THE INFLUENCE OF THIRD GENERATION ARTIFICIAL SOCCER TURF CHARACTERISTICS ON GROUND REACTION FORCES DURING RUNNING

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The aim of this study was to determine the effect of different artificial soccer turf pitches on the ground reaction forces of running soccer players. For this purpose ground reaction forces were determined for twenty soccer players while they ran at three different speeds across a 25 meter long track covered with a third generation artificial soccer turf. Three different pitches, two FIFA 1star and one FIFA 2star, were examined. There was no difference between the two 1star systems in the peak vertical and horizontal ground reactions forces. Data on the 2star system was equivocal due to a too small sample size. It is concluded that surface characteristics influence the loading of the human muscle-skeletal system more subtly than initially anticipated. A more detailed biomechanical analysis of the events during impact is required to identify the critical loading parameters.

KEY WORDS: injury, ground reaction forces, artificial soccer turf.

INTRODUCTION: The state of the art in soccer playing surfaces is the third generation artificial turf pitch. These systems combine fiber and infill technologies to mimic the properties of natural pitches. FIFA distinguishes between general purpose pitches (1star) and pitches for professional soccer (2star), based on a set of standardized tests. These tests, aimed at optimal playing characteristics, determine deformation, shock absorption, energy reduction, torsion and ball behavior, where data on natural turf serves as a reference. Although standardized material tests are an excellent means for maintaining a constant product quality, it is doubtful whether they will aid the development of load reducing soccer pitches. Static tests are not representative of the dynamic interaction between player and surface during a game. Moreover, they do not predict the loading experienced by humans (Nigg and Yeadon, 1987).

A major focus for new developments in fiber and infill technologies should be the reduction of injuries. Soccer injuries are a serious problem. In the Netherlands, for example, 13% of all sports injuries are soccer related, a major part (25 %) of which is associated with overloading and sprains (Vriend, Schoots, Inklaar and Backx 2005). To understand the influence of a soccer surface on human loading requires a biomechanical analysis of the actual human-surface interaction. Previous studies on athletic tracks have shown that such an approach has great potential (i.e. McMahon and Greene 1979).

The aim of this study was to test the effects of different surfaces on the load experienced by the human muscle-skeletal system. For this purpose, ground reaction forces were recorded while soccer players ran over three different artificial turf pitches, two FIFA 1star pitches with different elastomeric infill material and one FIFA 2star pitch. Running was studied, because it is the main soccer activity (Reilly 1990).

METHOD:

Data Collection: A 25 meter single lane running surface was constructed of plywood boards, screwed on wooden blocks that provided a stiff support. A force platform (Kistler 9281A, Kistler Instrumente AG) was located in the middle of the track, such that the approach was approximately 12.5 meters long. The entire track was covered with a third generation artificial turf system that was identical to experimental *pitch A*. The approach runway was not altered during the experiments. This choice was motivated by the fact that found that human runners instantaneously adjust to changes in surface stiffness (Ferris, Liang and Farley 1999). The area on the force platform was subsequently covered with different experimental pitches. The force platform and the tested pitch made no physical contact with the running track, to ensure that force platform data related only to the single foot impact. The experimental pitches were attached onto the force plate with two - sided tape.

Three experimental pitches were studied. They consisted of a 50 mm polypropylene grass fiber (8800 stitches/m^2, 1.1*10^3 Dtex) filled with a layer of 10 mm round shaped river sand (psd 0.5-1.0). They were different with respect to the extra elastomeric infill material and the use of an additional elastic layer. *Pitch A* had an additional 20 mm thick layer of thermoplastic elastomer (TPE) granules (2.0-2.2 mm). *Pitch B* had an additional 20 mm thick layer of pulverized car tire material (SBR) (0.8-2.5 mm). *Pitch C* was identical to *pitch A*, with one difference, there was an additional 10 mm rubber layer placed underneath *pitch C* to enhance the shock absorption. The pitches were designed to meet the FIFA qualifications for artificial turf (FIFA 1star, *pitches A & B*; FIFA 2star, *pitch C*), which was verified by a test with the Berlin Artificial Athlete.

Twenty healthy male soccer players were recruited at a local soccer club. Only players who had been free off injuries over the past year were included in the study. The subjects had an average age of 25.3 ± 9.1 years, an average weight of 80.1 ± 11.6 kilograms and an average length of 1.83 ± 0.09 meters.

Subjects were asked to run five times at each of the three different speeds: preferred jogging speed (Jog), a run at 17.5 km/h (Run) and a full sprint (Sprint). Subjects were instructed to land on the force platform with their right leg. They ran on their own soccer shoes with normal studs. Running speed was determined from the time it took the subject to cross the middle 3.5 meters of the track. Time was recorded with a custom made light-emitting diode system. For the *Run* trial the subjects were required to stay within 5% of this speed, otherwise the trial was repeated. During each run the ground reaction forces were recorded with the force platform and A-D converted at a sample rate of 1 kHz.

Data Analysis: The following parameters were determined from the ground reaction forces; the vertical impact peak, i.e. force peak within first 100 ms (F_p), the vertical active peak (F_a), the contact time (tc) and the peak horizontal impact force (F_h) was determined. Effects of surface characteristics and running speed on these parameters were statistically tested using a repeated measurements analysis of variance.

RESULTS: At identical running speeds, the force profiles of *pitches A and B* are very similar in amplitude and timing, although there appear to be differences in the force oscillations during impact (fig. 1). In comparison, for *pitch C* the amplitude of the vertical force is substantial lower and the peaks are delayed. In addition the contact time is increased and it seems as if the horizontal push-off force is increased. Unfortunately, only two subjects completed the trials on *pitch c*. As a consequence, only the data for *pitches A and B* were included in the statistical analysis.

Table 1 shows a summary of the data obtained for *pitches A and B*. The most striking result is that there is no difference between the two pitches on any of the examined parameters. It also shows that there are clear effects of running condition (jog, run and sprint). Horizontal impact force increased significantly with increasing speed. Furthermore, contact time decreased significantly with increasing speed. Surprisingly, running speed had no effect on the amplitude of the passive and active vertical peak forces.

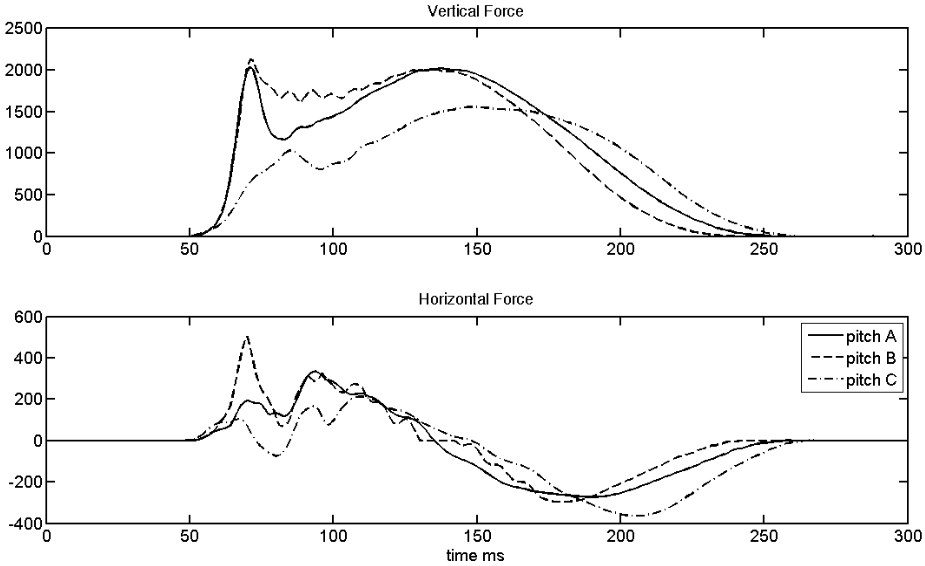

Figure 1: Typical example of ground reaction force profiles during running on the three different pitches (A, B & C). Data represents a 17.5 km/h run of a single subject.

Table1: Summary of the data obtained for pitches A and B. Vertical (F_p and F_a) and horizontal forces (F_h) are corrected for bodyweight (BW), tc= contact time of single leg support, * represents a significant effect of running condition (P<0.05).

	Jog		Run		Sprint	
Pitch	**A**	**B**	**A**	**B**	**A**	**B**
Speed (km/h)	13.9±2.2	14.8±1.7	17.6±0.4	17.5±0.3	24.6±0.9	24.5±0.8
F_p (BW)	2.30±0.32	2.30±0.41	2.52±0.36	2.50±0.43	2.53±1.31	2.65±1.02
F_a (BW)	2.66±0.23	2.62±0.25	2.70±0.27	2.65±0.28	2.58±0.29	2.60±0.35
tc (ms)*	217±27	208±19	192±14	191±12	143±13	144±12
F_h (BW)*	0.46±0.13	0.43±0.11	0.54±0.13	0.53±0.13	0.77±0.19	0.81±0.18

DISCUSSION: This is the first biomechanical comparison of different FIFA qualified soccer pitches. Initial analysis of the data for the two FIFA 1star pitches reveals that there is no effect of surface on the ground reaction forces. This indicates that for systems with identical mechanical characteristics, the type of infill material (e.g. grain size and shape) does not influence the human loading. Closer analysis of the force profiles, however, reveals that there are differences in force oscillations during the impact phase between pitch A and B (fig 1), even though the peak forces are the same. This could be attributed to surface related differences in the accelerations of the distal leg segments (foot, shank). It has been proposed that oscillation of soft tissue, i.e. muscles, induced by impact forces is a major cause of injuries (Nigg and Wakeling 2001). Therefore, future studies should include a more detailed analysis of the frequency components in the impact forces.

Analysis of the FIFA 2star experiments yielded equivocal results. For one subject, it appeared that the increased shock absorption of the FIFA 2star turf resulted in reduced loading in during running (fig. 1). In the other subject, however, the FIFA 2 star system actually increased the loading. It is unclear whether this is related to differences in running strategy, since subject one was a toe runner and subject two was a heel runner. Unfortunately, the number of subjects was too small to draw any definite conclusions.
The data of the current study is in general agreement with running studies on hard surfaces, there is however an interesting difference. In contrast with other studies (e.g. Arampatzis, Bruggeman and Metzler 1999; Hamill, Bates, Knutzen and Sawhill 1983; Munro, Miller and Fuglevand, 1987), it was found that the vertical forces (F_p & F_a) were independent of running speed. This difference might be related to speed dependent mechanical characteristics of the artificial turf pitches. Mechanical tests at different loading rates will need to be conducted to test this.

CONCLUSION: This study represents the first biomechanical comparison of the human-surface interaction on FIFA qualified artificial turf pitches. It is concluded that surface characteristics influence the loading of the human muscle-skeletal system more subtly than initially anticipated. A more detailed biomechanical analysis of the events during impact is required to identify the critical loading parameters.

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Acknowledgement

DSM thermoplastics for providing the facilities to perform the running experiments.