PLANTAR PRESSURE OF FOUR MOVEMENTS IN SOCCER

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The present study aimed to compare the plantar pressure among four soccer movements and to identify the plantar areas where high pressure was exerted. 15 male soccer players participated in the study. Four movements were conducted: running, sideward cutting, 45-degree cutting, and jump landing. Each footprint was divided into 10 masked areas for analysis. One-way ANOVA with repeated measures showed differences ($P < 0.05$) in peak pressure and pressure-time integral in all masked areas among the four movements. As compared to running, sideward cutting and 45-degree cutting had higher peak pressure ($P < 0.05$) under the second toe, medial forefoot, medial arch, and medial heel, while jump landing had lower peak pressure under the medial forefoot and lateral forefoot ($P < 0.05$). Pressure-time integral showed that sideward cutting and 45-degree cutting had higher values ($P < 0.05$) than running under all masked areas except on the lateral forefoot and the lateral arch. Among these movements, higher pressure was found on the medial side of the plantar surface and these areas may have higher risk of injury.

KEY WORDS: stress, football, running.

INTRODUCTION: Most soccer injuries occur in the lower extremities, especially in the ankle (Wong & Hong, 2005). In addition, about 17% of soccer injuries were caused by equipment (Wong & Hong, 2005). Specifically, of these injuries caused by equipment, 77% were ascribed to shoes, while 23% were ascribed to shin guards. Therefore, the improvement of the protective functions of soccer shoes would reduce soccer injuries.

Different foot problems such as metatarsal stress fracture, interdigital neuroma (mechanical entrapment neuropathy of the interdigital nerve), sesamoid pathology, and metatarsalagia (pain in the plantar aspects of the metatarsal heads) are the results of repetitive high load on the foot (Omey & Micheli, 1999). In addition, stress fracture is common among soccer players. It has been reported that 38% of the U.S. team players were diagnosed with stress fractures in the 1994 National World Cup Soccer (Knapp, Mandelbaum, & Garrett, 1998). Therefore, knowledge about the specific areas and the magnitude of the pressure beneath the foot in soccer movements is important for training, injury prevention, rehabilitation, and footwear design.

Therefore, the purposes of the present study were to compare the in-shoe plantar pressure of the four soccer movements, and to identify the plantar areas where high pressure was exerted.

METHOD:

Subjects: Fifteen male subjects (age: 20.87 ± 1.30 years; height: 173 ± 4 cm; weight: 61.67 ± 3.61 kg; self-reported experiences of playing soccer: 10.20 ± 2.98 years; self-reported experiences of wearing soccer shoes: 4.73 ± 2.19 years) participated in the study. They were asked to identify their dominant leg according to their experience. The subjects were current members of the university soccer team and were free from injuries during the time of the study. All of them were properly informed about the nature of the study, and each signed a written consent prior to participation. The protocol was approved by the Clinical Research Ethics Committee.

Shoe: The experimental shoe (Attiva R, Diadora, Italy) had 12 circular studs. We manually examined the shoe by palpation to ensure that it was fit for subjects, and no discomfort was reported by the subjects throughout the test.

Equipment: For the measurement of insole plantar pressure distribution, the Pedar Mobile System (Novel GmbH, Munich, Germany) was used (50Hz). Plantar pressures were recorded from the subjects' dominant foot.

Procedure: The warm-up was performed on a 20 m x 8 m artificial turf (FieldTurf, USA) approved by FIFA. The required movements included 210 meters of running (at self-paced speed), five sideward cuttings on the left and right sides (at self-paced speed), five 45-degree cuttings on the left and right sides (at self-paced speed), five landings from countermovement vertical jump (maximum height), and five minutes (or more if the subjects requested) of muscle stretching.

During the test, four movements performed were running (at 3.3m/s), sideward cutting (at fastest speed), 45-degree cutting (at fastest speed), and landings from countermovement vertical jump (at maximal jump height). Five successful trials were collected for each movement.

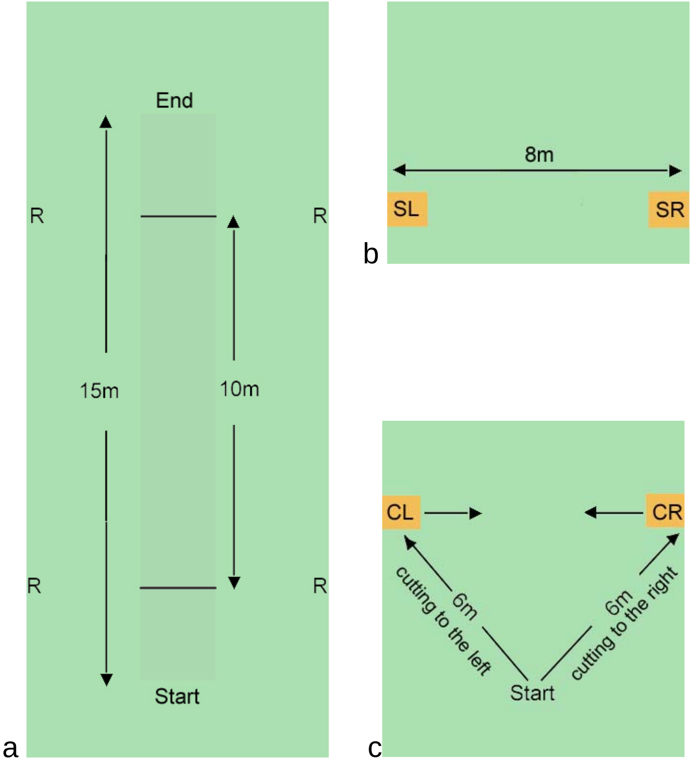

Figure 1: The Experimental Set Up and Running Paths for Subjects with Right Dominant Legs For the Following Movements: (a) Running, (b) Sideward Cutting, (c) 45-degree Cutting to the Right

Two pairs of infrared timing sensors ("R" in Figure 1a) (Speedtrap II Wireless Timing System, Brower Timing System, Australia) were located in the middle 10 m to determine if the running speed was within 5% of the desired range (3.3m/s). Only the trials that fell within the desired range of speed were accepted.

The subjects performed sideward cutting and 45-degree cutting movements with their dominant leg. The paths of sideward cutting and 45-degree cutting for subjects with a right dominant leg are shown in Figure 1b and 1c, the paths for subjects with a left dominant leg are in the opposite direction.

For countermovement vertical jump, the subjects performed the jump on the turf area near the starting point. They were required to land on both feet after reaching their maximal jump height.

Parameter: Each footprint was divided into 10 masked areas. For each footprint, peak pressure (in terms of kPa) and pressure-time integral (in terms of kPas) were extracted. Peak pressure represented the highest pressure recorded by each masked area at any time during the data collection period. Pressure-time integral was calculated as the product of the pressure and the time over which it was applied.

Data Analysis: One-way ANOVA with repeated measure (P < 0.05) was employed to examine the differences in plantar pressure among the four movements. Pairwise comparison with Bonferroni adjustment was employed when a significant difference in one-way ANOVA occurred.

RESULTS: The means and standard deviations of peak pressure and pressure-time integral are listed in Table I. The one-way ANOVA of peak pressure and pressure-time integral indicated significant differences ($P < 0.05$) among the four movements under all masked areas (Table 1). Results of pairwise comparisons among the four movements are presented in Table 2.

Table 1 Means and Standard Deviations for Peak Pressure and Pressure-time Integral of Running, Sideward Cutting, 45-degree Cutting, and Jump Landing (n = 15)

Parameter	**Movement**				**F**
	Running	**Sideward cutting**	**45-degree cutting**	**Jump landing**	
Peak pressure (kPa)					
Hallux	383 ± 124	436 ± 83	492 ± 75	375 ± 70	7.404**
Second toe	140 ± 33	221 ± 85	296 ± 109	126 ± 43	26.560**
Lateral toes	133 ± 42	145 ± 59	183 ± 47	129 ± 65	7.233**
Medial forefoot	367 ± 129	518 ± 78	550 ± 72	325 ± 108	35.371**
Central forefoot	325 ± 51	330 ± 150	347 ± 134	198 ± 35	9.881**
Lateral forefoot	178 ± 45	82 ± 27	79 ± 30	132 ± 28	29.939**
Medial arch	106 ± 25	181 ± 70	144 ± 84	111 ± 40	7.058**
Lateral arch	121 ± 24	86 ± 26	69 ± 18	113 ± 38	17.328**
Medial heel	237 ± 47	351 ± 82	441 ± 78	217 ± 116	29.260**
Lateral heel	247 ± 57	295 ± 90	401 ± 104	208 ± 115	15.274**
Pressure-time integral (kPas)					
Hallux	49.1 ± 12.3	101.4 ± 25.6	86.5 ± 21.9	34.3 ± 7.5	55.664**
Second toe	20.9 ± 5.5	47.9 ± 18.5	48.2 ± 19.0	12.1 ± 4.6	39.717**
Lateral toes	18.5 ± 6.6	32.4 ± 18.4	32.8 ± 12.0	11.4 ± 6.1	22.272**
Medial forefoot	46.9 ± 15.0	123.7 ± 31.8	105.6 ± 11.0	30.4 ± 9.5	111.045**
Central forefoot	43.4 ± 8.0	73.6 ± 33.0	58.9 ± 17.8	19.5 ± 3.2	26.955**
Lateral forefoot	23.7 ± 4.9	16.9 ± 6.0	12.7 ± 5.0	12.0 ± 2.4	19.612**
Medial arch	11.5 ± 2.7	27.9 ± 15.1	21.0 ± 10.1	5.7 ± 2.2	24.062**
Lateral arch	14.2 ± 3.3	13.0 ± 3.8	10.1 ± 3.1	5.8 ± 2.1	43.366**
Medial heel	19.0 ± 5.2	40.7 ± 12.0	42.5 ± 8.8	8.7 ± 4.2	95.106**
Lateral heel	20.4 ± 5.4	37.9 ± 12.5	40.1 ± 10.3	8.7 ± 4.2	62.102**

** *P* < 0 .01.

Table 2 Pairwise Comparisons among Running, Sideward Cutting, 45-degree Cutting, and Jump Landing (n = 15)

	Peak pressure						**Pressure-time integral**					
	R&S	**R&C**	**R&J**	**S&C**	**S&J**	**C&J**	**R&S**	**R&C**	**R&J**	**S&C**	**S&J**	**C&J**
Hallux		*				*	**	**	**		**	**
Second toe	*	**		**	**	**	**	**	**		**	**
Lateral toes		**		**		*	*	**	**		**	**
Medial forefoot	**	**			**	**	**	**	**		**	**
Central forefoot			**		*	**	*	*	**		**	**
Lateral forefoot	**	**	**		**	**		**	**	*		
Medial arch	**				*		**	*	**		**	**
Lateral arch	**	**		**		**		**	**	*	**	**
Medial heel	**	**		**	**	**	**	**	**		**	**
Lateral heel		**		*	*	**	**	**	**		**	**

* *P* < 0.05.
** *P* < 0.01.
Note. R = running, S = sideward cutting, C = 45-degree cutting, J = jump landing.

DISCUSSION: In general, the present study showed that: (1) a higher peak pressure and pressure-time integral were found under the medial areas rather than under the lateral areas of the plantar surface; (2) a higher peak pressure was found under the hallux, medial forefoot, central forefoot, and medial heel in all four movements; (3) a higher pressure-time integral was found under the hallux, medial forefoot, and central forefoot in all four movements; (4) sideward cutting and 45-degree cutting had a higher peak pressure than running under areas in the medial side of the plantar surface; and (5) as compared to running, sideward cutting and 45-degree cutting had a higher pressure-time integral under most of the areas, while jump landing had a lower pressure-time integral under most of the areas.

The data obtained in the present study generally agree with the findings reported by Eils *et al.* (2004) in which higher peak pressures were measured in the medial side rather than in the lateral side of the plantar surface during running and cutting movements in soccer. Although the sequence which appeared in the present study was not the same as that in the study of Eils *et al.* (2004), the three areas with the highest peak pressures during running were found to be the same: the hallux, the medial forefoot, and the central forefoot. Specifically, the peak pressure during running was found, in descending order, in the medial forefoot, the hallux, and the central forefoot in Eils *et al.*'s study (2004), and in the hallux, the medial heel, and the central forefoot in the present study. In addition, in both studies, the cutting movement had a higher peak pressure than running under the hallux, second toe, medial forefoot, medial arch, medial heel, and lateral heel in both studies, but it had a lower peak pressure than running under the lateral forefoot and lateral arch. However, the peak pressures under the lateral toes and central forefoot in the cutting movements were higher than those in running in the present study, though the opposite was reported by Eils *et al.* (2004).

A higher peak pressure was recorded under the hallux and the medial forefoot in both the present study and a previous study (Eils *et al.*, 2004). It is believed that a high peak pressure, together with high repetition, will lead to chronic injury (Omey & Micheli, 1999) and reduce perceived comfort (Cavanagh, 1980). In addition, a higher peak pressure and pressure-time integral were found in sideward cutting and 45-degree cutting in the present study, which implies that these two movements might have a higher chance of causing injury. Attention should be paid to these areas and movements when developing and implementing a training program, injury prevention program, rehabilitation program, and when designing footwear.

CONCLUSION: Sideward cutting and 45-degree cutting had a higher pressure, while jump landing had a lower pressure, as compared to running. Among these movements, higher pressures were found on the medial side of the plantar surface. Specifically, the hallux, medial forefoot, central forefoot, and medial heel received higher pressure, implying that these areas have a higher risk of injury. It is further suggested that foot orthosis may help reduce pressure and injury.

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