PLANTAR FORCE COMPARISONS BETWEEN THE CHASSE STEP AND ONE STEP FOOTWORK DURING TOPSPIN FOREHAND USING STATISTICAL PARAMETRIC MAPPING

Yuqi He[1], Zixiang Gao[1], Gusztáv Fekete[2], Dusan Mitic[3], Yaodong Gu[4]

[1] Faculty of Engineering, University of Pannonia, Veszprem, Hungary
[2] Savaria Institute, Eötvös Lorand University, Szombathely, Hungary
[3] Department of recreation, University of Belgrade, Belgrade, Serbia
[4] Faculty of Sports Science, Ningbo University, Ningbo, China

The purpose of this study was to investigate the plantar force characteristics of the chasse step and one step footwork during table tennis topspin stroke using one-dimensional statistical parameter mapping (SPM 1d). Twelve national players volunteered to participate in the study. The plantar force of the right foot during the chasse step and one step backward phase (BP) and forward phase (FP) was recorded by instrumented insole systems. Paired sample T tests in SPSS 24.0 (SPSSs Inc, Chicago, IL, USA) were used to analyze peak pressure of each plantar region. For SPM analysis, the plantar force time series curves were marked as a 100% process. A paired-samples T-test in MATLAB was used to analyze differences in plantar force. One step produced a greater plantar force than the chasse step during 6.92-11.22% BP (P=0.039). The chasse step produced a greater plantar force than one step during 53.47-99.01% BP (P<0.001). During the FP, the chasse step showed a greater plantar force than the one step in 21.06-84.06% (P<0.001). The findings indicate that athletes can enhance plantarflexion function resulting in greater weight transfer, facilitating a greater momentum during the 21.06-84.06% of FP. In addition, reducing the load on the foot during landing by utilizing a buffering strategy. The one step showed higher peak pressure in MR, LR and LF, in BP, and the chasse step showed higher peak pressure at T and FP, indicating the potential design direction of shoes and insoles.

KEYWORDS: plantar force, footwork, table tennis, chasse step.

INTRODUCTION: Footwork is a necessary factor influencing the performance of table tennis players. Players perform large amounts of active running to ensure that they can reach the most suitable hitting position prior to playing the next stroke (Malagoli Lanzoni et al., 2007). The chasse step and one step are the basic footwork patterns that combine with forehand and backhand strokes in table tennis (Lam et al., 2018). Proficient mastery of footwork can bring advantages to energy transfer in the power chain of lower extremities. In addition, the effect of foot performance during stroke play has been demonstrated in previous studies. Qian et al. (2016) have identified the significant differences of in-shoe plantar pressure between different level table tennis players. One possible explanation for the differences observed is the synergy that exists between the torso and lower extremities during the entire stroke motion (Kasai et al., 1998). Therefore, the study of biomechanics in table tennis footwork is an interesting field for athletes and scientists. The comparative study of plantar force between the two footwork can further understand the internal mechanism of the contribution of plantar mechanics characteristics to the forehand topspin, and can also suggest the information of possible plantar injuries.

Statistical parametric mapping (SPM) is a methodology that could test the statistical differences of continuous data such as kinematics and kinetics throughout the whole motion period to calculate accurately the significance threshold (Pataky, 2013). Based on the one-dimensional characteristics of footwork movements changing with time, this study combined traditional discrete analysis with one-dimensional statistical parameter mapping (SPM 1d) to conduct statistical analysis on the plantar force data of table tennis players during the chasse step and one step footwork. The results of this study will provide information for athletes and coaches to develop training programs and prevent foot injuries.

METHODS: Twelve national table tennis players (Height: 172 ± 3.80 cm, Weight: 69 ± 6.22 kg, Age: 22 ± 1.66 years, Experience: 11 ± 1.71 year) volunteered to participate in this study. All subjects held rackets in their right hands and the plantar data of the right foot was recorded using a Novel Pedar insole plantar pressure measurement system (Novel GmbH, Munich, Germany, sampling frequency of 100 Hz). In the formal experimental, participants were asked to return the coach's shot to the target area using chasse steps and one steps, respectively. The hitting methodology for this experiment was as follows: the coach was asked to serve to the impact zone, which was in the center line of the table tennis table, and then serve to the impact zone which in the right side of the table tennis table. The player then needed to use the chasse step and one step footwork to return the ball to the target area. Participants were asked to complete four successful strokes using chasse step footwork in the first instance, then complete four further successful strokes using one step footwork. The smoothness of the movement was judged by the players themselves, and the quality and effect of the ball play was supervised by a qualified table tennis coach.

The stroke action is divided into the backward phase (BP) and forward phase (FP). And the plantar was divided into six areas: Toe (T), Medial forefoot (MF), Lateral forefoot (LF), Midfoot (M), Medial rearfoot (MR) and Lateral rearfoot (LR). The data was then exported into MATLAB R2019a (The MathWorks, MA, United States), and a written script was produced to process the data.

Prior to statistical analysis, all data were tested using the Shapiro-Wilk normality test, and non-parametric data tests were conducted using a Wilcoxon matched-pairs signed-rank test. Paired sample T tests in SPSS 24.0 (SPSSs Inc, Chicago, IL, USA) were used to analyze peak pressure of each plantar region. For SPM analysis, the plantar force time series curves were marked as a 100% process. A paired-samples T-test in MATLAB was used to analyze differences in plantar force between the chasse step and one step during BP and FP, respectively. An alpha level of 0.05 ($\alpha = 0.05$) was set as being statistically significant.

RESULTS: As shown in Table 1, for the Toe, the chasse step produced a greater peak pressure than the one step in the FP ($P < 0.001$). In the LF, the one step produced a greater peak pressure than the chasse step during the BP ($P = 0.042$). In addition, the one step produced a greater peak pressure than the chasse step in the LR ($P < 0.001$) and MR ($P < 0.001$) during BP. As shown in Figure 1, one step produced a greater plantar force than the chasse step during 6.92-11.22% BP ($P = 0.039$). The chasse step produced a greater plantar force than the one step during 53.47-99.01% BP ($P < 0.001$). During the FP, the chasse step showed a greater plantar force than one step in 21.06-84.06% ($P < 0.001$).

Table 1: The peak pressure comparison of each plantar region between the chasse step and one step at BP and FP. (Unit: kpa).

Partition	Phase	Chasse Step Mean±SD	One step Mean±SD	P value
T	BP	174.97 ± 88.64	178.13 ± 89.03	0.742
	FP	388.85 ± 165.38	277.14 ± 59.61	<0.001*
LF	BP	100.52 ± 20.74	116.04 ± 42.58	0.042*
	FP	129.44 ± 45.84	132.60 ± 83.07	0.764
MF	BP	243.75 ± 91.12	262.45 ± 114.63	0.069
	FP	379.43 ± 83.39	348.65 ± 145.31	0.078
M	BP	119.01 ± 23.56	119.01 ± 41.84	1.000
	FP	55.82 ± 24.29	47.71 ± 19.72	0.104
LR	BP	395.11 ± 64.81	563.72 ± 83.89	<0.001*
	FP	90.43 ± 74.95	70.74 ± 61.52	0.206
MR	BP	404.27 ± 146.27	517.96 ± 119.44	<0.001*

	FP	85.58 ± 57.32	85.17 ± 60.46	0.976

Note: BP means backward phase; FP means forward phase. "*" refers to significance with $p < 0.05$. Toe (T), Medial forefoot (MF), Lateral forefoot (LF), Midfoot (M), Medial rearfoot (MR), Lateral rearfoot (LR).

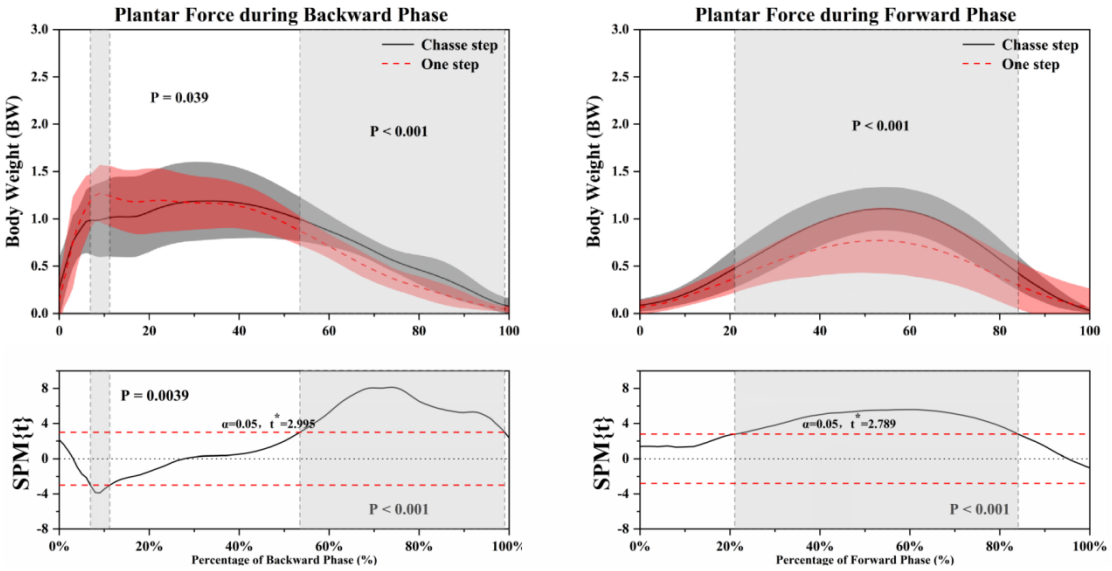

Figure 1: The Statistical Parametric Mapping (SPM) results of plantar force between chasse step and one step during the backward and forward phase. Grey shaded areas indicate that there are significant differences ($p < 0.05$) between the chasse step and one step. Top figures refer to the comparison of plantar force between the chasse step and one step. The bottom figures refer to the details of Statistical Parametric Mapping (SPM) results. BW means body weight. "α =0.05" means set the 0.05 as being statistically significant. "*" refers to significance with $p < 0.05$.

DISCUSSION: With the development of biomechanical measurement methods and techniques, biomechanical research of the lower limbs during table tennis has received extensive attention in recent years. The exploration of the lower limb kinetic mechanisms of footwork in table tennis can provide a theoretical basis for the optimization of lower limb dynamic chain, the prevention of sports injury and a contribution to the development of table tennis shoes. The key findings of this study were that: 1) In 6.92-11.22% of the BP, the one step showed greater plantar force than the chasse step, and in 53.47-99.01% of the BP, the chasse step showed greater plantar force than the one step, which means that the one step showed greater plantar force on landing, and that the chasse step showed a better force accumulation effect in the BP. In 21.06-84.06% of the FP, the chasse step showed greater plantar force than the one step, indicating better lower limb drive. 2)The one step showed greater peak pressure in the MR, LR and LF regions than the chasse step in the BP. In the FP, the chasse step showed a greater peak pressure in the T than the one step.

Compared with the one step, the chasse step showed greater plantar force in the 53.47-99.01% process of BP, and a greater plantar force during 21.06-84.06% process of FP, and a higher maximum plantar force in FP, as well as a greater peak pressure in the T. This means that the chasse step shows greater complete lower limb extension and drive during the FP. It appears that the greater energy transfer promotes the generation of momentum (He et al., 2020). We can speculate that the chasse step footwork can produce a greater racket speed during stroke play when compared with the one step. As the origin of the dynamic chain, the lower limbs transfer the optimal activation energy from the lower limbs to the upper limbs through the continuous movement of the dynamic chain (Elliott, 2006).

Lam et al. (2018) have investigated the biomechanical differences between different footwork during the topspin forehand in table tennis. In their study, the significantly higher peak pressures were in the plantar region of total foot, toe, 1st, 2nd and 5th metatarsal during chasse step and cross-step compared with one step. The chasse step also showed a higher peak

pressure than one step in toe area. This is consistent with the results of this study. However, the MR, LR and LF observed a higher peak pressure in the one step than the chasse step in this study, and this is not consistent with the results of Lam et al. (2018). This may be due to the different movement distances of the footwork resulting in different momentums resulting in different force values during landing. The chasse step showed higher peak pressure in the T than the one step. This could mean more plantarflexion during chasse step footwork in the FP. This may contribute to a greater range of weight transfer and thus momentum generation (Ball, 2007).

Previous studies have reported on the underlying mechanisms of lower limb energy transfer and racket speed (He et al., 2021). In this study, the chasse step showed significantly greater plantar force than the one step in the 21.06-84.06% process of FP. From a practical point of view, athletes can enhance the plantarflexion function to bring greater weight transfer, resulting in a greater momentum during the 21.06-84.06% process of FP, thus improving the performance of racket speed. As well as from the perspective of sports monitoring, the quality of strokes during one step footwork can be monitored by analyzing the plantar force curves of players in the 21.06-84.06% process of FP.

The key findings in this study not only provide information for exploring foot injuries of table tennis players, but also provides reference information for the design and development of table tennis shoes soles. There are some limitations in the study that should be mentioned. Firstly, this study simulated the competition environment in the laboratory, which may have some differences to real competitions. Secondly, the experiment did not consider the foot morphology of the subjects, and different foot shapes may show different plantar load characteristics under the same footwork. In the future, biomechanical research related to the lower limbs of table tennis players, should include the influence of foot morphology on experimental results. Real time data and more advanced methods and equipment should be used to collect experimental information during a real competition environment.

CONCLUSION: The findings indicate that athletes can enhance plantarflexion function resulting in greater weight transfer, facilitating a greater momentum during the 21.06-84.06% of FP. This is in addition to reducing the load on foot during landing by utilizing a buffering strategy. The one step showed higher peak pressure in MR, LR and LF, in BP, and the chasse step showed higher peak pressure at T and FP, indicating the potential design direction of shoes and insoles.

REFERENCES

Malagoli Lanzoni I., Di Michele R. & Merni F. (2007). Footwork techniques used in table tennis: A qualitative analysis. *Proceedings of the 10th ITTF sport science congress*, 401- 408.

Lam W.K., Fan J.X., Zheng Y. & Lee W.C. C. (2018). Joint and plantar loading in table tennis topspin forehand with different footwork. *European Journal of Sport Science,* 19 (4), 471--479. DOI 10.1080/17461391.2018.1534993.

Qian J., Zhang Y., Baker J.S. & Gu Y. (2016). Effects of performance level on lower limb kinematics during table tennis forehand loop. *Acta of Bioengineering and Biomechanics* 18 (3), 149-155.

Kasai J. & Mori T. (1998). A qualitative 3D analysis of forehand strokes in table tennis. In: Lees A, Maynard I, Hughes M, Reilly T, eds. *Science and Racket Sports II*. London: E. & F.N. Spon, 201-205.

Pataky T.C., Robinson M. A. & Vanrenterghem J. (2013). Vector field statistical analysis of kinematic and force trajectories. *Journal of Biomechanics,* 46 (14), 2394-2401. DOI 10.1016/j.jbiomech.2013.07.031

He Y., Lv X., Zhou Z., Sun D., Baker J. S. & Gu Y. (2020). Comparing the Kinematic Characteristics of the Lower Limbs in Table Tennis: Differences between Diagonal and Straight Shots Using the Forehand Loop. *Journal of Sports Science and Medicine,* 19 (3), 522-528.

Elliott B. (2006). Biomechanics and tennis. *British journal of sports medicine*, 40 (5), 392-396. DOI 10.1136/bjsm.2005.023150

Ball K & Best R. (2007). Different centre of pressure patterns within the golf stroke II: Group-based analysis. *Journal of Sports Sciences,* 25 (7), 771-779. DOI 10.1080/02640410600875002

He Y., Lyu X., Sun D., Baker J. S. & Gu Y. (2021). The kinematic analysis of the lower limb during topspin forehand loop between different level table tennis athletes. *PeerJ,* 9:e10841. DOI 10.7717/peerj.10841