# A KINETIC COMPARISON OF RUNNING ON TREADMILL AND OVERGROUND SURFACES: AN ANALYSIS OF PLANTAR PRESSURE

**Justin Wai-Yuk Lee, Mandy Man-Ling Chung, Kam-Ming Mok, Youlian Hong**

**Human Movement Laboratory, Department of Sports Science and Physical Education, Faculty of Education, The Chinese University of Hong Kong, Hong Kong SAR, China**

The purpose of this study was to compare the plantar pressure in treadmill and overground running. It aimed to investigate whether treadmill is a suitable surface to carry out running shoe cushioning test. Fourteen male volunteers were recruited to run on four different running conditions i.e. treadmill, tartan, grass, and concrete with controlled running speed. A mobile plantar pressure measuring system was employed and peak pressure was measured. The results showed that the plantar pressure of treadmill running was different to that of overground running in total foot, medial midfoot, lateral midfoot and lesser toes.

**KEY WORDS**: overground, running, treadmill, plantar pressure, shoe testing

**INTRODUCTION:** In running shoe testing, treadmill is widely adopted by sports scientists. The speed and slope can be easily controlled and data from repeated running cycle could be obtained (Lavcanska, Taylor, & Schache, 2005). Several studies reported that there are differences in different biomechanical aspects, such as 3D kinematics, kinetics and electromyography (EMG) between treadmill running and overground running (Dixon, Collop, & Batt, 2000; Nigg et al., 1995 ). However, the results are often conflicting and inconclusive. Researchers carry out cushioning functional tests on treadmill and gather kinetics data without running on overground surfaces, of which the runners spend most of the training time on. The aim of this investigation was to find out the plantar pressure difference between different running surface with a controlled running speed and condition.

**METHODS:** Fourteen male recreational heel-toe runners (age: 22.8 ± 4.4 years; height, 169.2 ±4.78cm; weight, 62.7 ± 9.7kg) were requested to run on four different running surfaces i.e. treadmill, tartan, grass, and concrete with controlled running speed. Every subject wore a standard running shoe model (TN 600, ASICS, Japan) with size 41. A mobile plantar pressure measuring system (Novel GmbH, Munich, Germany) was employed. Kinetic parameter, peak pressure was measured. Six minutes of warm up and familiarization with treadmill was carried out by each subject. After warm up, subjects were instructed to run at a speed of 3.8m/s for 2 minutes on treadmill with the mobile measuring system. The data of the last minute were extracted for data analysis. In the overground running, standard tartan track, grass and concrete surfaces were chosen. Figure 1 illustrates the experimental setting of the run way. The speed was controlled any between 3.6 and 3.8 ms-1. An infra red timing system (Brower, US) was used to monitor the running speed of each trial, and each trial was regarded as finishing the 8m runway. Six trials of each overground surface ware taken. The testing sequence was randomized.

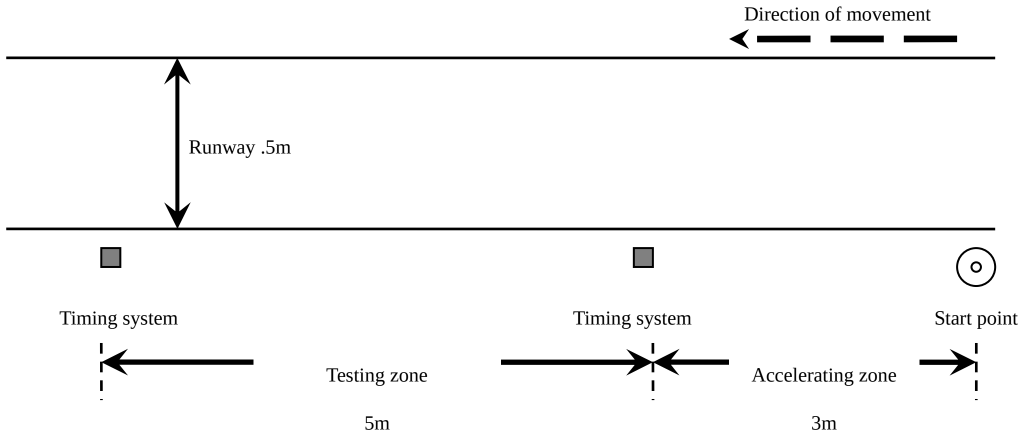


**Figure 1: Experimental setup of overground running, i.e. tartan, grass and treadmill**

All data were analyzed by Novel Pedar analyzing software (Germany). The only the dominant foot insole was used and divided into 9 recorded areas as shown in Figure 2. Using Novel Database-Pro software, peak pressure (PP) was extracted from each running step. A statistical tool SPSS 12 (SPSS, USA) was used. A repeated-measures analysis of variance (ANOVA) was performed. The assumption of sphericity was checked using Mauchly's test, and the LSD method was used to perform pairwise comparisons following a significant overall test result. The level of significance was set at an α level of 0.05 and data were presented as mean and standard deviation.

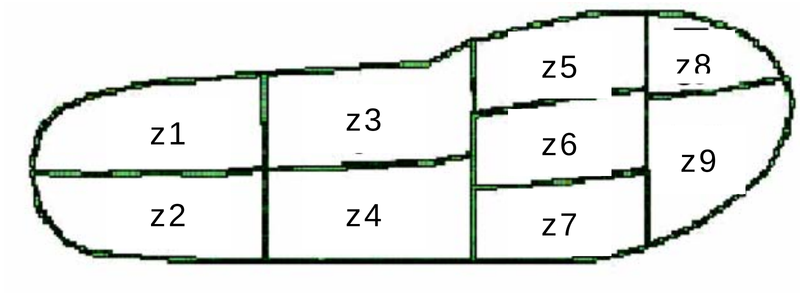


**Figure 2: Zones of the plantar pressure surface, z1 (medial heel), z2 (lateral heel), z3 (medial midfoot), z4 (lateral midfoot), z5 (first metatarsal head), z6 (second metatarsal head), z7 (third, fourth and fifth metatarsal head), z8 (great toe), z9 (lesser toe).**

**RESULTS AND DISCUSSION:** The aim of this study was to investigate the effect of different running surface on the plantar pressure in a controlled running speed. The results in table 1 showed that the plantar pressure of treadmill running was significantly lower than that of overground running in total foot, medial midfoot, lateral midfoot and lesser toes, $p<0.05$.

**Table 1 - Mean and S.D. of peak pressure (PP) (kPa) in z1-z9 and total foot area. Only ANOVA tests with p value < 0.05 are shown in the table.**

| Zone | Treadmill | Tartan | Grass | Concrete | ANOVA F |
|---|---|---|---|---|---|
| Total foot | 395.7 (86.3) | 420.6 (92.3) | 402.7 (75.9) | 456.1(84.3)[a d] | 3.5 |
| z3 | 108.5 (21.4) | 118.4 (36.8) | 121.0 (31.2)[a] | 124.5 (29.2)[b] | 3.07 |
| z4 | 137.3 (41.4) | 148.0 (53.4) | 142.1(50.2) | 161.7(62.8)[a d] | 3.76 |
| z6 | 342.3(84.5) | 338.2 (98.9) | 329.6 (86.9) | 379.0 (93.1)[d] | 2.90 |
| z7 | 245.2 (93.2) | 261.2(83.3) | 249.2 (72.1) | 288.7 (78.4)[d] | 3.01 |
| z9 | 174.2(31.6) | 198.6 (56.6)[a] | 197.0 (52.3)[a] | 219.0 (51.9)[b c] | 7.54 |

a p<0.05 when compared with treadmill; b p<0.01 when compared with treadmill;
c p<0.05 when compared with grass; d p<0.01 when compared with grass.

In the total foot, PP concrete was found greater than PP treadmill. It's shown that a 15% greater plantar pressure was found when running on concrete compared with that of treadmill, $p<0.05$. With a more detailed analysis, in zone 3, 4 and 9, which represent the medial midfoot, lateral midfoot and lesser toes respectively, PP treadmill was found smaller than PP concrete. In the z3 lesser toes area, PP tartan, PP grass and PP concrete were significantly higher than PP treadmill, i.e. 14%, 13% and 26% higher respectively. The result was in consistent with the study from Baur et al. (2007). Fourteen runners ran on treadmill and a 400m track with a controlled speed. It's reported that PP overground of total foot area were significantly higher than that of PP treadmill. The difference was found mainly in forefoot area, in which PP overground is 25% higher than PP treadmill. They concluded that the muscular activity while running on the treadmill differs from that during overground running.

The plantar pressure difference in forefoot and midfoot areas might be caused by a different running mechanism between treadmill and overground running. According to Wank (1998), there was a lower electromyography (EMG) signal of vastus lateralis explained the less vertical displacement in treadmill running. And the higher EMG signal of biceps femoris in the take off phase might be caused by a greater forward lean of the trunk compared to overground running. It supported that running on treadmill might adopt a different running mechanism to that of overground running. More comprehensive analysis of kinematics and neuromuscular activity would provide further insight.

**CONCLUSION:** Based on the results of the study, we conclude that:

1) The total foot plantar pressure in treadmill running was found to be lower than that of

concrete running. After further investigation, the difference was mainly found in lateral and medial mid foot and lesser toes. In the forefoot lesser toes area, plantar pressure of treadmill running was significantly smaller than all the overground running i.e. tartan, grass and concrete.

2) To create a well-controlled testing environment, sports biomechanists carry out shoe cushioning test on treadmill instead of overground surfaces. Systematic errors may be introduced in the experiment design according to our finding. There might be a possibility that the absolute forefoot cushioning properties of the sports shoes are overestimated when the test is carried on treadmill. We suggest treadmill may not be a suitable running surface to carry those tests

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