The effect of shoe sole thickness on body sway and heart rate during walking with platform shoes

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Abstract

The effect of shoe sole thickness on body sway and heart rate during walking with platform shoes

The purpose of this study was to investigate the effect of shoe ole thickness on body sway and heart rate during walking with platform shoes.　Eight male and female college students walked on a treadmill while wearing 5 types of sneakers with different thicknesses, i.e., 11-45mm at 5 km / h and simultaneously measured heart rate as indicator of whole body physiological burden.　There was no significant effects of shoe sole thickness on the average acceleration and heart rate.　The result of this study suggested that body sway and physiological burden are not influenced by different sole thickness of platform shoes, ranging from 11mm to 45mm, during walking.

厚底靴による身体動揺や心拍数との関連性

本研究の目的は、厚底靴を用いたソールの厚さが身体動揺や心拍数へ与える影響を調査することであった。若年男女 8 名の大学生が時速 5km/h で 5 種類のソールの厚さが異なる(11-45mm)スニーカーを着用してトレッドミル上を歩行し、同時に全身性の生理学的負担して心拍数も計測した。シューズのソール厚の違いは、上下方向、左右方向、および前後方向の平均加速度と心拍数に有意な影響を及ぼしていなかった($p>0.05$)。得られた結果から、歩行中の重心動揺や生体負荷は、シューズのソール厚が 11mm から 45mm の範囲で大きく異なっていても影響を受けていなかったと考えられた。

厚底运动鞋与姿势运动和心率的相关性

这项研究的目的是调查在穿厚底鞋行走过程中鞋的鞋垫厚度对身体摇摆和心率的影响。 八名男女大学生在跑步机上行走时，穿着 5 种厚度不同的运动鞋，即 5 km / h 的运动鞋厚度为 11-45mm，并同时测量了心率，作为全身生理负担的指标。 鞋底厚度对平均加速度和心率没有显着影响。 研究结果表明，在步行过程中，不同的厚底鞋的鞋底厚度（11mm 至 45mm）不会影响身体的摇摆和生理负担。

Introduction

In recent years, various shapes of sneakers have been developed in the market. Looking at the collections of each brand held each year, especially many shoes with thick soles were sold this year, for example, 5 type shoes for forefoot 5cm, heel 8cm, 5 types shoes for forefoot 3cm, heel 5cm from Maison Margiela (maisonmargiela, 2019), 15 type shoes with 5cm sole from Louis Vuitton (louisvuitton, 2019), 2 types shoes with 8cm sole from COMME des GARÇONS (comme-des-garcons, 2019), 1 type shoes for forefoot 2.1cm, heel 3.1cm from NIKE (nike, 2019) and 5 typed shoes with 5cm sole from Alexander McQueen (alexandermcqueen, 2019) are sold in the official online store. Although the danger of platform shoes has been suggested for several year reference, platform shoes have become popular among young women. According to the National Consumer Affairs Center of Japan, more than 20 accidents with platform shoes occurred in 1998, accounting for 39% of the total of women's shoes, with examples of falls and falls on steps and stairs mainly (National Consumer Affairs Center of Japan, 1999). Highest number of age group for its accidents is twenties (32, 40%), followed by thirties (18, 23%) (National Consumer Affairs Center of Japan, 1999). Around 20's (10's to 30's) alone will occupy 76% (National Consumer Affairs Center of Japan, 1999). In addition, it is pointed out that platform shoes neglect the functions necessary for walking, and furthermore, lack of stability tends to lead to sprains and toppling (National Consumer affairs Center of Japan, 1999). This higher foot position can be associated with some concern as it takes a longer time to adjust to a weight bearing surface change because of its greater distance. In other words, while wearing a thicker shoe sole, joint position sense may be altered by eliminating the adaptability of the joint to the change in surface. This condition may predispose the body to become more unstable because the center of gravity has been raised, and because the plantar surface of the foot is removed more from the contact surface.

In previous study, several other characteristics, including factors thought to be related to foot position sense (sole thickness and flexibility and heel-collar height), bore little apparent relation to risk of a fall (Tencer et al., 2004). Besides, other styles with relatively stiff soles included athletic shoes, sandals, and lace-up oxfords, all of which also had relatively thick fore-soles. These shoes characteristics were found to have little association with risk of a fall (Tencer et al., 2004). There have been some reports dealing with heart rate about its usefulness as a risk assessment for falls and physiological burden of whole body movement (Howcroft et al., 2013, Kavanagh et al., 2008, Menz et al., 2003, Doi, et al., 2013). However, these experiments were not use platform shoes.

Nowadays, number of young people wearing thick soles are increasing. Although it seemed that platform shoes associate with fall risk, no studies have investigated the relationship between fall risk and platform shoes. The purpose of this study is to examine the effect of shoe sole thickness on body sway and heart rate during walking with platform shoes. I hypothesized that body sway and heart rate are not influenced by difference in sole thickness of platform shoes.

Materials and Methods

Participants

Eight University students with no abnormalities in the lower limbs participated in this study. The subject gave informed consent for the study after receiving a detailed explanation of the purpose, potential benefits, and risk associated with participation in the study. In the case of female subjects, the method of attaching the equipment used was fully explained and attached in the correct position.

Experimental design

In the experiment, subjects walked on treadmill (WELL ROAD 200E, TAKEI, Niigata, Japan) with wearing five different (23cm, 24cm, 25cm, 26cm, 27cm, 28cm) custom-made shoes (MIZUNO corporation, Osaka, Japan). These custom-made shoes have different sole thickness (Forefoot-Heel: 11mm - 15mm, 21mm - 25mm, 31mm - 35mm, 41mm - 45mm, 25mm - 35mm). Before the experiment began, we asked to subjects about their height and the size of shoes they normally wear. In order to adjust the walking conditions, the subject walked on the treadmill. Walking speed was set at 5 km/h and walked for 2 minutes for each sole. According to Adachi et al. (2014), the average walking speed of the entire Japanese was 1.364m/s. Since this is about 5 km/h, the walking speed was set at 5 km/h. We used a three-axis accelerometer (FA-DL-111A, 4 assist, Tokyo, Japan) for estimating body sway in this experiment, and the sensor was attached to the subject's tailbone. The calibration values of the three-axis acceleration sensor were 1.97V in the vertical direction, 1.99V in the horizontal direction, and 1.97V in the longitudinal direction for 19.6m/s/s. Previous studies have shown that gait assessment using a three-axis accelerometer is effective in a clinical environment (Sakurai et al., 2010). Therefore, we used a three-axis accelerometer in this experiment. The accelerometer can evaluate the stationarity of the center of gravity in the walking motion, and the failure of the stationarity means an increase in the body sway (Koda et al., 2016). The foot switch was attached to the heel of the right foot to detect gait cycle. Electrodes (CMT-01MTH-0.8D, FUKUDA DENSHI, Niigata, Japan) were placed on the right sternal and left ribs between the bones, electrodes were placed on the right ribs of the bones, and the electrocardiogram / respiration transmitter was LX-8100 (FUKUDA DENSHI, To

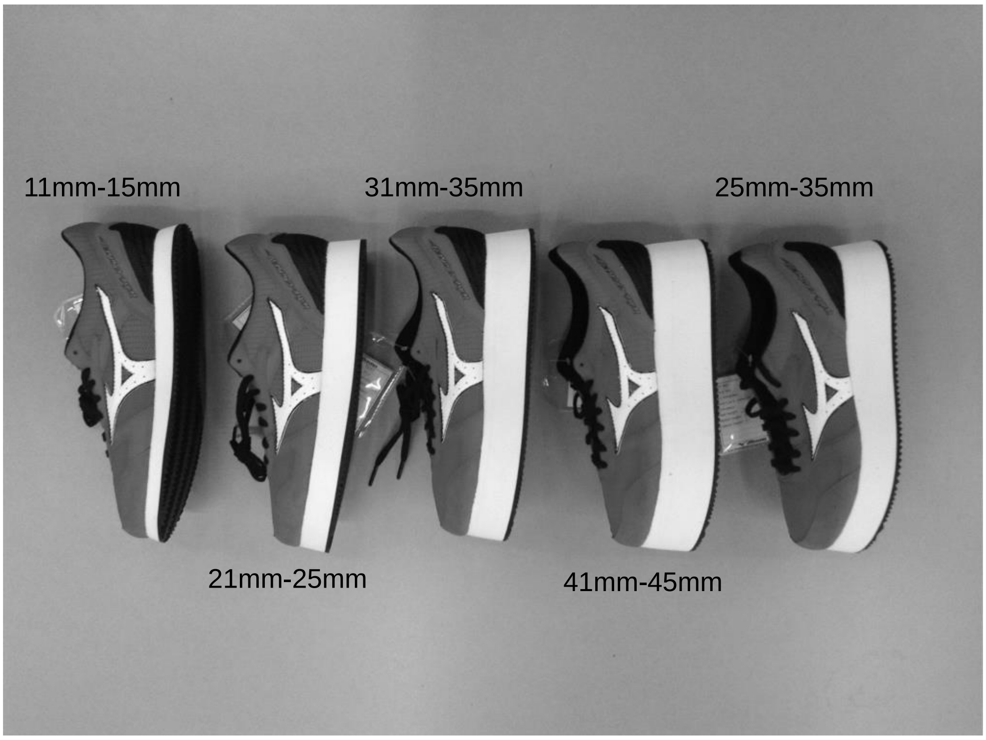

Fig. 1 Five type of sneaker used in this experiment (Forefoot-Heel: 11mm-15mm, 21mm-25mm, 31mm-35mm, 41mm-45mm, 25mm-35mm).

kyo, Japan). Data sent from LX-8100 was received by DYNASCOPE DS-8600 system (FUKUDA DENSHI, Tokyo, Japan). Time was measured with a stopwatch and the heart rate displayed on the DYNASCOPE DS-8600 system was recorded in a notebook every 10 seconds. During walking, a mark was hung at the tip of the subject's line of sight to prevent the line of sight from shifting, and the height of the mark was adjusted each time the shoe changed. While walking, used a lifting device to prevent the subject from falling. After wiping the three parts of the body with alcohol, we attached electrodes.

The data obtained at the time of walking measurement was synchronized with the acceleration data on a personal computer using Lab Chart 8 software (ADInstruments, Melbourne, Australia). One minute in the second half of the calculated acceleration data for 8 persons was extracted, and an average value and a standard deviation were calculated for each thickness of the sole. The walking cycle and the number of steps were calculated from the measured foot switch data. From the calculated cadence data, 1 minute in the second half was extract and the coefficient of variation was calculated to determine the variation in the walking cycle. Average heart rate was calculated for 1 minute of latter half of trial.

Statistics

The parametric analysis was used for normally distributed data and the non-parametric analysis was used for non-normally distributed data. The effect of different shoe sole thickness on vertical acceleration, lateral acceleration, longitudinal acceleration, and heart rate were tested the Friedman test. The level of statistical significance was set at $p < 0.05$. Statistical analyses were performed using SPSS software (version 25; SPSS, Tokyo, Japan).

Result

There were no significant effects of shoe sole thickness on the average acceleration and heart rate ($p>0.05$) (Figures 2 and 3). Figure. 4 and Figure. 5 show the average number of steps per minute and the average coefficient of variation of the walking cycle for each sole thickness obtained in this experiment. Figure 4. and Figure 5. did not perform statistical processing, but were graphed as obtained data. There was no significant effect of shoe sole thickness on the average coefficient of variation of walking cycle and steps ($p>0.05$).

Discussion

In this study, we investigated the effect of shoe sole thickness on body sway and heart rate during walking with platform shoes. There were no significant effects of shoe sole thickness on the average acceleration for vertical, lateral, and longitudinal directions and heart rate ($p>0.05$). These result supports the hypothesis. In the previous study, it was considered possible to evaluate the center of gravity sway using a three-axial accelerometer (Hiiragi, 2004).

The increase in up-and-down sway has been shown to be related to falling (Koda et al., 2016). Even when the sole was thick, the average acceleration in the vertical direction was almost flat. Therefore, there is no danger of falling in the front-rear direction of the platform shoes. It has been reported that the average fluctuation width of the left and right sides of the body's center of gravity depends on walking speed and decreases significantly with increasing walking speed under stable walking conditions (Shinoda et al., 2008). Other researchers have reported the speed dependence of the left and right swing width of the body center of gravity (Shinoda et al., 2008).

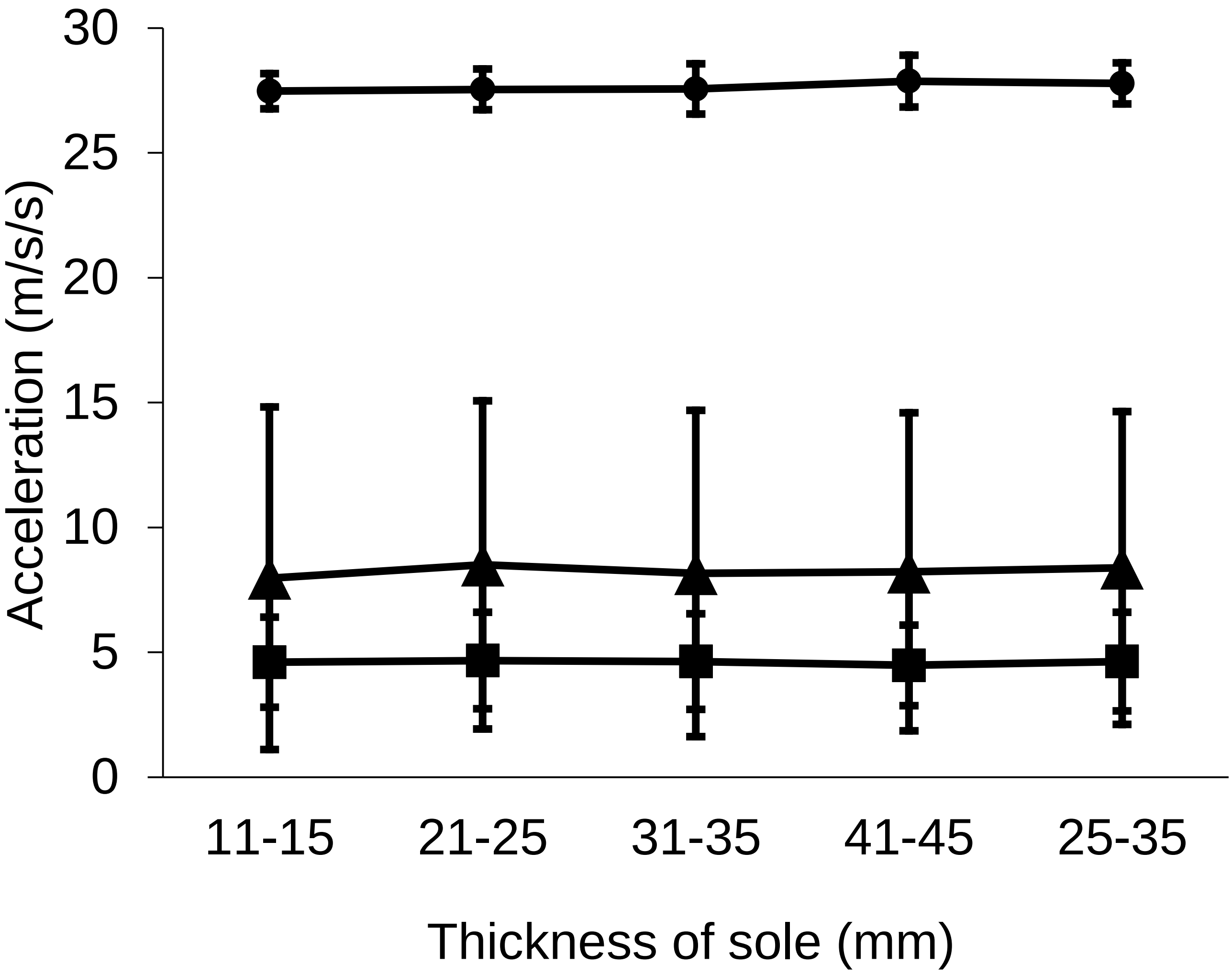

Fig. 2 Mean (SD±) transition of average acceleration for each sole for 1 minute ($p > 0.05$).

Black circle, vertical direction

Black triangle, horizontal direction

Black square, longitudinal direction

Forefoot-Heel: 11mm-15mm, 21mm-25mm, 31mm-35mm, 41mm-45mm, 25mm-35mm

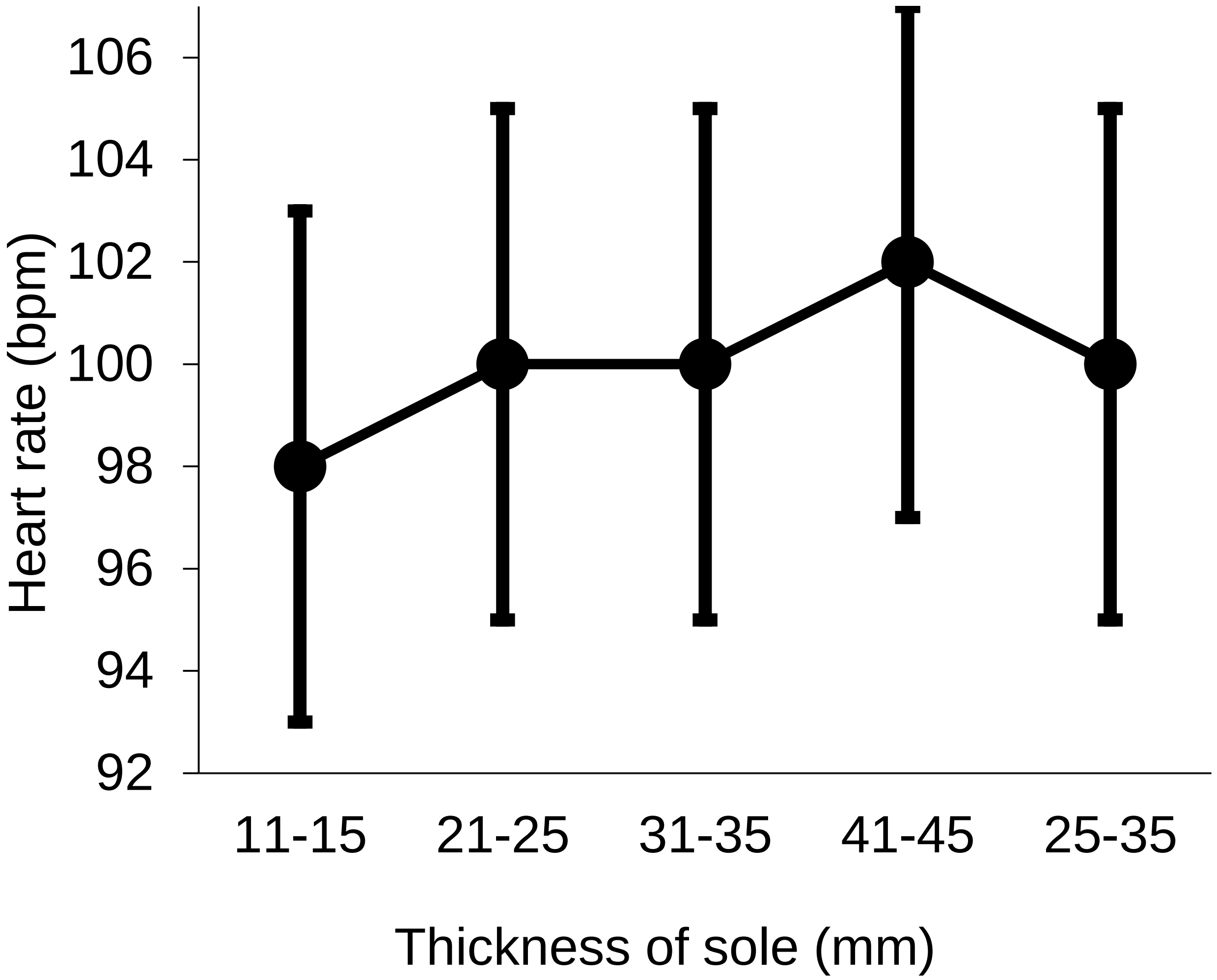

Fig. 3 Mean (SD±) average heart rate per minute recorded every 10 seconds on each sole (p>0.05).

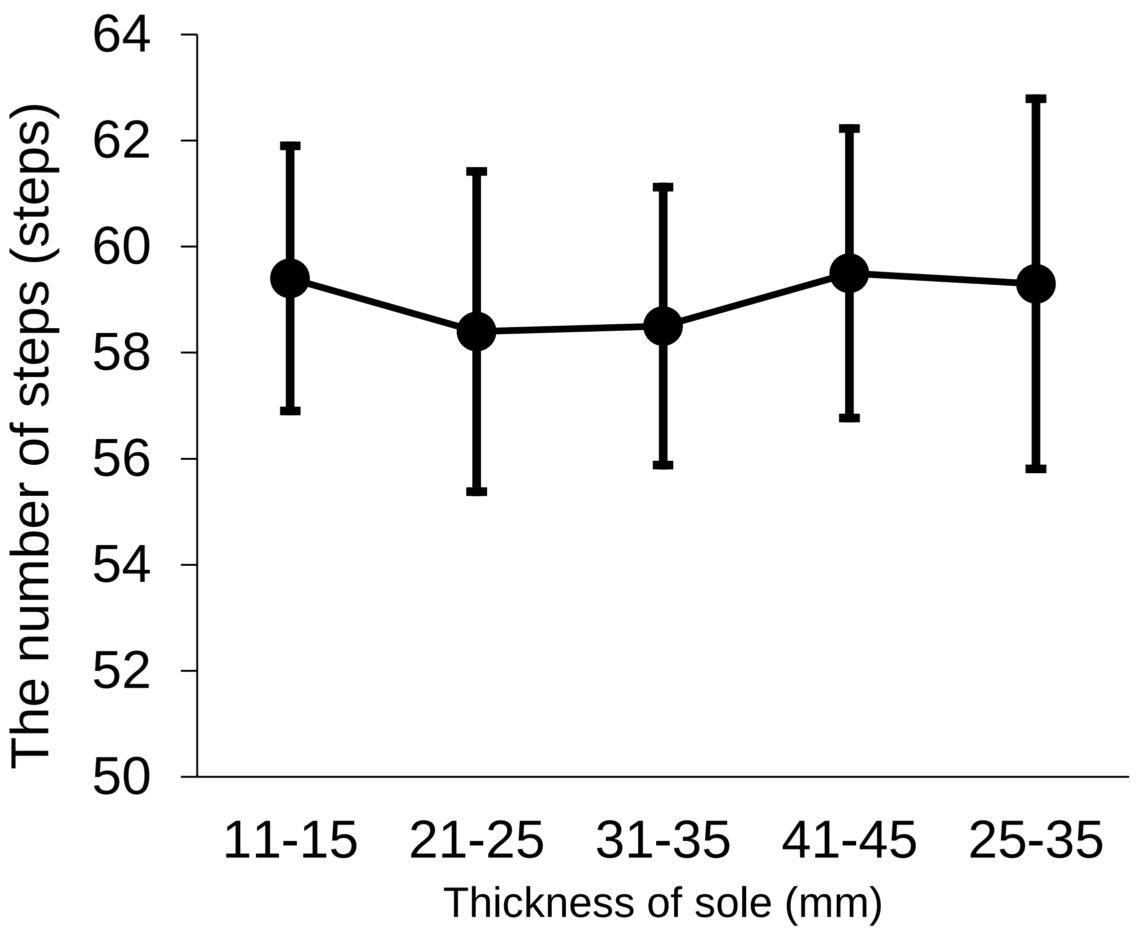

Fig. 4 Mean (SD±) average steps per minute in each sole (p>0.05).

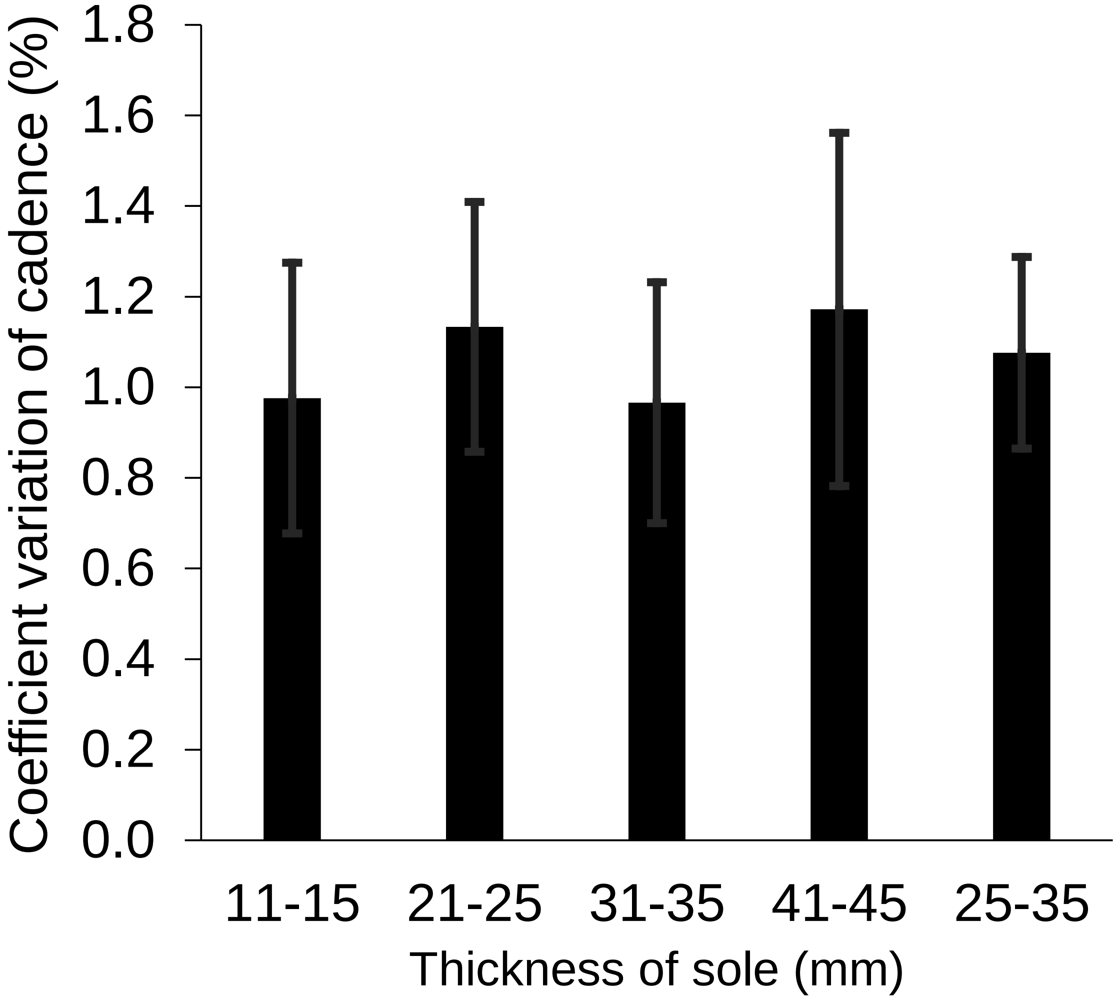

Fig. 5 Mean (SD±) 1 minute average walking cycle for each sole (p>0.05).

Orendurff et al. (2004) showed that the lateral variation of the center of gravity decreased with increasing walking speed (Orendurff et al., 2004). Compared with walking at low speed (1 km / h), walking at high speed (5 km / h) decreased the body sway of the center of gravity (Shinoda et al., 2008). In our study, we did not use the left and right sway width as an index, but because the treadmill speed (5km/h) was fixed as in the previous study, this experiment can be said to be stable walking depending on walking speed. As a result, there was no significant effects of shoe sole thickness on the average horizontal acceleration (Fig. 2). Therefore, it is considered that there is no risk of falling in the left-right direction with the shoe sole thickness used in our experiments.

There were reports that the sway in the front-rear direction becomes very large when the walking speed is not constant (Koda et al., 2016). In our study, the participants walked at a constant speed on a treadmill. As shown in Fig. 2, in this experiment, the average acceleration in the front-rear direction was generally flat even when the sole was thickened. Therefore, when walking at a constant speed, it is considered that there is no risk of falling in the back-and-forth direction for platform shoes.

In our experiments, there was no significant difference between the shoe sole thickness and the heart rate. According to Fig. 3, the lowest heart rate was 98 bpm and the highest heart rate was 102 bpm. This is equivalent to the data from the Ministry of Health, Labor and Welfare. In other words, it is considered that there is no risk of falling at any sole thickness used in this study.

The gait cycle variation (%) of 87 elderly people (76.7 ± 2.2) was 2.3 ± 1.0 (Arai et al., 2011). In this experiment, the walking cycle fluctuation was around 1%. Participants in this experiment were 8 young men and women, and stable walking with a fixed speed on the treadmill was considered, so the walking cycle variation was considered to be low.

In conclusion, there were no significant effects of shoe sole thickness on the body sway and heart rate. By further increasing the number of subjects in the future and clarifying the relationship with other factors such as walking cycle, muscle factor during walking, and trajectory length of shaking, the relationship between platform shoes and fall risk will become clearer right. As a result, the shape of the sole will be greatly affected. The shoes used in this experiment were thinnest 11mm-15mm and thickest 41mm-45mm. From the results of this experiment, it is considered that the thickness of the sole within this range has little influence on the fall risk and the biological load. We thought that an experiment using shoes with a thicker sole may have an effect on the risk of falls and the load on the body.

Acknowledgement

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