

SYMMETRY OF PLANTAR PRESSURE DURING SELF-SELECTED WALKING, FAST WALKING, HEEL RAISE AND SIT-TO-STAND ACTIVITIES

¹On-Yee Lo, ¹Louis Iannuzzi, ²Kenneth Mroczek, ¹Smita Rao

¹Department of Physical Therapy, New York University, ² Department of Orthopedics, NYU Langone Medical Center. Email for correspondence: onyee.lo@nyu.edu

INTRODUCTION

High levels of asymmetry have been associated with musculoskeletal injury in activities such as running. [1] Symmetry of plantar pressure has been studied in walking [2] but not in activities of daily living (ADL) such as sit-to-stand. Current studies indicate that plantar loading is strongly influenced by activity. [3] Walking, sit-to-stand and heel raise are common weightbearing ADL as well as critical exercises for clinical intervention such as muscle strengthening, coordination and balance training.

An improved understanding of plantar pressure symmetry in ADL may provide useful information in designing footwear, preventing lower extremity injuries, and assessing the effectiveness of training programs. The purpose of this study was to determine the degree of symmetry for in-shoe plantar pressure between the left and right feet of healthy subjects during walking, heel-raise, and sit-to-stand in six foot regions.

METHODS

All procedures were approved by the Institutional Review Board. Eleven healthy adults (7 males: 30.3±3.5years, BMI: 26.4±3.67kg/m²; 4 females: 29.5±3.70 years, BMI: 21.2±0.79 kg/m²) participated in this study. All subjects were free from any musculoskeletal and neurological symptoms and able to perform the following four activities without any limit: self-selected walking (W), fast walking (F), heel raise (H), and sit-to-stand (S). The self-selected walking trials were collected first and the fast walking (15% higher than the self-selected speed) trials were collected subsequently.

In-shoe plantar pressures were collected by the Pedar-X system (Novel, Munich, Germany).

Appropriately sized insoles were placed inside the subjects' own sneakers and were sampled at 50 Hz as the subjects performed four activities (W, F, H, S). Peak pressure (PP, kPa) and pressure-time integral (PTI, kPa/cm².s) were investigated at six foot regions: heel, midfoot, medial forefoot, central forefoot, lateral forefoot, and hallux. Absolute symmetry index (ASI, %) of PP and PTI for each activity and region were calculated based on the following formula [4]:

$$ASI = \frac{|X_R - X_L|}{\frac{1}{2}(X_R + X_L)} \times 100\%$$

where X_R indicates PP or PTI on right foot and X_L indicates PP or PTI on left foot.

The effect of activity and foot region on ASI of PP and ASI of PTI were determined by using a two way repeated measures ANOVA (SPSS Inc., Chicago, IL). If the interaction effect (activity x region) was significant ($\alpha < 0.05$), simple effects of activity on each foot region were assessed subsequently. In terms of post-hoc testing, ASI of PP and ASI of PTI during each activity were assessed using Bonferroni adjusted pair-wise comparisons.

RESULTS AND DISCUSSION

A significant activity-by-foot-region interaction was found for PP ($p = 0.03$), figure 1. Subsequently, significant simple effects were noted for PP at the lateral forefoot ($p = 0.01$) and hallux ($p=0.005$). Significant pair-wise differences compared to walking at self-selected speed are summarized in table 1.

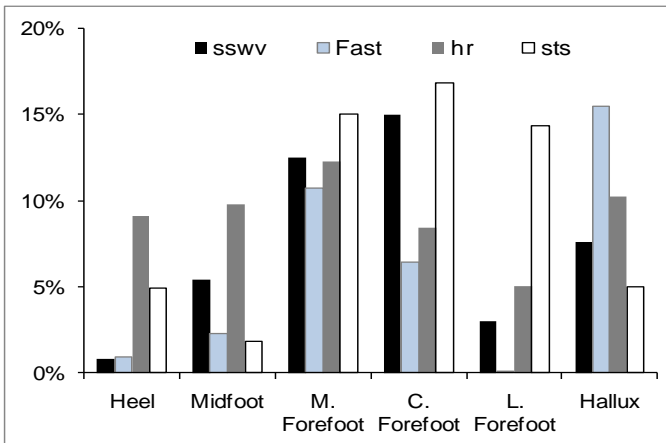


Figure 1. Summary of ASI for PP during self-selected (sswv) and fast (fast) walking, heel raise (hr) and sit-to-stand (sts) activities. Foot regions include heel, midfoot, medial forefoot, central forefoot, lateral forefoot and hallux.

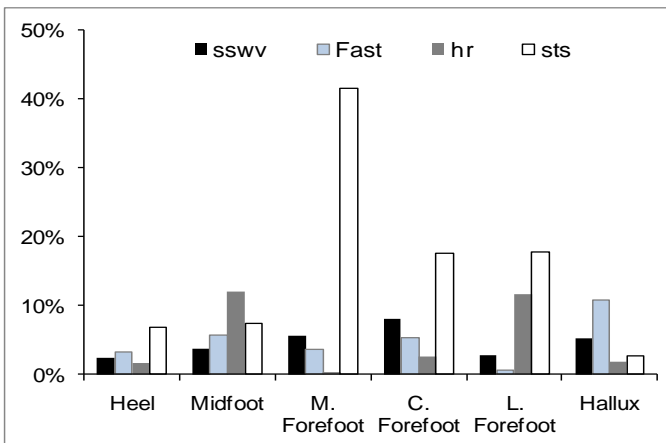


Figure 2. Summary of ASI for PTI during self-selected (sswv) and fast (fast) walking, heel raise (hr) and sit-to-stand (sts) activities. Foot regions include heel, midfoot, medial forefoot, central forefoot, lateral forefoot and hallux.

Table 1. Summary of PP (kPa) and PTI (kPa/cm².s) during self-selected (sswv) and fast (fast) walking, heel raise (hr) and sit-to-stand (sts) activities. Foot regions include heel, midfoot, medial forefoot, central forefoot, lateral forefoot and hallux. * indicates significant difference compared to sswv based on Bonferroni adjusted pair-wise comparisons.

	PP	PP	PP	PP	PTI	PTI	PTI	PTI
Activity	sswv	fast	hr	sts	sswv	fast	hr	sts
Heel	0.8%	0.9%	9.1%	4.9%	2.4%	3.2%	1.6%	6.8%
Midfoot	5.4%	2.3%	9.8%	1.8%	3.7%	5.7%	12.0%	7.3%
M. Forefoot	12.5%	10.7%	12.3%	12.0%	5.6%	3.7%	0.4%	41.5%*
C. Forefoot	15.0%	6.4%	8.4%	16.8%	8.1%	5.3%	2.6%	17.5%*
L. Forefoot	3.0%	0.1%	5.0%	14.3%*	2.7%	0.6%	11.6%	17.8%*
Hallux	7.6%	15.5%*	10.2%	5.0%	5.2%	10.7%*	1.8%	2.7%

Significant activity-by-foot-region interaction was also found for PTI ($p = 0.03$). Significant simple effects were noted for PTI at the medial forefoot ($p=0.016$), central forefoot ($p=0.012$), lateral forefoot ($p = 0.001$), and hallux ($p = 0.007$). Significant pair-wise differences compared to walking at self-selected speed are summarized in table 1.

CONCLUSIONS

We sought to assess the degree of symmetry for in-shoe plantar pressure between the left and right feet of healthy subjects during walking, heel-raise, and sit-to-stand in six foot regions. The chief findings of our study indicate that bilateral activities such as heel raises and sit-to-stand may be accompanied by significant asymmetry in plantar loading. Additional studies are indicated to examine patterns of asymmetry in clinical populations.

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