INFLUENCE OF FOOTWEAR ON WEIGHT-ACCEPTANCE PLANTAR PRESSURE DURING WALKING

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INTRODUCTION

The inlluence of footwear on external forces applied to the body during locomotion has been commonly assessed using a force platform (Clarke et al., 1983; Nigg et al., 1988). This method, however, measures forces at the level of the floor/shoe outsole interface and not directly at the plantar surface of the foot.

In addition, no information about the distribution of force over the plantar surface of the Soot (plantar pressure) is obtained using this method. The purpose of this study was to examine the influence of footwear on plantar pressure measured using an in-shoe pressure measurement system during the weight-acceptance portion of walking. During this time, the foot impacts the ground and rapid increases in force and pressure occur.

METHODOLOGY

Subjects. Five injury-free males volunteered to participate in the study. Informed consent was obtained from each subject prior to participation in accordance with university policies.

Experimental Set-up. A Tekscan* in-shoe pressure measurement system was used to measure plantar pressure during walking. The system included a thin (0.1 mm) pressure sensor insole (950 cells, 26 square mm each) which was placed inside the shoe under the plantar surface of the foot.

A method was developed to calibrate the pressure values using simultaneous force platform measurements. The sensor was attached to the bottom of a running shoe insole and the insole was then attached to the plantar surface of the foot.

Simultaneous in-shoe pressure and force platform measurements (both 100 Hz sampling rate) were than taken as the subject walked across the force platform. The pressure measures were converted to force values and a total of forces from each cell was obtained. Both the foot sensor and force platform curves were then normalized to 100 points using a spline function. The endpoints of the curve were forced to zero. **A** calibration curve was then obtained by dividing the force platform values by the foot sensor values. This calibration curve was smoothed using a 4th order Butterworth, non-recursive, digital filter (6.25 Hz cut-off).

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Protocol. Three experimental conditions were investigated. These included walking on (1) just running shoe insoles (no shoes) (2) running shoes with a hard midsole material (polyurethane, 50-55 shore A) and (3) running shoes with a soft midsole material (polyurethane, 25-30 shore A). The two pairs of shoes were identical in construction with the exception of the hardness of the midsole material.

Each subject walked at their preferred walking speed (+/- 5%) over a 10 m length for 5 trials of each experimental'condition. Data were collected during one right footfall of each trial. Two calibration trials were obtained before and after each condition. An average of the four calibration curves was used to calibrate the data for each condition.

Analysis. Custom written software was used to calculate plantar pressure distribution about the center of pressure during the first 30% of stance. Average pressure in three areas centered about the center of pressure was calculated. Area 1 was defined as the area inside a 20.4 mm square, area 2 as the area inside a 40.8 mm square exclusive of area I, and area 3 as the area inside a 61.2 X 102 mm rectangle exclusive of areas 1 and 2. The pressure distribution over the three areas was calculated for each 1% time interval for the first 30% of stance time. For each plantar area, maximum pressure and average pressure values during the time investigated were then determined. A two-way analysis of variance with repeated measures design and Tukey's HSD post-hoc comparison method when necessary were used to statistically analyze the variables of interest. A 95% level of conlidence was used for all tests.

RESULTS AND DISCUSSION

Mean maximum and average pressure for each plantar area for each condition are presented in Figure 1. Peak pressures occurred at a mean of 14.4, 15.5, and 20.2 percent of stance for areas 1, 2, and 3 respectively. Maximum pressure was significantly greater ($p < 0.02$) in all three areas for the insole with no shoe condition than for the hard and soft midsole shoe conditions. Average pressures followed the same trend for areas 1 and 2 ($p < 0.02$). For area 3, insole-no shoe values and hard midsole shoe values were significantly larger than soft midsole shoe values ($p = 0.03$).

For the insole-no shoe condition maximum pressure was significantly larger in area 1 than in areas 2 and 3 ($p = 0.0002$). For the hard midsole shoe condition. maximum pressure was significantly larger in areas 1 and 2 than in area 3 ($p = 0.01$). For the soft midsole shoe condition, maximum pressure in area 2 was significantly larger than in area 3 ($p = 0.04$). For the insole-no, shoe condition, average pressure was significantly larger in area 1 than area 2, and in area 2 than area 3 ($p = 0.0001$). No differences in average pressure were found between the areas for the two shoe conditions ($p > 0.05$).

Mean maximum weight-acceptance total force was 914 N for the insole-no shoe condition, 1097 N for the hard midsole condition, and 1061 N for the soft midsole condition. It appears that by more evenly distributing force over the plantar surface, shoes reduce plantar pressure during weight-acceptance.

In addition, a somewhat more even distribution of force and reduction in pressure occurs as the hardness of the midsole is decreased.

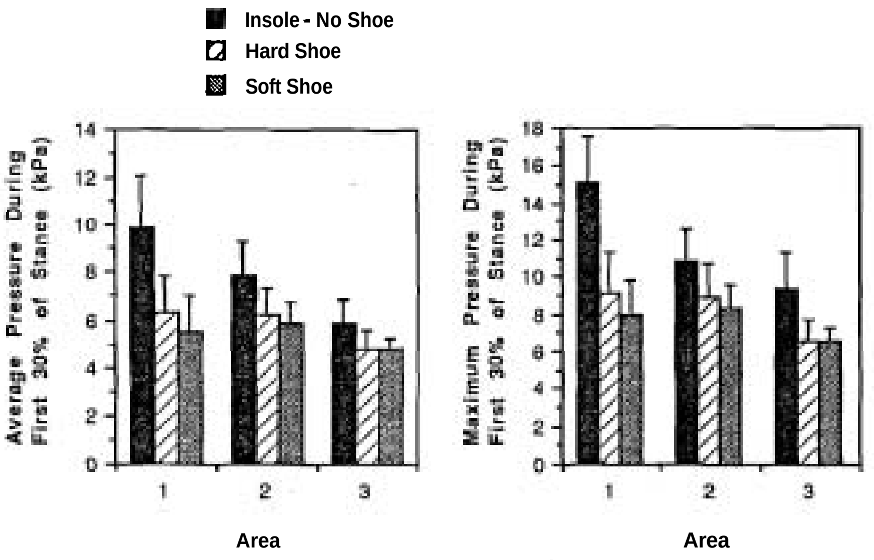

Figure 1. (a) Average and (b) maximum plantar pressure in three areas centered about the center of pressure (area 1, 20.4 mm square; area 2, 40.8 mm square exclusive of area 1; area 3, 61.2 x 102 mm rectangle exclusive of areas 1 and 2) during weight acceptance for walking on (1) insole-no shoe, (2) hard midsole shoe, and **(3)** soft midsole shoe.

To minimize plantar pressure during walking, it is therefore recommended that a shoe with a soft midsole to distribute force evenly over the foot be worn. However, it should be noted that the shoe should not be too soft so that it "bottoms out" during weight bearing. Nigg (1986) found that peak vertical ground reaction force was not different for running in shoes with midsoles ranging in hardness from 30 to 55 shore A. A marked increase was observed, however, during running in shoes with a midsole hardness of 20 shore A. It should also be noted that it has been established that increases in rearfoot motion occur with decreases in midsole hardness (Clarke et al., 1983). A compromise therefore between a soft midsole for cushioningand a hard midsole for stability may be necessary.

CONCLUSIONS

The results of this study indicate that shoes serve to reduce and more evenly distribute plantar pressure during the weight-acceptance portion of walking. Slightly greater reductions in pressure and slightly more even distributions occur for shoes with a soft midsole material compared to a hard one.

Future research should consider not only the amount of force applied to the plantar surface of the foot during weight bearing but also the magnitude of pressure.

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