COMPARISON OF PLANTAR LOAD WHEN RUNNING ON TREADMILL AND ON CEMENT AND GRASS OVERGROUND SURFACES

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The objective of this study was to compare plantar loads during running on a treadmill and on concrete and grass surfaces. Sixteen experienced heel-to-toe runners participated in the study. Plantar loads were collected using a Novel Pedar insole sensor system during running at 3.8 m/s. Compared with running on the two other surfaces, treadmill running showed a lower magnitude of maximum plantar pressure and maximum plantar force for the total foot, maximum plantar pressure for the two toe regions, maximum plantar force for the medial forefoot and the two toe regions, and longer absolute contact time at the two toe regions (p<0.05). The results suggest that treadmill running may be useful in early rehabilitation programs. Patients with injuries in their lower extremities may benefit from the reduction in plantar loads.

KEY WORDS: treadmill, grass, concrete, running surfaces, plantar load.

INTRODUCTION: Treadmill is widely used in laboratory settings for training and research to simulate running on overground surfaces. The increased use of treadmills in scientific investigations raises issues on differences in running patterns on treadmill and on overground surfaces. Literatures have compared the running kinematics on treadmill and on overground in some detail (Wank & Frick, 1998; Riley et al., 2008). Plantar loads are widely used to assess injury risks. Many studies have discussed plantar pressures when running and performing specific sports movements on different overground surfaces (Ford et al., 2006; Tessutti, Trombini-Souza, Ribeiro, Nunes, & Sacco-Ide, 2010). However, little is known about the differences in plantar load distributions during treadmill and overground running. Thus, this study aims to compare the plantar load while running on treadmill, as well as on hard (concrete) and soft (grass) overground surfaces.

METHODS: Sixteen experienced heel-to-toe runners participated in the study. They ran at 3.8 m/s on concrete, natural grass, and treadmill. The in-shoe load was measured by an insole measurement system (Novel, Munich, Germany). Data were transferred online via bluetooth and were collected by the Pedar-X online program on a computer. Only the data from the right plantar were collected. The sample frequency was set at 100 Hz. For each subject, five steps of right-foot rollover were extracted for running on each surface. The insole was divided into nine masks in accordance with the anatomic structure (Hong, Wang, Li, & Zhou, 2011).

The plantar load parameters of the whole foot, and the nine selected plantar regions were calculated, which included: maximum plantar pressure (MP), maximum plantar force (MF), and contact time (CT). The maximum plantar force measures were normalized to body weight (%BW) For each subject, plantar load data of five successful stances collected from different trials were used to calculate the mean of each variable across all participants for further statistical analysis.

A repeated-measures analysis of variance (ANOVA) was performed on the selected plantar loading parameters of the three running surfaces. Simple effects were calculated using paired Fisher LSD student t-tests (P<0.05).

RESULTS: Running on concrete induced higher maximum plantar pressure than running on treadmill at the total foot (p<0.05, 95% CI=29.11 to 116.42 kPa) and than running on natural grass at the total foot (p<0.05, 95% CI =22.97 to 93.08 kPa) and the central (p<0.05, 95% CI=18.84 to 57.55 kPa) and lateral forefoot (p<0.05, 95% CI=22.14 to 83.28 kPa). Compared with overground running, treadmill running also recorded lower maximum pressures at the great toe (p<0.05, concrete vs. treadmill, 95% CI=45.67 to 129.72 kPa; grass vs. treadmill, 95% CI=35.11 to 96.13 kPa) and at the lesser toes (p<0.05, concrete vs. treadmill, 95% CI=32.89 to 94.74 kPa; grass vs. treadmill, 95% CI=25.16 to 96.98 kPa) (Figure 1-1).

With regard to the maximum plantar force, there was no difference between running on concrete and on natural grass. However, compared with overground running, treadmill running induced a lower maximum plantar force at the total foot (p<0.05, concrete vs. treadmill, 95% CI=21.88 to 41.93 %BW; grass vs. treadmill, 95% CI=12.42 to 42.99 %BW), medial forefoot (p<0.05, concrete vs. treadmill, 95% CI=4.52 to 14.29 %BW; grass vs. treadmill, 95% CI=4.10 to 14.69 %BW), great toe (p<0.05, concrete vs. treadmill, 95% CI=3.65 to 11.14 %BW; grass vs. treadmill, 95% CI=2.65 to 10.24 %BW), and lesser toes (p<0.05, concrete vs. treadmill, 95% CI=3.44 to 12.91 %BW; grass vs. treadmill, 95% CI=2.70 to 10.23 %BW) (Figure 1-2).

Among the three surfaces, no significant differences were found in the total contact times of the right foot; however differences were found in specific regions of the foot. Compared with treadmill running, overground running induced a shorter absolute contact time at the great toe (p<0.05, concrete vs. treadmill, 95% CI=-3.02 to -1.13 ms; grass vs. treadmill, 95% CI=-2.54 to -0.90 ms) and the lesser toes (p<0.05, concrete vs. treadmill, 95% CI=-2.43 to -0.74 ms; grass vs. treadmill, 95% CI=-2.28 to -0.59 ms) (Figure 1-3).

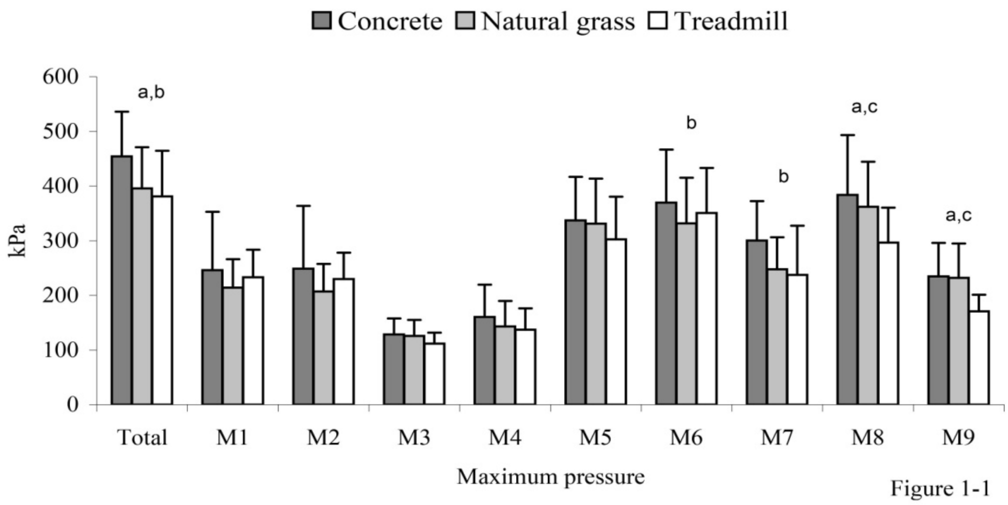

Figure 1-1

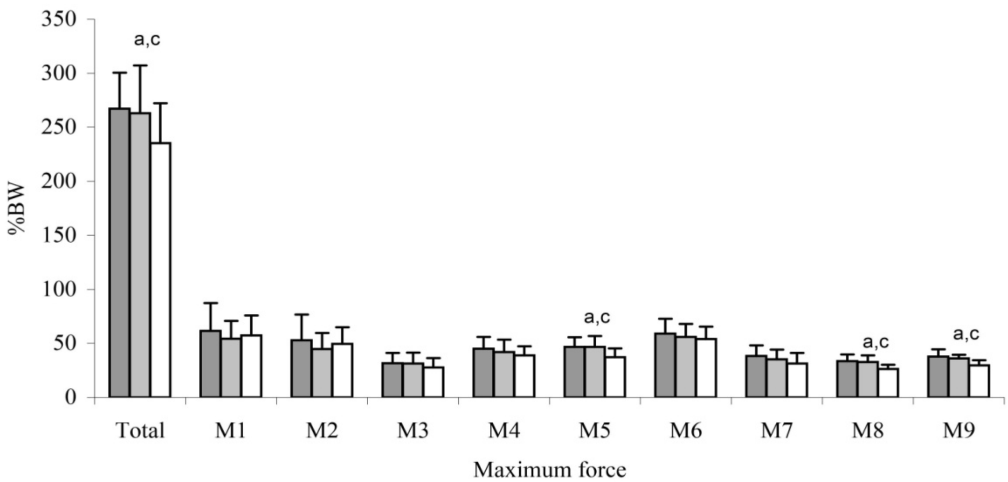

Figure 1-2

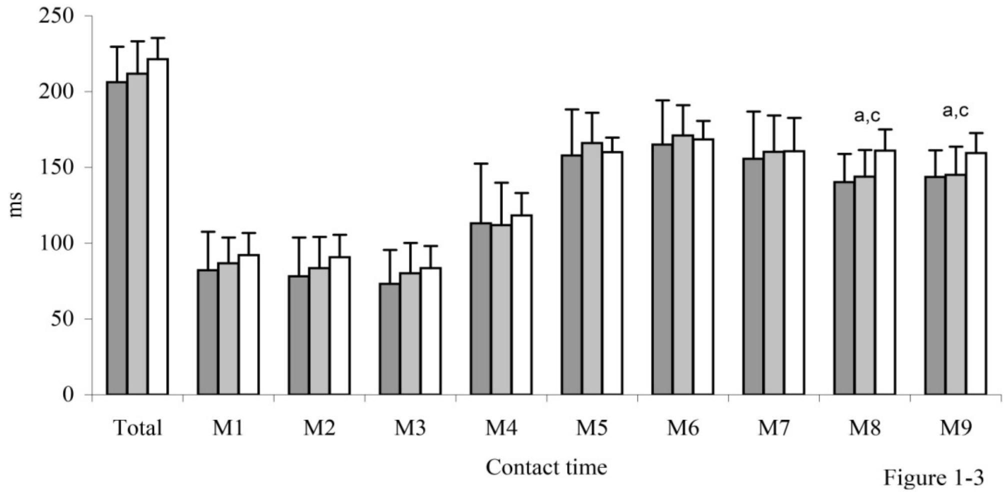

Figure 1: Comparison of insole loads between treadmill running and overground running.
Note: M1=medial heel, M2=lateral heel, M3=medial midfoot, M4=lateral midfoot, M5=medial forefoot, M6=central forefoot, M7=lateral forefoot, M8=great toe, M9=lesser toes.
a, p <0.05 treadmill vs. concrete; b, p <0.05 concrete vs. grass; c, p <0.05 treadmill vs. grass.

DISCUSSION: The similar the maximum plantar force between running on concrete and on natural grass might be due to the kinematics adaptation of the runners. Some previous studies have indicated that harder surfaces induced kinematic changes in the sagittal plane of the lower limb such as ankle, knee and hip flexion and these changes were interpreted as a form of active adaptation to maintain similar impact forces between differences in hardness of the running surface (Dixon, Collop, & Batt, 2000; Hardin, van den Bogert, & Hamill, 2004;). Moreover, the mean maximum vertical GRFs of running on overground surfaces and on treadmill have been found to be 2.6 and 2.3 times the body weight, respectively. This variable was also significantly lower on treadmill than on overground surfaces at the midfoot, forefoot, and toe areas. One possible reason to explain lower plantar loads in treadmill running is the increased belt speed in the late stance. Several studies have shown that the treadmill belt speed decreased at heel strike and then increased (White, Yack, Tucker, & Lin, 1998). The reduction in the vertical force is probably related to the increased belt speed in the late stance because energy is transferred from the belt to the runner.
In regard to plantar pressure, treadmill running produces the lowest maximum pressure at the toe regions. Previous studies found that vertical GRF is sustained by the forefoot and toes at the push off for running (Chen,, Tang, & Ju, 2001), and the vertical force increases during the push off phases of running (Novachek, 1998).
In the current study, the absolute great toe contact time in treadmill running is 12% longer than that in grass running, and 14.8% longer than that in concrete running. The contact times for the lesser toes are 9.9% and 11.0%, respectively. The longer contact time at the toes in treadmill running may imply a strategy of kinematic adaptation in anatomical structure to alternative running conditions during push off. Changes in contact time in treadmill running may influence the distribution of plantar loads.
The lower maximum plantar force and pressure at the medial forefoot and toes in treadmill running than in overground running found in our study suggests that treadmill running may decrease the risk of forefoot overuse injury, such as metatarsal shaft stress fracture and metatarsalgia in long distance running

CONCLUSION: The similar plantar loads in running on concrete (hard) and grass (soft) surfaces were found. The plantar load distribution in running on treadmill is not equal to the plantar load distribution in running on concrete and grass overground surfaces.

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