSU: Bipedal, ball facing upwards (reps 15)
Jump			
Vertical jump (reps 30)	Lateral jump (reps 20/side)	Star jump (reps 20)	Star jump: left to right side (reps 30)
Wobble board training protocol			
Double leg stance on wobble board with open eyes (15 sec)	Double leg stance on wobble board with closed eyes (10 sec)	Double leg stance on wobble board with eyes open and closed [Open eyes (25 sec)/Closed eyes (15 sec)]	Double leg stance on wobble board with open eyes (facing down) (30 sec)
Single leg stance on wobble board with eyes open and closed (15 sec)	Single leg stance on wobble board with closed eyes (5 sec)	Single leg stance on wobble board with eyes open and closed [Open eyes (25 sec)/Closed eyes (5 sec)]	Single leg stance on wobble board with eyes open (facing down) (5 sec)
Static stretch: groin, hamstrings, quadriceps, calves (TA tendon) (30 sec/each), buttock kicks 2 min			
Dynamic stretch: leg swings (side) - 30 sec/side, leg swings (front & back), 30 sec/direction 2 min			

Frequency: 3 days per week, Rest: 30 sec. during set and 1 min. during movement.
reps = repetitions
Modified from Azeem & Zutshi, 2017; Baltich *et al*., 2014; Michell *et al*., 2006.

Table 2.   Characteristics of the participants.

Variables	CG	FBTG	P-value
Age (y)	21.36±0.67	21.00±0.77	0.068
Height (cm)	160.59±5.13	159.00±4.04	0.260
Weight (kg)	50.84±4.61	51.21±.33	0.495
Body Mass Index (kg/m^2)	19.69±1.86	20.18±3.15	0.661

Data are presented as mean±SD.
CG=control group, FBTG=functional balance training group.

legs was not significantly different (P>0.05), with the CG left and right composite reach distances were 71.15±10.21 and 72.49±11.69%, respectively, and the FBTG left and right composite reach distances were 76.12±6.64 and 76.05±6.83%, respectively (Table 3).

A comparison of measurements for the dynamic postural controls between the CG and the FBTG after four weeks showed that the composite reach distances of both legs were significantly different (P<0.05). The left composite reach distances of the CG and FBTG were equal to 71.32±11.07 and 90.35±7.94%, respectively, and the right composite reach distances of the CG and FBTG were equal to 71.22±11.07 and 89.39±8.37%, respectively (Table 4) (Figure 3).

3.2 Comparing postural stability assessed by the provocation test

Postural stability was documented as the sum of all sways within 5 sec of releasing the lever for the provocation test at baseline, and comparisons between the CG and FBTG found that the mean±SD values were 237.57±83.98 and 218.07±45.77 mm, respectively. These were not significantly different (P>0.05). However, a comparison between the CG and FBTG after four weeks found that the mean and SD values were 241.26±65.96 and 174.21±26.80 mm, respectively, which were significantly different (P<0.05) (Table 5) (Figure 4).

The main purpose of the study was to compare the balancing abilities in terms of dynamic postural control and postural stability in those who wear high-heeled shoes. Nineteen participants were in the study which included the CG (n=9) and the FBTG (n=10). The ages of the participants in both groups were from 20 to 22 years, and they all had histories of wearing high heels measuring 5 cm or more for at least 20 h a week. The FBTG trained for three days each week for four weeks.

Table 3.   Composite reach distances for the participants at baseline.

Reach distance	CG		FBTG	
	Left side	Right side	Left side	Right side
Anterior	52.17±5.37	52.28±5.74	54.65±4.58	53.84±3.73
Posteromedial	67.96±7.95	68.25±9.41	70.29±7.97	71.00±5.29
Posterolateral	57.97±9.14	59.98±10.28	59.84±7.73	59.81±9.09
Leg length	83.82±4.07	83.45±4.18	80.91±3.24	81.00±3.22
Composite*	71.15±10.21	72.49±11.69	76.12±6.64	76.05±6.83

Data are presented as mean±SD and percentages.
CG=control group, FBTG=functional balance training group.
* Sum of the 3 reach distances (anterior, posteromedial, and posterolateral), divided by 3 times limb length, multiplied by 100.

Table 4.   Composite reach distances for the participants after four weeks.

Reach distance	CG		FBTG	
	Left side	Right side	Left side	Right side
Anterior	52.60±5.38	52.12±5.22	63.73±8.32	61.73±8.32
Posteromedial	68.01±6.45	67.01±9.50	85.04±8.23	82.70±6.13
Posterolateral	55.56±11.81	56.36±11.17	71.10±10.35	73.15±7.93
Leg length	82.78±4.24	82.56±3.91	81.10±3.35	81.20±3.33
Composite	71.32±11.07*	71.22±11.07**	90.35±7.94*	89.39±8.37**

Data are presented as mean±SD and percentages.
CG=control group, FBTG=functional balance training group.
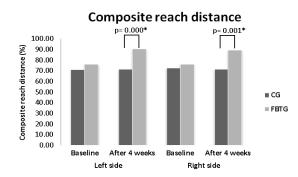*, ** The difference between CG and FBTG was statistically significant at P<0.05.

Figure 3.   Means and standard deviations of the dynamic postural control test results for participants in the control group (CG) and functional balance training group (FBTG) after four weeks.
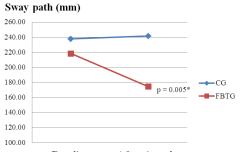* The difference between CG and FBTG after 4 weeks was statistically significant at P<0.05.

Table 5.   Sway paths from the provocation test at baseline and after four weeks.

Variables	CG	FBTG	P-value
Baseline	237.57±83.98	218.07±45.77	0.670
After 4 weeks	241.26±65.96*	174.21±26.80*	0.005*

Data are presented as mean±SD and mm.
CG=control group, FBTG=functional balance training group.
* The difference between CG and FBTG was statistically significant at P<0.05.

Figure 4.   Means and standard deviations of sway path test results for participants in the control group (CG) and functional balance training group (FBTG) at baseline and after four weeks.
* The difference between CG and FBTG after 4 weeks was statistically significant at P<0.05.

The study revealed that the FBTG was significantly better than the CG in terms of dynamic postural control which was the result of the composite reach distance of both legs and the postural stability that measured the sway paths after the training period.

Previous studies have reported that functional balance training has beneficial effects that may prove to be an effective means of proprioceptive rehabilitation. Therefore, it may be an effective tool in reducing the epidemiology of ankle sprains in sports (Azeem & Zutshi, 2017). Baltich, Emery, Stefanyshyn, and Nigg (2014) found that following functional balance training programs for eight weeks reduced the intrinsic risk factors for running injuries and the resulting injury rates in novice runners (Baltich *et al.*, 2014). Functional balance training involves learning patterns of skilled body movements that simultaneously require movement and production of stabilization forces. Essentially, one part of the body is in motion while another is held immobile (Potach & Chu, 2000). Dynamic postural control, which is the result of the composite reach distance of both legs, represents the body's ability to maintain the center of mass within the base of support (Winter, Patla, & Frank, 1990) while the body is moving in different directions. This program uses exercises that control the movement of the head, body, and extremities in all planes of motion. Dynamic postural control can be developed by practicing balance training that improves muscular strength, range of motion, neural control of movements, and psychological factors through areas of the central nervous system such as the visual, vestibular, and neurosensory systems, and sensations of the joints (proprioception) (Wang, Li, Xu, & Hong, 2008).

Postural stability, which measures the sway path decrease from baseline, shows that the center of gravity is in alignment with the base of support and the participants have automatic adjustments that they can use to return the body to alignment to prevent falls. Functional balance training should also include protocols that require the body to respond to varied perturbations and exercises to reinforce the control movements of the head, body, and extremities, triggering a reaction that enhances stability. Alteration in the spatial locations of the data points for the centers of pressure may indicate a more optimally functioning sensorimotor system (Mettler, Chinn, Saliba, McKeon, & Hertel, 2015). Exercises should be executed in all planes of motion while keeping in mind that the sensory system provides the body with information. Exercise shows improved postural stability through shifts away from the center of balance with a return to sta-

bility. The findings of this study were similar to those of Rozzi *et al.* (1999), who reported that balance training appears to indicate that four weeks is a sufficient amount of time in which to develop the reflex muscular activation patterns that are necessary for the maintenance of posture and balance (Rozzi *et al.*, 1999).

This study of functional balance in relation to dynamic postural control supports a recent study (Michell *et al.*, 2006) which showed that dynamic postural control and postural stability can be developed by practicing functional balance and this helps to prevent slipping and ankle sprains (Azeem & Zutshi, 2017). Therefore, it can be recommended that those who wear high-heeled shoes follow this program on a daily basis, doing the training on their own since it is not complicated. However, to confirm the beneficial effects of practicing functional balance training for those who wear high-heeled shoes, further studies should be undertaken using high quality equipment to investigate the effects of functional balance training on ankle instability.

4. Conclusions

The study concludes that functional balance training for four weeks leads to improved balancing abilities (dynamic postural control and postural stability) among those who wear high-heeled shoes. These results may help to prevent the occurrence of slipping and ankle sprains in people who wear high heels.

Acknowledgements

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