SLIDING ON HARDCOURT SURFACE WITH SPECIFIC SHOES, PRELIMINARY RESULTS

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The purpose of this study was to investigate the sliding characteristics of a new shoe (NSh) concept. The NSh has been developed with the specific aim of facilitating sliding on hard surface such as tennis players can do on clay or synthetic turf. Five young tennis players performed several trials on a walkway instrumented with seven force platforms synchronized with a motion capture system. Results revealed that the coefficient of friction was still higher for the NSh-hard surface condition than for the regular shoe-synthetic turf condition but the players were able to obtain the same sliding length provided that approach velocity was higher.

KEY WORDS: tennis, hard surface, friction, synthetic turf

INTRODUCTION: In tennis, several court surfaces are used and specific training interventions are proposed depending on the surface characteristics. More specifically, foot work and running speed are different according to the court surface (Ferrauti, Fernandez-Fernandez, Klapsing, Ulbricht & Rosenkranz. 2013). Furthermore, knee (Kulund, McCue, Rockwell & Gieck, 1979) and back (Von Salis-Soglio 1979) injuries have been predominantly observed for players playing on hard courts compared to courts that favor sliding such as clay or turf . The reason would be that the ground reaction force and internal loading are lower when playing on surfaces that allow sliding (Tiegermann, 1984; Girard, Eicher, Fourchet, Micallef & Millet, 2007). Recently, a new concept of shoe (NSh : Wilson prototype, AmerSports Footwear, Annecy, France, Patent USA n°US2013019505) was specifically designed to allow players to slide more easily on hard courts and thus mimic clay/turf conditions . The purpose of this study was to compare the sliding characteristics (coefficient of friction, length of the slide, approach velocity) of the NSh on a hard surface to a regular shoe (RSh) on synthetic turf (the reference condition) We hypothesized that the NSh does allow players to slide on hard courts but less than on synthetic turf.

METHODS: Five young tennis players (mean age 14.2 years old, mean height 1.7 m, mean mass 52.5 kg) with at least 6 years of tennis regular training took part in this study. Before the experiment, they practiced several months with the NSh, were given specific training and even participated in tournaments with them. Testing took place in the human motion analysis experimental room. Six force platforms (Sensix, Poitiers France) of dimension 600×400mm and one force platform (Kistler, Switzerland) of dimension 600×900mm were used. Force platforms were synchronized with a motion capture system (Vicon 10 T40, 4 Mpx cameras). Kinematics data were collected at 200 Hz and forces data were collected at 1000 Hz. Force platforms were consecutively covered with the two surfaces: synthetic turf and a hard surface (GreenSet®) specifically cut to fit the dimension of each force platform (Fig. 1). A set of 43 reflective markers (diameter 9 mm) were put on each body segments in order to reconstruct segmental and body centers of mass following the anthropometric model of Zatsiorsky modified by de Leva (de Leva, 1996).
Subjects were instructed to play a ball thrown by a partner ten times with a forehand slice and ten times with a backhand slice for both conditions.

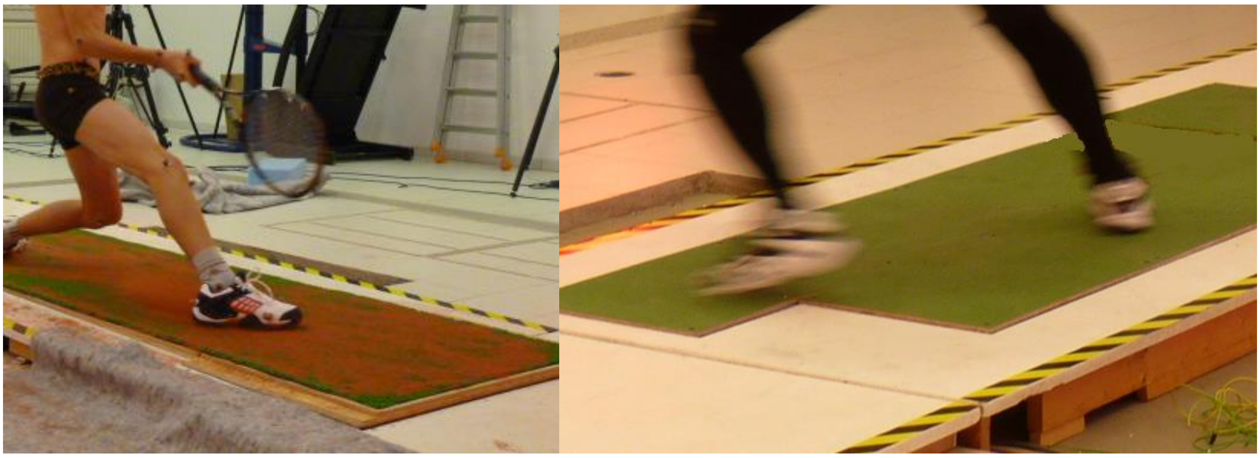

Figure 1. Experimental setup with force platforms covered with synthetic turf (left) and with a hard court surface (right).

In order to characterize the sliding, three parameters were calculated:

- coefficients of friction defined as the ratio between horizontal force and normal force. This parameter was calculated from the force platforms data
- length of the slide defined as the horizontal distance travelled by the forward foot during the slide (calculated from kinematics data with markers fixed on the shoe).
- horizontal approach velocity that is the velocity of the body center of mass just before the beginning of the slide. This parameter was calculated from kinematics data and the anthropometric model.

To detect the beginning of the sliding phase, three variables were examined: the vertical position of the forward foot, its longitudinal velocity and the friction coefficient. The beginning of the slide was assumed when the friction coefficient started to become constant. (Fig. 2).

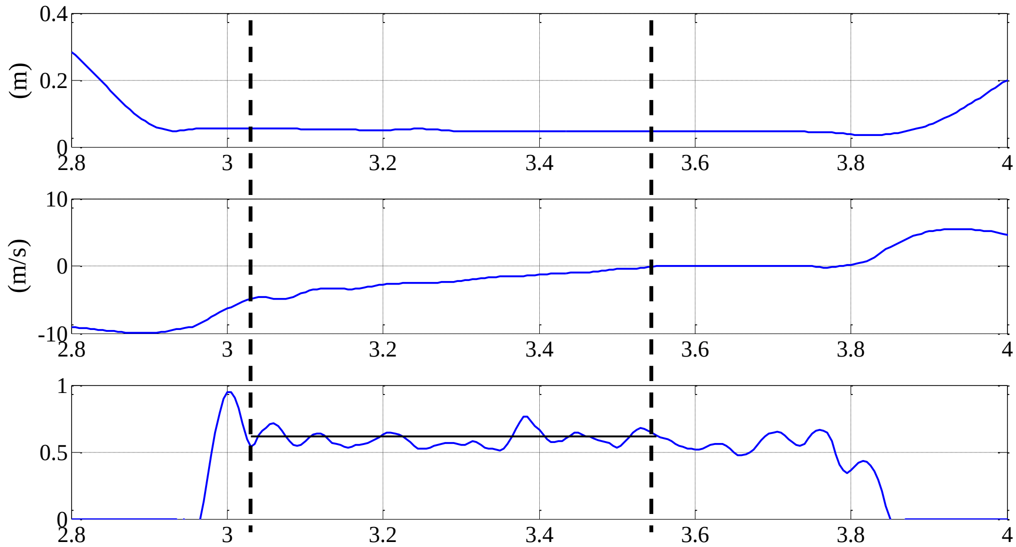

Figure 2. From top to bottom: Vertical position (m) of the marker fixed on the back of the forward shoe, longitudinal velocity (m/s) of the forward foot center of mass and friction coefficient of the forward shoe. The vertical bold dotted lines represent the beginning and end of the sliding phase. The horizontal line on the friction coefficient plot represents the mean coefficient of friction calculated for that slide.

For each parameter (friction coefficients, sliding length and approach velocity), a wilcoxon-test was performed to test if there was a significant difference between the two conditions.

RESULTS: The coefficient of friction was lower on synthetic turf (0.52±0.07) than on hard court with NSh (0.68±0.08) with $p<0.05$ (Fig. 3A). The slide length was similar ($p=0.27$) for both conditions (Fig. 3B). The approach velocity was also not significantly different between hard court with NSh (4.00±0.32 m/s) and synthetic turf with RSh (3.81±0.33 m/s) with $p=0.09$ (Fig. 3C).

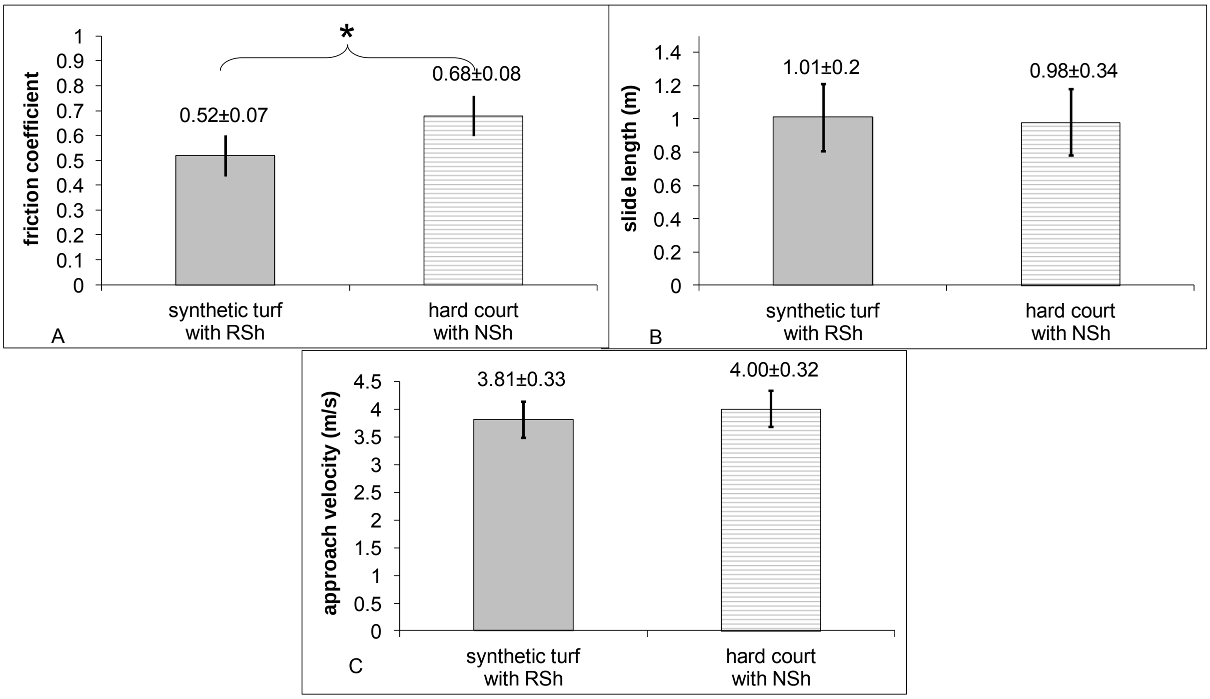

Figure 3. Coefficient of friction (A), slide length (B) and approach velocity (C) on synthetic turf with regular shoe (RSh) and on hard court with new concept of shoe (NSh). * reveals a significant difference.

DISCUSSION: The purpose of this study was to analyse the sliding ability on hard courts given by a new concept of Shoe (NSh) compared to the sliding on synthetic turf with a regular shoe. In a first attempt, the RSh was also tested on hard surface but players were unable to slide, therefore this condition was not included in this study.

Previous studies reported that friction coefficients range from 0.5 to 0.7 for clay surface and 0.8 to 1.2 for hard surfaces (Nigg, 2003). The synthetic turf used in this study can then be compared to clay as the friction coefficient that we found was 0.52. More importantly, using NSh on hard surface resulted in a friction coefficient of 0.68, which is in the range of the clay surface as well.

Whereas friction coefficients are usually determined using a bespoke traction testing device (Clarke, Carré, Damm & Dixon, 2012), another originality of this study is to provide friction coefficients from experimental “in vivo” measurements. As results found in this study are very similar to those obtained with mechanical testing devices, we think that it is a very promising approach. In fact, we addressed real human response whereas mechanical testing device are not able to emulate loading conditions occurs during playing tennis.

The friction coefficient of the NSh was also evaluated using a mechanical testing device and found to be 0.67 (vs. 0.68±0.08 "*in vivo*"). This coefficient was obtained on a dry ceramic surface following the recommendation of the EN 13287 norm. Then, even if the surface were different, the similarity of the coefficient obtained from both methods argues again for a good validity of our experimental protocol.

The main finding of this study was that it is possible to slide on hard court with NSh even if the friction coefficient remains higher than on synthetic sand.

Mechanically, because the friction coefficient was higher on hard surface with NSh than on synthetic turf, the slide length should have been smaller and/or the approach velocity higher. From our results, it seems that the player were capable to obtain a similar sliding length thanks to a greater velocity (but not significant). Future work will include more subjects and better standardize the player movement in order to deepen the analysis of the *in vivo* sliding mechanisms.
As of now, using NSh seems to require a more important "energy input" and learning sessions are essential to get used to the shoes. The possibility to slide on hard surface has two main advantages. Firstly sliding offers the possibility to catch more balls and to replace faster to get ready for the next shot (Nigg 2003). Secondly the reaction force under the forward feet is lower when sliding (Girard, Eicher, Fourchet, Micallef & Millet, 2007). As injury frequency is higher in hard surface, using NSh may potentially reduce injuries and offer new possibility for regular or casual tennis players.

CONCLUSION: We demonstrate that sliding on hard surface is possible with specially dedicated shoes and potentially offers tennis players the benefits of catching more balls and reducing injury risks.

REFERENCES:

Clarke, J., Carré, M., Damm, L. & Dixon, S. (2012). The influence of surface characteristics on the tribological interactions at the shoe-surface interface in tennis. Procedia Engineering, 34, 866-71.

Ferrauti, A., Fernandez-Fernandez, J., Klapsing, G.M., Ulbricht, A. & Rosenkranz, D. (2013). Diagnostic of footwork characteristics and running speed demands in tennis on different ground surfaces. Sports Orthopaedics and Traumatology, 29, 172-9.

Girard, O., Eicher, F., Fourchet, F., Micallef, J.P. & Millet, G.P. (2007).Effects of the playing surface on plantar pressures and potential injuries in tennis. British Journal of Sports Medicine, 41, 733–8.

Kulund, D.N., McCue, F.C. Rockwell, D.A. & Gieck, J.H. (1979). Tennis injuries: prevention and treatment. The American Journal of Sports Medicine, 7, 249-253.

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. Journal of Biomechanics, 29, 1223-30.

Nigg, B (2003). Injury and performance on tennis surface. The effect of tennis surfaces on the game of tennis.

Tiegermann, V.R. (1984) Load of the locomotor system and its quantification with the help of EMG Doctoral Thesis. ETH Zürich, Switzerland.

von Salis-Soglio, G. (1979). Sport injuries in tennis. Deutsche Zeitschrift für Sportmedizin, 8: 244-7.