



Original Article

The effect of shoe type on static and dynamic balance during treadmill walking in young healthy women

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Abstract. [Purpose] The purpose of this study was to analyze the effect of various shoes on the static and dynamic balance of young women in their 20s. [Subjects and Methods] The subjects of the study were 15 healthy young women and repeated measured design. The subjects walked on the treadmill at a speed of 4 km/h for 30 minutes wearing three types of shoes: sneaker, rain boots, and combat boots. Balance was measured by a Romberg test and a limits of stability test. One-way ANOVA was used for statistical analysis. [Results] As the results of the Romberg test, the main effect of time was shown in the EO-COG area, EO-COG length, and EO-COG velocity. As the results of the limits of stability test, the main effects of time in LT, RT, FW, and total. There were significant differences in the LT in the sneaker group, the rain boots group, and the LT and RT in the combat boots group between the pre- and post-test. [Conclusion] The characteristics of shoes such as the materials, hardness, and thickness of the soles, the coefficient of friction of the outsoles, and the collar height affected the static and dynamic balance.

Key words: Sneaker, Rain boots, Combat boots

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INTRODUCTION

Humans have been walking as a means of movement for a long time. This movement includes external shocks and stimulation, and thus humans wear shoes to protect their joints and absorb shock loads¹⁾. Now, studies about effective walking and running include testing the effectiveness of materials and types of shoes, and are no longer limited to human motion analyses²⁾.

Balance is maintained through the dynamic integration of internal and external³⁾. Balance is essential for functional activity and functional motion. Functional balance is the ability to maintain a position and adjust posture during moving a postural position or a functional motion.

Many previous studies were widely studied in relation to shoes and balance. Wearing high heels was determined to induce muscle fatigue, and decrease static and dynamic balance ability⁴⁾. Another study analyzed the static balance of women in their 20s who wore shoes with different heels, finding that static balance decreased in the high-heel shoe group⁵⁾. A different study analyzed the effects of athletic shoes, five-toed shoes, and standing barefoot on the balance of young adults, and found significant differences in the anterior-posterior and all conditions⁶⁾.

People must consider the type of shoes and the heights of heel to wear in daily life. Despite the diversification of the purpose and desire for shoes in young women and the women in their 20s tend to wear low-heeled casual shoes⁷⁾, most previous studies have performed about high-heeled shoes and sports shoes. Thus, the purpose of this study was to analyze the effects of wearing certain shoes on the balance of healthy women in their 20s during treadmill walking, specifically sneaker, rain boots, and combat boots.

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SUBJECTS AND METHODS

The participants of this study were 15 healthy women in their 20s at an N university. The study group included women with normal vision⁸⁾, and excluded those with musculoskeletal or neurological disorders, a history of surgery of the back or lower extremities, and joint diseases, such as, Gout, OA, or RA. They had to understand the purpose and content of this study before the experiment and voluntarily consent to the experiment. This study was approved by the Institutional Review Board of Namseoul University

A body composition analyzer (InBody720, Biospace Co., Ltd., Seoul, Republic of Korea) was used to determine the general characteristics of the subjects. A treadmill (SNS care m-400m, SNS Care Co., Ltd., Goyang, Republic of Korea) was used to measure walking. A computerized balance platform (BT4, HUR Labs Oy, Tampere, Finland) was used to determine balance control.

The experimental design of this study hinged on repeated measures; the participants wore three kinds of shoes sneaker (Converse Inc.), rain boots, and combat boots) and walked on the treadmill. The three shoes were selected with similar characteristics (total height=17 cm, heel height=2 cm, weight=0.8 kg) to avoid the effects of shoe's characteristics. Their balance was measured three times with barefoot before and immediately after the treadmill walking to improve the accuracy of the data and to remove the characteristics of the shoe. The mean of three measures was used for statistical analysis. The participants walked at a speed of 3.6 km/h⁹⁾ for 30 minutes on the treadmill. They rested for 24 hours in order to prevent fatigue between sessions wearing each shoe⁶⁾.

The Romberg test and limits of stability test were performed to measure balance after treadmill walking. The Romberg test was also performed with eyes opened (EO) and eyes closed (EC) on bare feet for 30 seconds¹⁰⁾. The participants were asked to bend one leg along the anterior-posterior axis of the balance platform at 30 degrees and to stand on the contralateral leg, in order to maintain as stable a stance as possible¹¹⁾. When the limits of stability were measured, their feet were aligned along the mark point of the medial malleolus printed on the platform, and their center of pressure was placed as a curve shown in the first position on a computer monitor. They were asked to move their weight along each direction (one direction at a time) according to the appearance of a target on the monitor as soon as possible (using the ankle joint according to the primary axis of movement, without changing the foot position). The directions of the target, which had been randomly selected by the researcher, were shown for only 8 seconds⁸⁾. In this study, the directions measured included forward (FW), backward (BW), right (RT), left (LT) and all directions (total).

The data measured in this study were analyzed using SPSS version 18.0. The Kolmogorov-Smirnov test was used to demonstrate a normal distribution, and the Levene F-test was used to verify the homogeneity of the subjects. One-way ANOVA (analysis of variance) was used to compare the difference in balance, depending on the group (sneaker, rain boots, and combat boots) and time (pre- or post-test). When there was a significant difference, the Scheffé test was used for post-hoc analysis. The statistical significance level was set at $\alpha=0.05$. This study was approved by the Institutional Review Board of Namseoul University (Cheonan, Korea, NSU-140528-1).

RESULTS

The purpose of this study was to analyze the effects of various shoe types on the balance of 15 young healthy women. The general characteristics of the participants (age, height, weight) are shown in [Table 1](#).

The results of the Romberg test did not show significant differences in the interaction effect between groups and time. The main effects of the group did not appear to be significant. The main effects of time appeared in EO-COG area, -COG length, and -COG velocity. There were significant differences in the EO-COG area, -COG length, and -COG velocity in the sneaker group; in the EO-COG length in the rain boots group; and in the EO-COG area in the combat boots group between the pre- and post-test ([Table 2](#)).

The results of the limits of stability test did not show significant differences in the interaction effects between the groups and time. The main effects of the group did not appear to be significant. The main effects of time appeared in the LT, RT, FW, and total directions. There were significant differences in the LT in the sneaker group; in the LT in the rain boots group; and in the LT and RT in the combat boots group between the pre- and post-test ([Table 3](#)).

DISCUSSION

The functions of feet include providing plantar pressure, body support, shock absorption, and postural adjustments to maintain a standing posture¹²⁾. This study was to analyze the effects of the static and dynamic balance according to three types of shoes on treadmill walking of healthy women in their 20s.

As the results of the Romberg test, no significant difference was found in the interaction effect between groups and time. The main effects of the group did not appear to be significant. The main effects of time appeared in the EO-COG area, -COG length, and -COG velocity. There were significant differences in the EO-COG area, -COG length, and -COG velocity in the sneaker group; in the EO-COG length in the rain boots group; and in the EO-COG area in the combat boots group between the pre- and post-test.

Table 1. General characteristics of the participants

	Mean ± SD
Age (years)	20.50 ± 0.52
Height (cm)	159.08 ± 4.96
Weight (kg)	51.42 ± 7.29

Table 2. Comparison of Romberg test between the pre- and post-test

Variable	Group	Pre-test	Post-test
EO COG area* (mm ²)	Sneaker	18.91 ± 13.79	30.18 ± 40.69 ⁺
	Rain	18.91 ± 13.79	105.41 ± 126.21 ⁺
	Combat	18.91 ± 13.79	86.05 ± 136.59 ⁺
EO COG length* (mm)	Sneaker	5.42 ± 0.99	5.46 ± 0.86 ⁺
	Rain	5.42 ± 0.99	7.83 ± 3.57 ⁺
	Combat	5.42 ± 0.99	6.06 ± 1.69 ⁺
EO COG velocity* (mm/s)	Sneaker	0.26 ± 0.04	0.28 ± 0.06 ⁺
	Rain	0.26 ± 0.04	0.39 ± 0.19
	Combat	0.26 ± 0.04	0.31 ± 0.08
EO length/cm ² (mm/cm ²)	Sneaker	50.36 ± 45.68	19.92 ± 22.93
	Rain	50.36 ± 45.68	37.88 ± 32.26
	Combat	50.36 ± 45.68	32.89 ± 63.91
EC COG area (mm ²)	Sneaker	21.66 ± 30.55	15.66 ± 21.61
	Rain	21.66 ± 30.55	67.66 ± 85.17
	Combat	21.66 ± 30.55	45.91 ± 54.52
EC COG length (mm)	Sneaker	5.25 ± 1.24	5.02 ± 1.22
	Rain	5.25 ± 1.24	7.34 ± 3.39
	Combat	5.25 ± 1.24	5.49 ± 2.46
EC COG velocity (mm/s)	Sneaker	0.25 ± 0.06	0.35 ± 0.16
	Rain	0.25 ± 0.06	0.24 ± 0.06
	Combat	0.25 ± 0.06	0.26 ± 0.12
EC length/cm ² (mm/cm ²)	Sneaker	5.25 ± 1.24	7.34 ± 3.39
	Rain	5.25 ± 1.24	5.97 ± 2.67
	Combat	5.25 ± 1.24	5.02 ± 1.22

Expressed as mean ± SD; *p<0.05; ⁺p<0.05: compared with post-test; EO: eyes open; EC: eyes closed; COG: center of gravity

Table 3. Comparison of limits of stability between the pre- and post-test (degrees)

Variable	Group	Pre-test	Post-test
Left**	Sneaker	6,342.00 ± 1,803.99	8,455.33 ± 2,209.37 ⁺
	Rain	6,342.00 ± 1,803.99	7,993.36 ± 2,380.12 ⁺
	Combat	6,342.00 ± 1,803.99	8,556.08 ± 2,078.23 ⁺
Right*	Sneaker	5,760.50 ± 1,689.20	6,990.17 ± 1,332.05
	Rain	5,760.50 ± 1,689.20	6,822.27 ± 1,876.45
	Combat	5,760.50 ± 1,689.20	7,611.83 ± 1,910.35 ⁺
Forward**	Sneaker	7,853.25 ± 3,008.33	11,141.75 ± 2,292.52 ⁺
	Rain	7,853.25 ± 3,008.33	10,297.82 ± 3,450.76
	Combat	7,853.25 ± 3,008.33	10,712.33 ± 3,654.99 ⁺
Back	Sneaker	3,970.92 ± 1,177.37	4,647.17 ± 1,855.00
	Rain	3,970.92 ± 1,177.37	4,526.82 ± 1,722.33
	Combat	3,970.92 ± 1,177.37	4,569.83 ± 1,337.51
Total**	Sneaker	12,102.50 ± 3,384.57	15,622.25 ± 2,664.55 ⁺
	Rain	12,102.50 ± 3,384.57	14,704.82 ± 3,993.19
	Combat	12,102.50 ± 3,384.57	16,146.83 ± 3,862.23 ⁺

Expressed as mean ± SD; *p<0.05; **p<0.01; ⁺p<0.05: compared with post-test

In a previous study, the impact force of high-heel shoes and running shoes was analyzed, and the impact force was higher in the high-heel shoes than the running shoes¹³. The potential benefits of high-heel and high-collar shoes would be that they may help with balance and the gait¹⁴. A study that compared the balance CVA patients achieved with slippers, flat shoes, and high heel and high-collar shoes found they had more difficulty with postural control in the slippers and flat shoes than the high-heel and high-collar shoes¹⁵. After inducing muscle fatigue in the young women, significant differences were evident in their pre- and post-fatigue levels in the results of the Romberg test¹⁶. Another previous study demonstrated higher postural control with EO than EC; these results occurred because postural control depends on multisensory interaction¹⁷. The visual system plays an important role in proprioceptive action, postural control, and the body's neutral fluctuation maintenance in verticality and limits of stability tests¹⁸.

In this study, based on the results of the Romberg test, the main effects of time were significant differences in the EO-COG area, -COG length, and -COG velocity. These results occurred due to the participants' decreased balance ability after muscle fatigue was induced by treadmill walking for 30 minutes. No significant difference was found with EC. It is considered that the movement was decrease due to a fear, such as falls, because they were not provided visual feedback.

The static balance of the sneaker group was note worthily lower than that of the rain boots group and the combat boots group across most variables. It can be hypothesized that the sneaker group didn't alleviate weight loads and ground reaction force was delivered intact because the sneaker has relatively lower heels and cushion soles, and are close to the ground. The static balance also decreased because the action of low-heel and low-collar shoes was weak and led to difficulty in postural control compared to the other shoes, although the heels were not high.

As the results of the limits of the stability, the interaction effect of the group and time did not appear, and the main effect of the group also did not appear to be significant. The main effect of time appeared in the LT, RT, FW, and of all directions. There were significant differences in the LT in the sneaker group; in the LT in the rain boots group; and in the LT and RT in the combat boots group between the pre- and post-test.

In measuring balance based on heel height and muscle fatigue, the results showed that both static and dynamic balance decreased when muscle fatigue was induced. In these results, the fatigue of the lower extremities was a factor in decreasing balance, while increased muscle fatigue caused an unbalance and weakened the stability of the foot and the ankle, which induces the balance mechanism to increase the ankle's muscle activity and can be a factor in increasing both overall musculoskeletal problems and the risk of falls⁴. In a study related to effect of stability on healthy women walking in uncomfortable sandals, it was reported that muscle activity increased when they were wearing the uncomfortable sandals, with these affects appearing specifically along the gait steps and sole shape, related to a mechanism of instability on the central pressure variable and joint angle¹⁹. Another previous study reported that a risk of falls brought the higher baseline of sway in the ML direction²⁰.

The results of the limits of stability test showed there were significant differences in the LT, RT, FW, and total directions between the pre- and post-test; in the LT in the sneaker groups; in the LT in the rain boots group; and in the LT and RT in the combat boots group. The muscle fatigue induced by treadmill walking caused muscle activity to become unbalanced and weakened the stability of the joints, which led to significant differences in the limits of stability. There were significant differences in the combat boots group in more directions than in the sneaker and rain boots group. The higher heels and inflexible high-heel collars of the combat boots brought limits to the ankle joint angle, which affected the maintenance of dynamic stability, unlike static balance. There were significant differences in EO, except the BW and in the LT, RT not the FW, and BW in each shoe type. Because of the participants' fear regarding the risk of falls, there was no significant difference in the BW and in the AP directions between each shoe type.

In conclusion, this study analyzed the effects of three types of shoes on the static and dynamic balance of healthy women in their 20s: sneaker, rain boots, and combat boots.

The results of this study are as follows. (1) The results of the Romberg test showed that the main effects of time were significant differences in the EO-COG area, EO-COG length, and EO-COG velocity. There were significant differences in the EO-COG area, EO-COG length, and EO-velocity in the sneaker group; the EO-COG length in the rain boots group; and the EO-COG area in the combat boots group between the pre- and post-test. (2) Based on the limits of stability test, the main effects of time were significant differences in the LT, RT, FW, and total directions. There were significant differences in the LT in the rain boots group, and in the LT and RT in the combat boots group between the pre- and post-test. These results showed that the characteristics of the shoe, the material, hardness, and thickness of the sole, the coefficient of friction of the soles, the heel height, the height of the collar, etc., affect static balance and dynamic balance differently. The static balance is better with the rubber materials, soft soles, low heel heights, and high collar heights, while the dynamic balance is better with soles that have an appropriate coefficient of friction and a low collar height. Thus, this study can help people to choose the appropriate shoes for walking in accordance with the objectives of their daily lives and the balance capacity of modern shoes.

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