Comparisons of Plantar Pressure Distributions between the Dominant and Non-dominant Sides of Older Women during Walking

JINSEOP KIM, PT, PhD1, KYOUNG KIM, PT, PhD1, CORAL GUBLER, PT, PhD2

1) Department of Physical Therapy, Daegu University: 15 Naeri-ri, Jinlyang, Gyeongsan-si, Kyeongbuk-do, Republic of Korea. TEL: +82 53-850-4351, FAX: +82 53-850-4351, E-mail: kykim257@hanmail.net
2) Department of Physical Therapy, University of South Alabama

Abstract. [Purpose] The purpose of this study was to investigate the differences in plantar pressure distributions between the dominant and non dominant sides during walking by older women with a history of falling. [Subjects] Fourteen older women without foot problems participated in this study. [Methods] Plantar pressure distributions between the dominant and non-dominant sides were recorded using the F-scan system (Tekscan Inc, Boston, USA). Measured parameters included peak plantar pressure and surface area contact during the stance phase from heel-strike to toe-off. [Results] Although there were no differences in peak pressure, contact surface area was significantly greater in the first metatarsal (M1) and heel (H) regions of the dominant side compared to the non-dominant side. [Conclusion] Unequal weight distribution indicated by a greater contact surface area may be an indicator of fall risk during walking by older adults with a history of falls. Key words: Older women, Dominant side, Foot contact area

INTRODUCTION

The incidence of falls increases with age. Falls can result in severe consequences such as loss of functional independence, disabilities and even increased mortality11. Risk factors associated with falls among community-dwelling elderly persons4–3) include muscle weakness, use of certain medications, cognitive impairment, depression, and a history of previous falls4–7). Although falls often have a multi factorial etiology, most falls occur while walking8), and it is not surprising that gait impairment is also associated with increased risk of falls8). Gait dysfunction is a factor that makes daily living activities difficult and is a cause of serious functional disorders11). Furthermore, subjects who fall can develop a fear of falling, which may limit their physical and social activities, and lead to reduced mobility, physical fitness, thereby increasing the risk of falling12).

The incidence of fall-related injuries among the elderly becomes higher as elements of balance control, postural alignment, concentration, strength, environmental awareness and endurance are challenged13). Attention plays an important role in balance control during walking. Shumway-Cook et al.14) and several other investigators have explored the effect of attention-demanding tasks on postural sway and balance control of older adults.

Walking surfaces and shoe features also affect gait stability15). Thus far, few studies have investigated the effects of walking surfaces and shoe features such as heel height on gait variables associated with balance control and the risk of slips and falls for older people13). Even fewer studies have compared differences in plantar foot peak pressure and contact area between the dominant and non-dominant side during walking. Plantar pressure distribution on individual foot regions can be accurately assessed and analyzed to provide information for the diagnosis and treatment of injuries10). By measuring plantar pressure distribution, we can examine the distribution of body weight between the dominant and non-dominant sides and its effect on the balance and stability of those with a history of falls. Therefore, the purpose of this study was to investigate plantar pressure distributions during walking between the dominant and non-dominant sides of healthy older women with fall risk.

SUBJECTS AND METHODS

The subjects of this study were fourteen healthy older women with a history of falls. A description of the purpose and method of this study was provided to all the participants and the experiments were conducted after they had read and signed an informed consent form. The study inclusion criteria were a Frenchay Instrumental Activities of Daily Living score17) of > 36, a Physical Function score18) of > 20, and a Berg Functional Balance Scale score19) of > 44 and a history of falls. By self-report, all participants had experienced one or more falls in the previous year. Exclusion criteria were severe dementia (an MMSE score < 20) or an inability to walk independently. All participants scored greater than 24
on the Mini Mental Status Examination (MMSE)\(^{20}\). Subject characteristics are summarized in Table 1.

To measure plantar foot pressures during the stance phase, the F-scan in-shoe system (Tekscan Inc, USA) and a 10-m walkway were used. The dominant and non-dominant sides were determined by self-report. The pressure was recorded at 50 Hz by a pressure sensitive insole consisting of a 0.15 mm thick sensor with an embedded matrix of 960 pressure-sensing cells evenly distributed at 0.5 cm (0.2 in) intervals. Before use, the disposable insole was trimmed to fit into the participants’ shoes. A 9.25-m cable was connected to the sensor, and the sensor was set to collect data at 50 Hz for 4 seconds.

For this experiment, we used an indoor shoe and a standardized heel height of 1 cm. Each participant walked on a treadmill for 10 min at 1.3 mph to adapt to the heel height and walking speed. After adaptation, the insole was positioned in each shoe, and the subjects were allowed to walk approximately 20 to 30 meters over ground to get them acquainted with the system. Then the subjects performed 3 10-meter test walks while wearing the shoes with sensor insoles. To prevent possible fatigue, each participant took a 3 minute rest between test sessions. Plantar pressure was recorded of both the dominant and non-dominant sides during three strides in the middle of the test walk and recorded at 50 Hz by a pressure sensitive insole consisting of a 0.15 mm thick sensor with an embedded matrix of 960 pressure-sensing cells evenly distributed at 0.5 cm (0.2 in) intervals. Before use, the disposable insole was trimmed to fit into the participants’ shoes. A 9.25-m cable was connected to the sensor, and the sensor was set to collect data at 50 Hz for 4 seconds.

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For data analysis, the plantar surface area was divided into 7 regions: T1, Hallux; T2-5, Toe 2–5; M1, Metatarsal 1; M2, Metatarsal 2–3; M3, Metatarsal 4–5; MF, Midfoot; and H, Heel. Mean peak pressure and area of contact were collected and calculated for each region of the dominant and non-dominant sides. The independent t-test was used to analyze differences in the dominant and non-dominant sides’ peak plantar pressures and contact surface areas of each foot region. The alpha level for significance was chosen as 0.05.

**RESULTS**

Subject characteristics are summarized in Table 1. Table 2 shows the peak plantar pressure values of the plantar regions on the dominant and non-dominant sides during walking. There were no significant differences observed between peak plantar pressures on the dominant and non-dominant sides. Table 3 shows the contact area values of the dominant and non-dominant sides of each region during the walk test. In the T2-5 region, the area of contact was remarkably greater on the non-dominant side compared to the dominant side, whereas in the M1 and H regions, the area of contact was remarkably greater on the dominant side rather than on the non-dominant side.

**DISCUSSION**

The women in this study were older adults with a history of falls. We investigated differences in peak plantar pressure and contact surface area between the dominant and non-dominant sides because these measurements have been shown to be clinically useful in the diagnosis of fall risk, the treatment of gait disorders and falls, and the identification of anatomical foot deformities\(^{21, 22}\). The peak pressures recorded were similar to those reported in previous studies of older adults\(^{23}\). In this study we found no significant differences between the dominant and non-dominant sides in peak plantar pressure area. These findings are consistent with previous studies. Imamura et al.\(^{24}\) found no differences in peak pressure between the two sides when walking. A previous study researched walking speed of older adults and reported that at a slow walking speed there were reduced peak and mean peak plantar pressures the compared to a
faster walking speed\textsuperscript{23}. These results support our findings of there being no significant difference between the two sides, because older people tend to walk at comfortable speeds.

The present study revealed that there is a larger contact area in the mid-foot and heel regions during heel touch and toe-off on the dominant side. In addition, weight-bearing on the dominant side preferentially occurred on the medial surface and heel during normal walking. These findings are consistent with the results of Hessert et al. who found that the forces needed to stabilize the ankle are increased in the medial and posterior foot of older adults during the heel touch phase\textsuperscript{22}. The presence of the larger contact area during walking may indicate increased sway and decreased stability, and therefore, increased fall risk. Another study\textsuperscript{23} described older adults as having relatively lower plantar pressures under the heel and central metatarsals when walking in shoes compared to barefoot walking; a similar result was found in the present study. Our study further contributes to these findings having investigated the differences between the dominant and non-dominant sides.

In conclusion, we consider that increases in contact surface area of the foot, particularly on the medial and posterior aspects of the plantar surface of the dominant side of older subjects, may be an indication of a high risk of falls. The presence of the larger contact area during walking may indicate increased sway and decreased stability, and therefore, increased fall risk. In addition, unequal balance between the dominant and non-dominant feet may also identify those with a high risk of falling. Therefore, we should work on designing various interventions to encourage equal pressure distribution. Limitations of this study include the small sample size, and the lack of specific measurement of subject’s ankle and knee ROM for analysis. Future studies should employ larger sample sizes, and include examination of variations of foot and knee ROM related to the plantar pressures of healthy elderly women during walking.

REFERENCES