

Foot Pressure Distributions When Walking on Floors of Different Surface Profiles

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Abstract—In order to understand the distributions of foot pressure when walking on hardwood floors with different surface geometry, we recruited four healthy adult subjects (2 men and 2 women) to join our experiment. Five walkways were constructed using same type of hardwood. The foot pressures under eleven stepping conditions were analyzed using a T & T Medilogic Medizintechnik plantar pressure measurement device. Descriptive statistics was adopted to analyze the data. The results showed that flat floor resulted in the lowest foot pressure than all other walkway conditions. Foot pressures under the 11 stepping conditions were discussed.

Keywords—foot pressure, gait, wood floor, floor surface geometry

I. INTRODUCTION

WALKING is one of the fundamental locomotion and capabilities of human and is the most common activities in our daily lives. Floor is the intermediaries between feet and ground when we walk. Most of the time, people wear shoes. Sometime, they walk barefoot. The bottom of the foot suffers impact upon the foot landing on the ground. The distribution of the force of the foot, or human plantar pressure distribution, could be uneven or even foot injuries could occur due to stepping on surface of uneven geometric, hardness, and/or materials [1].

Plantar foot pressure is the pressure acting on the sole when stepping on the ground. Force platforms have been widely used in determining the ground reaction force on the foot. But they can measure only the force on the whole foot. Distribution of the force, or the pressure, on the foot is unknown using such a device. In addition, a force platform must be fixed in a certain location and catches the ground reaction force of that specific step. Insole pressure pads have also been used. An insole pad can be placed inside a shoe to collect the force distribution underfoot. They are easier and are more convenient to be used in measuring the force and pressure on the foot when walking.

Plantar pressure analysis has been not only widely used in medical research to study foot diseases [2]-[4] but has also been used to test the moving force body during exercise. If humans

apply greater force on the ground, the ground will react more force back to human. This will result in larger plantar pressure. Via assessment of plantar pressure distribution we can understand the situation of human plantar pressure [8]. Foot pressure distribution is affected by many factors such as foot structure, gender, weight, the way and even the range of activities [5]. But foot pressure studies for people when walking on floors with different surface profile are rare.

Based on the literature review, in the process of walking the floor of different types of materials and can lead to uneven distribution of plantar pressure, and made the foot injury. Through the plantar pressure gauge can be learned human foot plantar pressure distribution scenarios. Therefore, the purpose of this study is to compare the plantar pressures when walking without shoes on different wood flooring conditions.

II. METHOD

A. Participant

In this experiment, we recruited four adults (two males and two females) who have no serious lower limb disease to be our subject. The researchers described experimental procedures before the experimental. All the subjects signed an informed consent before participating in the experiment. The basic information of the subjects are shown in Table 1

TABLE I
Subjects Basic Information (n = 4)

	mean	std	Min	Max
age(year)	21.75	2.36	20	25
height (cm)	161.75	8.42	154	170
weight (kg)	55.77	8.83	46.2	65

B. Floors & walkway

There were three floors tested in this study. Fig. 1 shows the first one. This floor is characterized by elevating the central part of the floor (in cross-sectional direction) as a plateau and there is a slope in each side. This floor was termed floor A. The top one in Fig. 1 is a single floor. The bottom in Fig. 1 shows the junction of two floors. The junction of the two floors forms a valley. A subject could walk on this type of floor in either longitudinal or cross-sectional directions. When these happened, the floors were termed floor A-longitudinal or floor A-cross.

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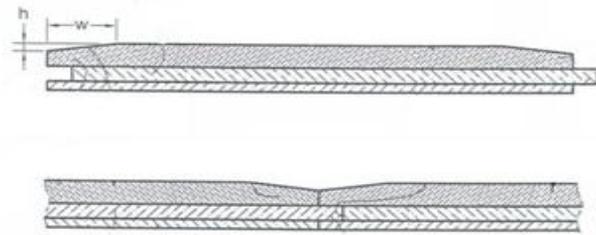


Fig. 1 Profile of floor A in cross-sectional direction

Fig. 2 shows the second type of floor (floor B). The design of this floor is reverse to that of the first one. It has a concave profile in the middle and raised ridge on the sides. The junction of two floors was higher than other part of the floor. A subject could also walk on this type of floor in either longitudinal or cross-sectional directions. When these happened, the floors were termed floor B-longitudinal or floor B-cross. The third floor is a flat floor. This floor is traditional one that has an even, horizontal surface and was termed floor C. It was our assumption that the foot pressure when stepping on this floor is the same no matter walking in either longitudinal or cross sectional direction. In summary, there were five floor/orientation conditions: floor A-longitudinal, floor A-cross, B-longitudinal, floor B-cross, and floor C.

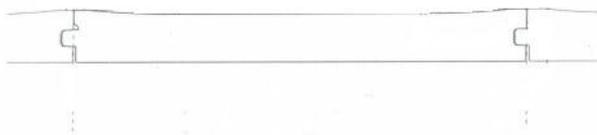


Fig. 2 floor B

There are a total of 11 conditions that a subject could step on these floor/orientation conditions. The first condition occurred when the walking direction of the subject was perpendicular to the longitudinal direction of the flooring (floor A-cross) and his/her forefoot touched the seam of the floors (condition a). Conditions b and c was when the middle or the back of subject's foot touched the seam, respectively. Conditions d, e, and f was specified, respectively, if the front, middle, and back of the foot stepped on the seam of the flooring when the subject was walking perpendicularly to the longitudinal direction of the flooring (floor B-cross). Conditions g and h referred to the conditions when the subject stepped on the seam or the middle of the floor when the walking direction was parallel to the longitudinal direction of flooring (Floor B-longitudinal). Conditions i and j referred to the conditions when the subject stepped on the seam or the middle of the floor when the walking direction was parallel to the longitudinal direction of flooring (Floor A-longitudinal). Condition k referred to the condition when the subject stepped on a flat floor (floor C).

TABLE II
Experimental wkways

Picture	Name (code)
	A: floor A- cross
	B. floor B cross
	C. floor B-longitudinal
	D floor A - longitudinal
	E flat floor

Generally speaking, the foot may be partition into three areas to examine the plantar pressure: forefoot area, middle foot area and hind (or back) foot areas [6,7] (Fig. 3).



Fig.3 Three areas of foot

C. Experiment flow and procedures

A foot pressure pad measuring system (T & T Medilogic Medizintechnik GmbH) was adopted (see Fig. 4). This system uses foot pressure pads, with embedded force sensors, to collected foot pressure. The sampling rate of foot pressure was 60 Hz. Fig. 5 shows one of the foot pressure collecting condition. In the experiment, the subject needed to walk on one of the five

walkways. To simulate the 11 stepping conditions mentioned in the previous section, the foot pressure pad for collecting the foot pressure was placed in a specific location pertained to one of the 11 stepping conditions. In condition a, for example, the insole foot pressure pad was placed on the flooring so that the forefoot was on the seam of the floor A-cross condition (see Fig. 6). The subject was standing one step behind the foot pressure pad. The subject then started walking by stepping on the foot pressure pad using his/her dominant leg. This test was completed if the foot pressure was successfully collected. Foot pressure was collected twice for every of the 11 stepping conditions.



Fig. 4 T & T Medilogic Medizintechnik GmbH



Fig.5 Example of foot pressure collection

D. Statistical analysis

The foot pressure data collected were analyzed using descriptive statistics. Microsoft Excel 2010 was adopted for data processing and analyses.

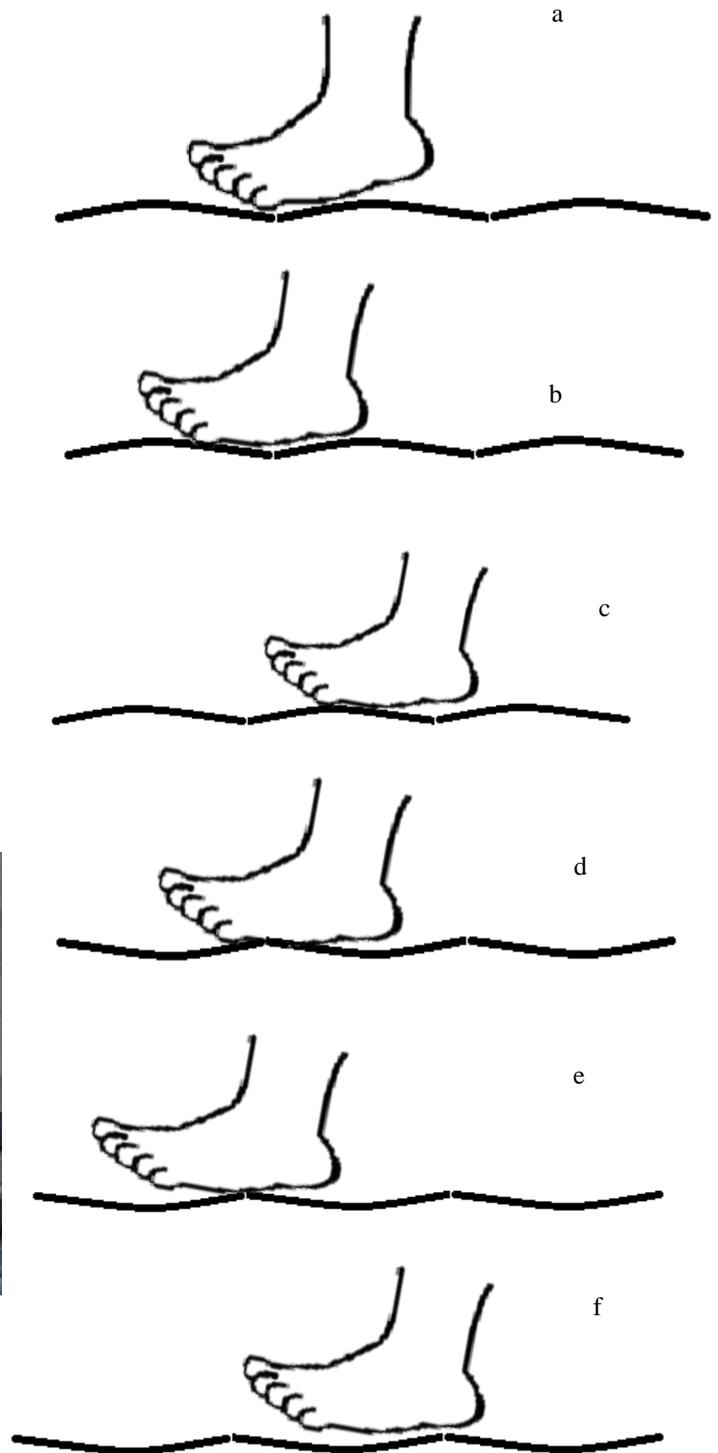


Fig. 6 Stepping conditions (to be continue)

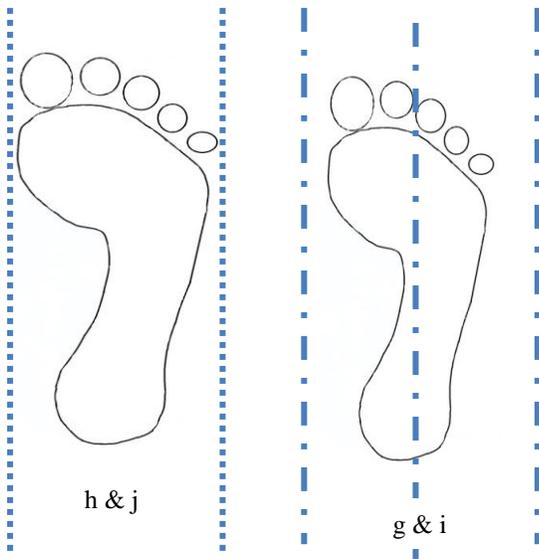


Fig. 6 Stepping conditions (continued)

III. RESULTS

Fig. 7 shows the foot pressure of forefoot, middle foot, and hind foot on the five walkways. For all the conditions, forefoot always had higher foot pressure than those of the middle and hind feet conditions. The foot pressures in the middle of the foot were the lowest among all three parts of the foot. This implies that middle foot plays a relatively minor role in supporting our body than the other two parts of the foot. If we compare the three types of floors, floor B had relative high pressure than the other two types of floors and floor c, or the flat floor, had the lowest.

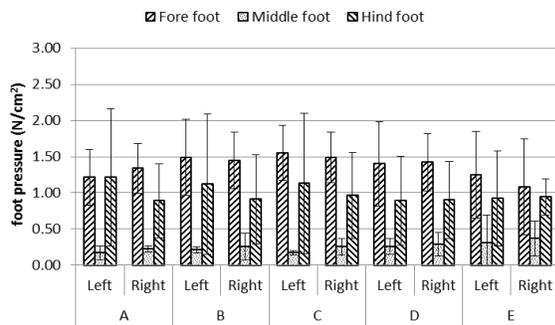


Fig.7 Foot pressure in the three regions of the foot on five walkways

Fig. 8 shows foot pressure comparison among the three conditions (a, b, c) stepping on floor A-cross condition. Condition b was the condition that the forefoot was stepping on the seam of the flooring and middle foot and hind foot were both stepping on the plateau of the flooring. The foot pressure in the forefoot in this condition was higher than conditions of a and c. The pressure in hind foot in condition b was, however, lower

than that of the other two conditions.

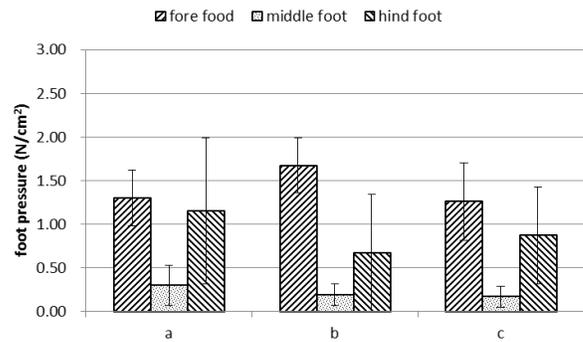


Fig 8 Foot pressure comparing conditions a, b, and c

Fig. 9 shows foot pressure comparison among the three conditions (d, e, f) stepping on floor B-cross condition. Condition d was the condition that the forefoot was stepping on the seam of the flooring and middle foot and hind foot were both stepping on the plain of the flooring. The foot pressure in the forefoot in this condition was higher than conditions of e and f. The pressure in hind foot for the three stepping conditions were very similar.

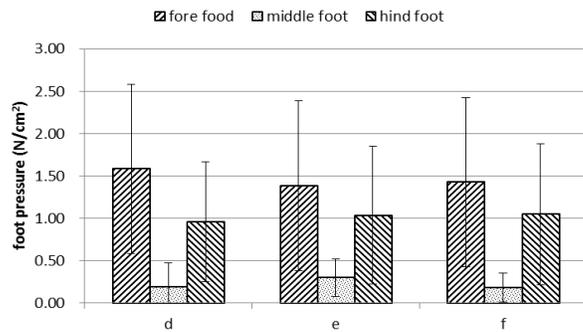


Fig 9 Foot pressure comparing conditions d, e, and f

Fig. 10 shows foot pressure comparison among conditions g and h stepping on floor A-longitudinal condition. Condition g was the condition that the foot was stepping on the seam of the flooring and condition h was for the foot stepping on the plateau condition. It was hypothesized that stepping on the seam results in higher foot pressure. However, the foot pressure between the two conditions were similar.

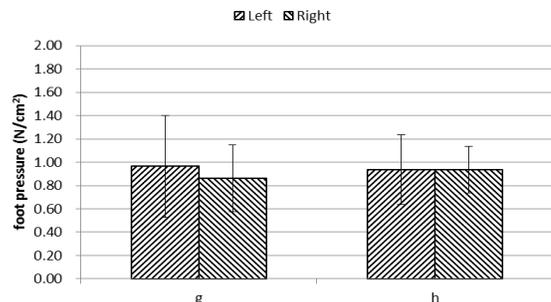


Fig. 10 Foot pressure comparing conditions g, h

Fig. 11 shows foot pressure comparison among conditions i and j stepping on floor B-longitudinal condition. Condition i was the condition that the foot was stepping on the seam of the flooring and condition j was for the foot stepping on the plateau condition. It was also hypothesized that stepping on the seam results in higher foot pressure. However, the foot pressure between the two conditions were similar.

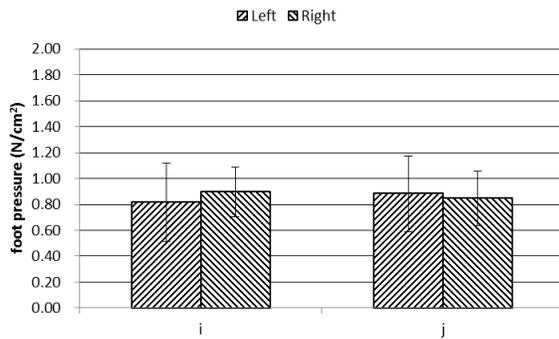


Fig. 11 Foot pressure comparing conditions i, j

This study was a pilot study examining the effects of surface geometry design of wood flooring. The limitation of the study was that we had only four subjects at the time of preparing this manuscript. Even with this limitation, we found that the foot pressure of the flat wood flooring had lower foot pressure than those of the other flooring conditions. Future research are required to have more subjects so as to obtain more solid conclusions.

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