EFFECTS OF FOOTWEAR ON LATERAL BRAKING AND TURNING MOVEMENTS IN TENNIS

**Salvador Llana, Gabriel Brizuela, Enrique Alcántara, Arturo Forner,
Ana Cruz García,
Universidad Politécnica de Valencia, Paterna, Spain**

KEY WORDS: pronation, lateral movement, footwear, tennis

INTRODUCTION: In tennis, as in most non-cyclic sports, a wide variety of displacements are performed; these can be classified as walking, running, hopping, jumping and other (Nigg *et al*., 1989). Table 1 shows the results of a comparative study of differences between senior and amateur players, where it is indicated how the influence of displacements depends on the sport category.

Table 1: Frequency of the types of displacement for a sample of senior and amateur players on synthetic surface (Nigg et al., 1989).

Sports category	**Type of displacement**				
	Walking	**Running**	**Hopping**	**Jumping**	**Other**
Senior	30.5	29.8	29	5.8	4.9
Amateur	73.5	15.2	8.8	1.8	0.7

Hopping is a type of displacement characteristic of racquet sports, when the player is waiting for the opponent's action. This is the third more frequent type of displacement made by amateur players, and it has a frequency similar to walking and running by senior players. They generally imply lateral displacements, with sudden brakings and followed by changes of direction. The mechanical requirements made by these sudden lateral brakings can be a direct cause of several types of injury, such as ankle joint injury caused by excessive supination. Furthermore, they have a decisive influence on performance, since they determine whether the ball can be hit during play. Therefore, it is not unusual that lateral displacements with changes of direction have been chosen by many authors for the study of technical tennis footwear (Luethi *et al*., 1986; Simpson, 1991; Stüssi *et al*., 1989; Van Gheluwe & Deporte, 1992).

The present study aimed at analyzing the effect of a commercially available tennis footwear sample on the most relevant kinetic and kinematic variables in lateral braking with a change in direction.

MATERIALS AND METHODS: The footwear sample consisted of the 10 best tennis technical shoes sold in Valencia, according to a previous market survey. Five senior male players were selected who had no pathology of the locomotor system.

The technical movement selected was a lateral displacement followed by braking and a change of direction (Figure 1). Each subject performed

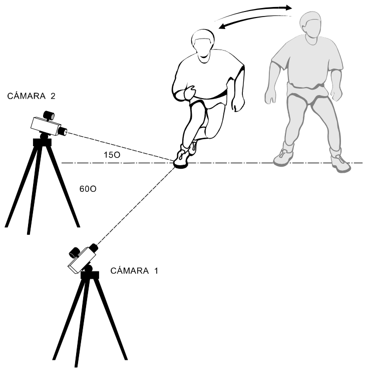

Figure 1: Movement analyzed.

the test movement five times with each footwear model in the sample. The order in which the 10 shoes were tested was chosen at random before each test.

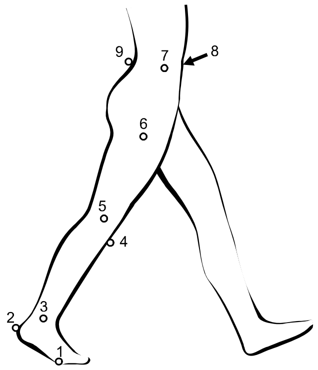

Figure 2: Model by Vaughan et al.

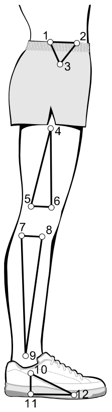

Figure 3: Digitization model.

The registering of kinetic variables was done by means of a Dinascan-IBV force plate with extensometric characteristics, with a sampling frequency of 1000 Hz. The upper side of the plate was replaced by a 55 mm thick synthetic surface, officially approved by the Spanish Tennis Federation.

Kinematic variables were recorded by means of Kinescan-IBV video-photogrammetry system of automatic digitization. The kinematic lower limb-pelvis model used was that proposed by Vaughan et al. (1992) (Figure 2). However, since some of the markers in this model were hidden during the performance of certain movements, a second model, called a "digitization model" was finally used. In this model, each segment was defined by means of three markers placed in such a way that they were visible all the time during the performance of the movement (Figure 3). In this way, before performing the movement, the subjects were filmed with both model's markers and, later, Vaughan's model markers were deleted. Since the position of any rigid solid can be calculated from the known positions of three points of the same rigid solid, it was possible to calculate the positions of the markers of Vaughan's model from the positions of the markers in the digitization model.

The 250 files obtained were processed using Kinescan-IBV software to obtain the three-dimensional co-ordinates. They were smoothed by means of GCV 5th order spline functions, and exported to ASCII code to MATLAB software, where the parameters of interest were extracted.

The kinetic and kinematic data files were imported into Statgraphic-plus software and each parameter was considered a statistical variable with which an analysis of variance (ANOVA) was done, considering the footwear models and the subjects as factors, setting the significance level at 0.05 and doing a *post hoc* LSD analysis. With the kinetic and kinematic footwear-dependent variables a parametric correlation analysis (Pearson) was done.

RESULTS: Tables 2 and 3 present the kinetic and kinematic footwear-dependent variables, and Table 4 shows the strongest correlations after correlating these parameters.

Table 2: Kinematic footwear-dependent parameters.

Parameter	Code	Significance level (p)
Hip flexion in contact with surface	FCIP	0.0313
Maximum knee flexion	MFRP	< 0.0001
Ankle extension in contact with surface	ETIP	0.0002
First maximum ankle flexion	PFTP	0.0135
Second maximum ankle flexion	SFTP	0.0065
Supination in contact with surface	SSIP	< 0.0001
First supination maximum	PSSP	< 0.0001
Second supination maximum	SSSP	< 0.0001

Table 3: Kinetic footwear-dependent parameters.

Parameter	Code	Significance level (p)
Second maximum of vertical forces	FZ2	0.0004
Time between the first and the second maximum of vertical forces	TFZ2-TFZ1	0.008
Second maximum of medio-lateral forces	FY2	0.0326
Time between the first and the second maximum of medio-lateral forces	TFY2-TFY1	0.0139

Table 4: Existing correlations.

	FCIP	**MFRP**	**ETIP**	**PFTP**	**SFTP**	**SSIP**	**PSSP**	**SSSP**
FZ2	r = -0.132 p = 0.019	r = -0.169 p = 0.006	r = 0.226 p < 0.001	r = -0.162 p = 0.006	r = -0.213 p < 0.001	p > 0.05	r = -0.122 p = 0.028	r = -0.172 p = 0.004
TFZ2-TFZ1	r = -0.546 p < 0.001	r = -0.129 p = 0.022	r = -0.311 p < 0.001	r = -0.129 p = 0.022	p > 0.05	r = 0.311 p < 0.001	r = 0.402 p < 0.001	r = 0.139 p = 0.005
FY2	r = 0.463 p < 0.001	r = 0.534 p < 0.001	r = 0.357 p < 0.001	p > 0.05	p > 0.05	r = -0.357 p < 0.001	r = -0.431 p < 0.001	r = -0.228 p < 0.001
TFY2-TFY1	r = -0.558 p < 0.001	r = -0.675 p < 0.001	r = -0.2765 p < 0.001	r = -0.122 p = 0.028	p > 0.05	r = 0.290 p < 0.001	r = 0.378 p < 0.001	r = 0.142 p = 0.013

CONCLUSIONS: In the movement analyzed there are two maximums both in medio-lateral and in vertical forces. The first corresponds to the landing or shock absorption phase, whereas the other stands for the take-off or impulsion phase. Consequently, higher levels of force in the second maximum mean a faster start, and the kinematic variables associated with this can be considered performance variables. From this, we can conclude that in those lateral displacements which include a braking and a change in direction higher levels are reached in the second maximum of vertical and medio-lateral components of reaction forces when the footwear controls (limits) the supination movement of the subastragalar joint.

In the same way, shorter time intervals between the first and second maximums of vertical and medio-lateral forces indicate a shorter step time, and consequently, a faster performance of the movement. Shorter time intervals were associated with lower values of subastragalar joint supination, and therefore this control can be considered a criterion of performance improvement.

As a consequence, the control of the prono-supination movement, traditionally considered important from an epidemiological point of view, can be considered an important criterion of performance in lateral displacements.

REFERENCES:

- Nigg, B. M., Luethi, S. M., Bahlsen, H. A. (1989). The Tennis Shoes. Biomechanical Design Criteria. In B. Segesser, W. Pförringer (Eds.), *The Shoe in Sports*. London: Wolfe Publishing, Ltd.
- Luethi, S. M., Frederick, E. C., Hawes, M. R., Nigg, B. M. (1986). Influence of Shoe Construction on Lower Extremity Kinematics and Load during Lateral Movements in Tennis. *Int. J. Sports Biomech*. **2**(3), 166-174.
- Simpson, K. (1991). Factors Related to Rearfoot Kinematics during a Rapid Braking Movement. In R. N. Marshall, G. A. Wood, B. C. Elliot, T. R. Acland, P. J. McNair (Eds.), *XIIIth International Congress on Biomechanics*. Perth, Australia.
- Stüssi, E., Stacoff, A., Tiegermann, V. (1989). Rapid Sideward Movements in Tennis. In B. Segesser, W. Pförringer (Eds.), *The Shoe in Sports*. London: Wolfe Publishing, Ltd.
- Van Gheluwe, B. V., Deporte, E. (1992). Friction Measurement in Tennis on the Field and in the Laboratory. *Int. J. Sports Biomech*. **8**, 48-61.

ACKNOWLEDGEMENTS:

This study was supported by IMPIVA (Institute for the Small and Medium Valencian Enterprise) and by J'Hayber, a Spanish footwear manufacturing company.