http://ansinet.com/itj

ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 12 (24): 8551-8554, 2013
ISSN 1812-5638 / DOI: 10.3923/itj.2013.8551.8554

Influence of Sports Surface on Characteristics of Plantar Pressure in Running

Weijie Fu
School of Kinesiology, Shanghai University of Sport, Shanghai 200438, China

Abstract: The purpose of this study was to explore the effect of three common sports surfaces on plantar pressure characteristics and performance of impact in lower extremity during running. Methods: Medilogic insole plantar pressure system® was utilized to collect plantar pressure data (including contact time, peak pressure, pressure-time integral) and pressure distribution during touch-down and toe-off phases. Grass surface, rubber running track, and concrete surface were chosen as testing surfaces. Results: During touch-down, the first peak pressure (time) and pressure-time integral within first peak period of running on the concrete were significantly greater (or earlier) than the other two. However, the pressure distribution of all insole areas (forefoot, mid-foot, heel, lateral and medial) were similar among the three types of sports surfaces both in touch-down and toe-off. Conclusion: Surfaces with less or no cushioning would lead to a higher risk of sports injury during long-term running. However, the further effect of different surfaces on pressure distribution and the influence it may bring subsequently was not as distinct as expected.

Key words: Sports surfaces, peak plantar pressure, plantar pressure distribution, running

INTRODUCTION

As a low cost and accessible sport, running is a very popular activity among sports enthusiasts and competitive athletes. The popularity of running and running has consistently increased since the latter half of the twentieth century. Millions of people worldwide participate for recreation and the physical benefits that come from running with the evocations of “Olympic sport, nationwide body-building”. Based on statistic data, the popularity of sport in China has exceeded 40 million, among which the favorite sports item is running (GAS, 2002). Unfortunately it is estimated that between 37 and 56% of all runners are injured during a year of running (Van Mechelen, 1992) and running injuries make up the majority of sports related injuries in the physically active population.

Repetitive impact forces in running have a maximum of about one to three times body weight. They have been proposed as a major reason for sports (especially running) -related injuries which would induce overuse injuries during running for athletes (Konradsen *et al*., 1990). However, sports surfaces have also played an important role during this stage. Synthetic surfaces were first implicated as source of injuries in track and field in the late 1960s (Nigg and Yeadon, 1987). In order to reduce the amplitude of impact and prevent sports injuries during movements, researchers has proposed a cushioning function for sports surfaces (Aguinaldo and Mahar, 2003). However, the results of subsequent research were uncertain. Findings of many studies on impact forces and their consequences did not show the indispensable connection between impact forces and sports-related injuries (Gruber *et al*., 1998).

The purpose of this study was to explore the effect of three common sports surfaces (grass, track and concrete) on plantar pressure characteristics and performance of impact in lower extremity during running. Furthermore it was also considered to be a theoretic reference to the mechanisms of sports-related injuries.

METHODS

Participants: Three male students major in physical education (age: 23.7±1.2 yrs; weight: 65.7±5.2 kg; height: 173.7±5.7 cm) from Shanghai University of Sport were recruited to participate in this study. All the subjects have the experience of long distance running. The average kilometers for running are 20 km week^{-1}. They had no previous musculoskeletal injuries of the lower extremity half a year prior to this study.

Equipment and devices: Medilogic Insole Measuring System® was utilized to collect the plantar pressure during running. The insole sizes were chosen for 39-40 and 43-44 (China) according to the shoe size of the subjects. In addition, the thickness of the insole was 1.2 mm each. It consisted of 64 matrix pressure sensors. The sampling rate was 300 Hz. The data was recorded and analyzed by Medilogic 4.4 software. In order to eliminate the influence by the greatest extent which may caused by shoes and insoles, an over-the-court canvas shoe with no cushioning effect was selected during the entire testing. Testing Surfaces: The index of ball rebound from International Association for Sports Surface Science (IASSS) standard was chosen as a reference of cushioning ability of the sports surface. Procedure: An Adidas basketball (size 7 # with an air pressure of 0.06 M Pa) was used in such kind of testing according to the guidelines of IASSS. The ball was vertical dropped from a height of 2 m. The average rebound height (total 5 times) was then recorded as a reference of the surface hardness. Significant differences were found between the grass and the rubber running track and the grass and the concrete (Table 1).

Protocols: The subjects were required to run at the speed of 3.3 m sec^{-1} on a treadmill. The stride frequency was then recorded through a timing-monitor device. 3 sets of 15 m running (3×15 m) on the three different surfaces (glass, track and concrete) were completed by using the same stride frequency. Plantar pressure data for 10 strides during mid-acceleration phase running were collected and the velocity was monitored during the outdoor tests in a track and field stadium.

Statistical analysis: Munro *et al.* (1987) reported that no statistically significant difference were found between the right and left feet. Thus, as a group, right-left asymmetries could not be detected. Therefore, in this study, the data for both right and left feet had been considered. All values are expressed as Mean±SD. A one-way analysis of variance (one-way ANOVA) was executed to determine significant differences between the respective surface conditions by using SPSS 13.0 (SPSS Inc., Chicago, IL, U.S.A.). The significant level was set at $\alpha = 0.05$.

RESULTS

Comparison of plantar pressure among three surfaces: During the initial stage of touch-down, a first-peak pressure appeared, and subsequently during the mid-stage of take-off, a second-peak pressure also showed. Based on the two-peak character of plantar pressure during running, the entire contact phase was subdivided into Touch-Down (TD) and Toe-Off (TO) phase. The main parameters were: Average velocity, peak pressure (TD and TO phase, contact time for one step, pressure-time integral for First Peak (FPTI) and pressure-time integral for whole contact phase (PTI).

For the velocity, contact time and pressure values during TO, there were no differences among three sports surfaces (Table 2). However, for the FP and the time to FP, running on the concrete indicated a larger FP and an earlier time to it.

Meanwhile, the PTI did not showed a significant difference between surfaces during the entire contact phase (Table 3). But for the FPTI, compared with track and glass, running on the concrete indicated a larger FPTI value. Since the FPTI means an accumulation of plantar pressure during a period of time which also has a relationship with sports injuries. In this study, running on the concrete showed a relative larger FPTI. Thus compared with the other two sports surfaces, jogging on the concrete may increase mechanical loads and impacts to a certain extent.

Comparison of pressure distribution among three surfaces: Based on the analysis of insole area investigation done by Bontrager *et al.* (1997) and the structure of Medilogic insole hardware system itself, the regions of the plantar was then divided into five areas to be analyzed, i.e. forefoot, midfoot, heel, medial and lateral. TD phase: for the forefoot area, the concrete showed a low pressure; for the midfoot, compared with concrete and glass, the track showed a greater pressure; for the heel,there were no significant differences among the three surfaces; for the medial and lateral, the peak pressure were

Table 1: Rebound height from three different sports surfaces during surface testing

Surface types	Rebound height (m)
Glass	0.81±0.06
Rubber Running Track	1.49±0.01*
Concrete	1.52±0.02**

*p<0.05, **p<0.01, compared with the glass

Table 2: Temporal and pressure variable values for the running surfaces (normalized by weight)

			Plantar Pressure (PP)			
			1st peak (FP)		2nd peak (SP)	
	Velocity (m sec^{-1})	Contact Time (ms)	((N cm^{-2}) kg^{-1})	Time to FP (ms)	((N/cm^{-2}) kg^{-1})	Time to SP (ms)
Glass	3.38±0.73	256.5±8.7	0.0620±0.020	46.4±8.8	0.105±0.004	101.2±7.2
Track	3.29±0.21	266.7±28.9	0.0569±0.030	43.3±9.3	0.108±0.006	102.4±14.2
Concrete	3.24±0.58	272.6±18.5	0.0676±0.014*#	36.7±9.2*#	0.103±0.009	100.2±16.4

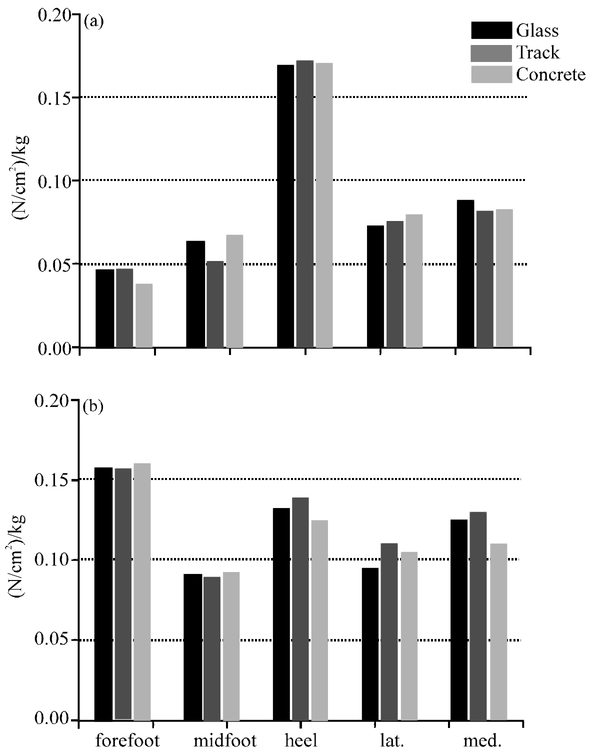

Fig. 1(a-b): Comparison of pressure distribution among three surfaces during touch-down (a) and toe-off (b) phase

Table 3: Pressure-time integral normalized by weight for the running surfaces [(N/cm^2)×ms kg^{-1}]

	Pressure-time integral for first peak (FPTI)	Pressure-time integral for contact phase (PTI)
Glass	1.38±0.54	13.1±2.1
Track	1.22±0.40	13.6±3.3
Concrete	1.53±0.49*#	13.8±2.8

*p<0.05, compared with the glass; #p<0.05, compared with the track

similar among the surfaces (Fig. 1a). Generally, during the TD phase, there were no differences for all the sports surfaces on each area of plantar pressure characteristics. TO phase: for peak pressure of each area, there were significant differences among three surfaces. In other words, the propulsive force applied to body was similar under a consistent speed (Fig. 1b).

DISCUSSION

In this study, the speed of running for all participants was monitored and control at 3-3.5 m sec. Therefore, the results of significant differences between surfaces had no relationship with speed. For peak plantar pressure and characteristics of pressure distributions, during TD and TO phase, the differences among three sports surfaces were not significant. Either for grass surface or track, the contact time, the first and second peak force, the time to peak force and the distribution characters was not different. Meanwhile, compared with other two surfaces, the concrete was showed a significantly larger first peak force, an earlier time to peak impact and a larger pressure-time integrate.

Fransen *et al.* (1997) found that gait became more consistent with increasing speed. The additional speed necessary for running may further increase this repeatability. Therefore, any measured differences in gait parameters could not be attributed to speed. The results of no significant differences among three sports surfaces during a jogging circle in this study were thus supported by the above issue.

The findings are also consistent with the results of Dixon *et al.* (2000), who compared with similar impact forces for three different sports surfaces. In addition, the authors also reported a part of runners utilized kinematic adjustments to keep similar impact forces. Actually, these results was suggested that the greater initial amount of knee flexion found for an individual jogging on track was a compensatory adjustment intended to decrease the stiffness of the lower extremity to adjust for the high stiffness of the surface which have been confirm as kinematic adaptation phenomenon. Some scholars even stated that runners might be able to adjust the stiffness of their limbs subconsciously based on their perception of the hardness of the surface (Feehery, 1986). Nigg (1990) also pointed out athletes may change their movement patterns in response to different surfaces. Ferris *et al.* (1998) have also observed this occurrence: Runners could adjust the stiffness of their lower extremity in order to achieve a consistent effective vertical stiffness (including the surface stiffness and leg stiffness). Proper control of the effective vertical stiffness results in a consistent pattern of vertical displacement of the Center of Mass (COM) regardless of the running surface.

In this study, we did not find differences in the plantar pressure and the center of pressure which means that the vertical acceleration of the COM for the participants remained less changed across the surfaces. Although the present investigation did not contain kinematic or stiffness testing it is still possible to propose that the subjects in the study were changing above factors in order to adapt to the different sports surfaces.
During jogging, the ability to alter leg stiffness allows humans to run on different surfaces but keeping similar stride frequency, contact time and characteristics of ground reaction forces. Nevertheless, those adjustments could sometimes lead to sports injury. Runners still needed to increase their leg stiffness on soft surfaces while reduce stiffness on relative hard surfaces. Thus, the

individual will assume a straighter limb posture when jogging on a compliant surface with increased leg stiffness during ground contact which would result in lower muscle forces and joint moments. The reverse would also be true. Furthermore, Dixon *et al.* (2000) found a small angular alter in the lower extremity among different surfaces. However, even such tiny changes may induce a large effect on the moment arm, muscle tendons and relative ligaments.

CONCLUSION

During TD and TO phase, the characteristics of peak pressure and pressure distribution for three surfaces were similar; meanwhile, compared with the other two surfaces, running on the concrete showed a significantly difference on first peak force, the time to peak impact and pressure-time integrate which indicated that running on hard surfaces may increase mechanical loads and impacts to a certain extent. The results of this study implied that different surfaces do not affect the forces acting at the lower extremity while running. This indicated that whether to choose stiffer or softer surfaces runners both had a risk of injuries. The most important thing is the scheme of adaptation to different surfaces varies among runners. In addition, runners may be better able to adjust to different surfaces when they are not fatigued, such as by using kinematic adaptation and muscle tuning to reduce the impact of foot brought by different sports surfaces.

ACKNOWLEDGMENT

The research work was supported by National Natural Science Foundation of China (11302131), the Doctoral Fund of the Ministry of Education of China (20123156120003), the Innovation Program of Shanghai Municipal Education Commission (14YZ125) and the Cultivating Program of Young Collegiate Teacher of Shanghai (Zzsty12002).

REFERENCES

Aguinaldo, A. and A. Mahar, 2003. Impact loading in running shoes with cushioning column system. J. Applied Biomech., 19: 353-360.

Bontrager, E.L., L.A. Boyd, J.G. Heino, S. Mulroy and J. Perrry, 1997. Determination of novel pedar masks using harris mat imprints. Gait Posture, 5: 167-168.

Dixon, S.J., A.C. Collop and M.E. Batt, 2000. Surface effects on ground reaction forces and lower extremity kinematics in running. Med. Sci. Sport. Exer., 32: 1919-1926.

Feehery Jr, R.V., 1986. The biomechanics of running on different surfaces. Clin. Podiat. Med. Surg., 3: 649-659.

Ferris, D.P., M. Louie and C.T. Farley, 1998. Running in the real world: Adjusting leg stiffness for different surfaces. Proc. Royal Soc. B: Biol. Sci., 265: 989-994.

Fransen, M., J. Crosbie and J. Edmonds, 1997. Reliability of gait measurements in people with osteoarthritis of the knee. Phys. Ther., 77: 944-953.

GAS, 2002. Reports of investigation results for the present situation of Chinese popular physical education in 2001. Sports Information Center, General Administration of Sport, China.

Gruber, K., H. Ruder, J. Denoth and K. Schneider, 1998. A comparative study of impact dynamics: Wobbling mass model versus rigid body models. J. Biomech., 31: 439-444.

Konradsen, L., E.M. Hansen and L. Sondergaard, 1990. Long distance running and osteoarthrosis. Am. J. Sport Med., 18: 379-381.

Munro, C.F., D.I. Miller and A.J. Fuglevand, 1987. Ground reaction forces in running: A reexamination. J. Biomech., 20: 147-155.

Nigg, B.M. and M.R. Yeadon, 1987. Biomechanical aspects of playing surfaces. J. Sport. Sci., 5: 117-145.

Nigg, B.M., 1990. The validity and relevance of tests used for the assessment of sports surfaces. Med. Sci. Sport. Exer., 22: 131-139.

Van Mechelen, W., 1992. Running injuries. A review of the epidemiological literature. Sports Med., 14: 320-335.