Journal of Visualized Experiments

Comparison of Kinetics Characteristics of Footwork During Stroke in Table Tennis: Cross-Step and Chasse Step

--Manuscript Draft--

Article Type:	Invited Methods Article - JoVE Produced Video
Manuscript Number:	JoVE62571R2
Full Title:	Comparison of Kinetics Characteristics of Footwork During Stroke in Table Tennis: Cross-Step and Chasse Step
Corresponding Author:	F Dr. Ren Ningbo University Ningbo, Zhejiang CHINA
Corresponding Author's Institution:	Ningbo University
Corresponding Author E-Mail:	renfengnb@yeah.net
Order of Authors:	Huiyu Zhou
	Yuqi He
	Xiaoyi Yang
	F Dr. Ren
	Ukadike Ugbolue
	Yaodong Gu
Additional Information:	
Question	**Response**
Please indicate whether this article will be Standard Access or Open Access.	Standard Access (US$2,400)
Please specify the section of the submitted manuscript.	Behavior
Please indicate the **city, state/province, and country** where this article will be **filmed**. Please do not use abbreviations.	Ningbo/Zhejiang/China
Please confirm that you have read and agree to the terms and conditions of the author license agreement that applies below:	I agree to the Author License Agreement
Please provide any comments to the journal here.	
Please indicate whether this article will be Standard Access or Open Access.	Standard Access ($1400)

TITLE:

Comparison of Kinetic Characteristics of Footwork During Stroke in Table Tennis: Cross-Step and Chasse Step

AUTHORS AND AFFILIATIONS:

Huiyu Zhou[1,2], Yuqi He[1], Xiaoyi Yang [1], Feng Ren, Ukadike C. Ugbolue[2], Yaodong Gu[1*]

[1]Faculty of Sports Science, Ningbo University, China
[2]School of Health and Life Sciences, University of the West of Scotland, UK

Email Addresses of co-authors:
Huiyu Zhou (B00385863@studentmail.uws.ac.uk)
Yuqi He (1811042041@nbu.edu.cn)
Xiaoyi Yang (2011042109@nbu.edu.cn)
Feng Ren (renfengnb@yeah.net)
Ukadike C. Ugbolue (u.ugbolue@uws.ac.uk)
Yaodong Gu (guyaodong@nbu.edu.cn)

*Corresponding author:
Yaodong Gu (guyaodong@nbu.edu.cn)

KEYWORDS:

cross-step; chasse step; ground reaction force; table tennis

SUMMARY:

This study presents a protocol to investigate the ground reaction force characteristics between cross-step and chasse step during stroke in table tennis.

ABSTRACT:

The cross-step and chasse step are the basic steps of table tennis. This study presents a protocol to investigate the ground reaction force characteristics between cross-step and chasse step during stroke in table tennis. Sixteen healthy male national level 1 table tennis players (Age: 20.75 ± 2.06 years) volunteered to participate in the experiment after understanding the purpose and details of the experiment. All participants were asked to hit the ball into the target zone by cross-step and chasse step, respectively. The ground reaction force in the anterior-posterior, medial-lateral, and vertical directions of the participant was measured by a force platform. The key finding of this study was that: the posterior ground reaction force of cross-step footwork (0.89 ± 0.21) was significantly large ($P = 0.014$) than the chasse step footwork (0.82 ± 0.18). However, the lateral ground reaction force of cross-step footwork (-0.38 ± 0.21) was significantly lower ($P < 0.001$) than chasse step footwork (-0.46 ± 0.29) as well as the vertical ground reaction force of cross-step footwork (1.73 ± 0.19) was significantly lower ($P < 0.001$) than chasse step footwork (1.9 ± 0.33). Based on the mechanism of the kinetic chain, the better lower limb dynamic performance of sliding stroke may be conducive to energy transmission and thus bring gain to the swing

speed. Beginners should start from the chasse step to hit the ball technically, and then practice the skill of cross-step.

INTRODUCTION:

Table tennis has developed continuously in sports training and competition practice for more than 100 years[1]. With economic globalization and cultural exchanges, table tennis has developed rapidly in various countries[2,3]. In Croatia, for example, table tennis is not only played in clubs, but also in universities, schools, and even in dormitories[4]. For athletes, the establishment of sports analysis is helpful for training and competition[5]. In table tennis competitions, players need good strategies to try to win the match[6]. Additionally, footwork is a skill that must be mastered in table tennis, and it is also the basis and one of the key points of table tennis training. The chasse step and cross-step are the basic steps of table tennis[7]. Every sports skill has a basic mechanical structure. The study of biomechanics is of high interest to the progress and development of table tennis skills. In training and competition, table tennis players find the accurate position through their steps[7]. Therefore, it is necessary to study the step of table tennis.

There are differences in the step of table tennis players from different regions, with Asian players using steps more frequently than European players both during training and in competition[8]. During competition, a high-level table tennis player will hit the ball in a shorter time, at a more steady step, and have enough time to hit the next ball[9]. In table tennis, because of the cross-step hitting action, in most cases it is a technical action to save the ball, leading to the inability to complete the hitting action with high quality. On the contrary, different from cross-step hitting, chasse step hitting is a common technical action, so athletes can better grasp the hitting technical action through practice to ensure the quality of their stroke. A chasse step is when the drive leg (right leg) moves to the right side (toward the ball) and then the left leg follows to move. A cross-step is when the drive leg (right leg) moves to the right side (toward the ball) with a large distance, and the left leg does not move.

Through previous studies, lower limb muscles play an important role in table tennis performance[10]. Table tennis has similarities with tennis moves. There are differences in the driving stability of lower limbs of tennis players with different levels of serving skill[11]. Table tennis involves knee flexion and asymmetrical torsion of the trunk[12]. In order to improve the skills of table tennis players, attention should be paid to the rotation of the pelvis[13]. When playing forehand loop, excellent table tennis players have a better sole control ability[14]. High-level table tennis players can better control the plantar pressure deviation, increase the inner and outer pressure deviation, and reduce the front and back pressure deviation[15]. Compared with a straight shot, a diagonal shot has a greater knee extension during the swing[16]. Table tennis service technology is diverse and has complex biomechanical characteristics. Compared with standing serves, squatting serves require higher lower-limb drive[17]. Compared with beginners, elite athletes are more flexible in their stride in cross-step exercises[7].

In light of the above, with the increasing progress of science and the continuous development of table tennis skills, more and more players and researchers have joined table tennis, which requires high-quality biomechanical research to support the sport. However, due to the complexity of table tennis, it is difficult for researchers to measure the biomechanics[1]. There are few studies on the biomechanics of the lower limbs of table tennis. The purpose of this study was to measure the ground reaction force of elite college table tennis players in the movement of the racket lead and swing in chasse step and cross-step. The ground reaction force data of the two steps are compared. The first hypothesis of this study is that the chasse step and cross-step have different ground reaction force characteristics. The ground reaction force of chasse step and cross-step is used to obtain the kinetic data of two kinds of steps, which provides guidance and suggestions for table tennis players.

PROTOCOL:

This study was approved by The Human Ethics Committee of Ningbo University, China. Written informed consent was obtained from all subjects after they were told about the goal, details, requirements, and experimental procedures of the table tennis experimental.

1. Laboratory preparation for table tennis

1.1. Insert the USB dongle into the PC's parallel port and open the motion-capture infrared cameras and analog-to-digital converter.

NOTE: In this laboratory, the force platform (sampling frequency of 1000 Hz) is used together with the motion acquisition system, and the data collected by the force platform was displayed and preliminarily analyzed through the same system. The default sampling frequency of the force platform is 1000 Hz.

1.2. Double-click the software icon on the desktop to open the tracking software.

NOTE: Before opening the software, remove all obstacles in the experimental environment and clean the ground.

1.3. Every camera node will show a green light if the hardware connection is true. When the indicator light of all cameras is green, select eight cameras in the **Local System**.

1.4. Click on **Camera** in the Perspective window and adjust the Strobe Intensity as 0.95–1, Gain to times 1 (x1), Threshold as 0.2–0.4, Minimum Circularity Ratio as 0.5, Grayscale Mode to Auto, as well as Max Blob Height to 50.

1.5. Place the T correction rack in the center of the shooting area, and select eight cameras in the system. Using a 2D model, confirm that the camera can discern T correction and that there are no noise points.

1.5.1. Place the T correction rack in the center of the camera area. Click on the **System Preparation**, the **L – Frame** drop-down list, and select **5 Marker Wand & L – Frame**. Then, click on the **Start** button under the **AimMX cameras** option.

1.6. Select the **System preparation** button, and click on the **Start** button in the Calibrate MX Camera section in the **Tool** pane. Then, wave the T-wand in the capture range. When the blue light on the infrared camera stops flashing, stop the action.

1.6.1. Observe the progress bar until the calibration process is complete at 100% and returns to 0%. At the same time, observe the error of the image. When the error of the image is less than 0.3, continue the following operation.

1.7. Place the T-shaped correction frame in the center of the moving area to ensure that the axis direction is consistent with the boundary direction of the force platform.

1.8. Select the **Start** button under the **Set Volume Origin** section in the Tool pane.

2. Participants' preparation

NOTE: Sixteen healthy male national level 1 table tennis players volunteered to participate in the experiment (Ages: 20.75 ± 2.06year; Height: 173.25 ± 6.65 cm; Weight: 66.50 ± 14.27 kg; Training Year: 12.50 ± 2.08 year). All of them belong to the Ningbo University table tennis team. Before the formal start of the experiment, the details and process of the experiment were briefly explained to the participants again, and the written informed consent of the participant who met the conditions of the experiment were obtained.

2.1. Select participants that are right-handed, have the right leg as dominant, and are in good physical health, free of any form of lower limb disease or injury in the last 6 months. A total of 16 male participants who met the experimental conditions were included in this experiment. The demographic information of participants is shown in **Table 1**.

NOTE: Because there are few left-handed racket users, it was easier to find enough right-handed racket users to participate in this experiment.

2.2. Ask all participants to fill out a questionnaire related to fitness.

NOTE: Questions include: Have you had a history of table tennis competition? How often do you take part in table tennis training in a week? Have you suffered any lower-limb disorders and injuries in the last 6 months?

2.3. Ensure that all participants wear professional table tennis match shoes as well as identical t-shirts and tight-fitting pants. Have all participants use the same professional table tennis racket.

2.4. Give each participant 5 min to adapt to the experimental environment and 15 min to warm up with light running on the professional treadmill and stretching. Due to the short duration of the experiment, restrict subjects from eating and drinking during the formal experiment in order to keep them in a stable state.

NOTE: Participants first completed a 5 min jog at an adaptive speed on the lab's professional running table, followed by a 5 min stretch of their lower limb muscles. Finally, they practiced table tennis footwork technique for 5 min. After completing the warm-up task, the participants were given 2 min to adjust their state. The formal data collection began.

3. Static calibration

3.1. Click on the **Data Management** button on the toolbar.

3.2. Click on the **New Database** tab on the toolbar, click on the **Location**, and then import the description of the trial. Select **Clinical Template** and click on the **Create** button.

3.3. Select the name of the database created in the **Open Database** window. Then, click on the green **New Patient Category** button, the yellow **New Patient** button, and the gray **New Session** button to create experimental information in the newly opened screen.

3.4. Click on **Subjects** to create a New Subject data set in the Nexus main pane.

3.5. Click on the **Start** button in the **Subject Capture** section to create a static model. Click on the **Stop** button when the image frames are at 140–200 to finish the establishment of the static model.

NOTE: The participants were asked to stand on a force platform during the experiment. They were asked to maintain a stable posture with their hands folded and raised on their chest, looking ahead, and their feet shoulder-width apart.

4. Dynamic trials

4.1. As shown in **Figure 1,** place the table tennis table and ball basket in the experimental environment to ensure that the subjects have enough space to execute two kinds of footwork.

NOTE: The table tennis table and balls are up to the standards of professional events.

4.2. Ask the participant to hold the ready position, When the experimenter gives the start command, ask the coach to serve the table tennis balls to the first and final impact area, respectively.

4.2.1. Before the formal experiment begins, give the participants enough time to get accustomed to this position through practice.

4.2.2. Ask the participants to start on the left side of the table, about half a meter away from the table. Then, ask them to hit the first and second served ball by forehand with maximum force and return to the ready position after finishing the second stroke task.

4.2.3. Ask the participants to first use the chasse step footwork to complete 5 successful strokes, and then use the cross-step footwork to complete 5 successful strokes.

4.3. In the software, click on the **Capture** button in the pressure platform to start the recording and click on the **Stop** button to end the recording. Repeat five times for each participant.

NOTE: If the shot is not within the range of the target area, or if the subject's right foot is not fully on the force platform, the measurement will be re-taken.

5. **Post-processing**

5.1. Double-click on the trial name in the **Data Management** window. Click on the **Reconstruct Pipeline** and **Labels** buttons in the toolbar to display the experiment demonstration.

5.2. In the **Perspective window**, move the blue triangle on the time bar to intercept the desired time interval.

5.3. Select the **Dynamic Plug-in Gait** that is in the **Subject Calibration** pane. Click on the **Start** button to run and export the data.

6. Statistical analysis

6.1. Analyze all data using professional statistical software. Run the Shapiro–Wilks tests to check the normal distribution for all variables.

6.2. Use a paired *t*-test to compare kinetics characteristics of chasse step footwork and cross-step footwork during table tennis stroke.

6.3. Set the significance level at $p < 0.05$. The results are presented as the mean ± the standard deviation throughout the text unless otherwise stated.

REPRESENTATIVE RESULTS:

As shown in **Figure 2** and **Table 2**, the posterior ground reaction force of the cross-step footwork (0.89 ± 0.21) was significantly larger ($P = 0.014$) compared with the chasse step footwork (0.82 ± 0.18). However, the lateral ground reaction force of cross-step footwork

(-0.38 ± 0.21) was significantly lower (P < 0.001) than the chasse step footwork (-0.46 ± 0.29). Additionlly, the vertical ground reaction force of cross-step footwork (1.73 ± 0.19) was significantly lower (P < 0.001) than the chasse step footwork (1.9±0.33). No differences were observed between the medial or anterior ground reaction forces between the cross-step and the chasse step footwork during stroke in table tennis (P > 0.05).

FIGURE AND TABLE LEGENDS:

Figure 1: Experiment setup

Figure 2: The ground reaction force in the posterior, anterior, medial, lateral, and vertical directions.

Table 1: The participant demographic information table.

Table 2: The ground reaction force information of chasse step footwork and cross-step footwork in three planes during stroke in table tennis. Significant differences between the chasse step footwork and cross-step footwork are denoted with an asterisk (*). BW means multiple of body weight.

DISCUSSION:

The aim of this study is to investigate the ground reaction force characteristics between cross-step and chasse steps during stroke in table tennis. The key findings of this study are stated here. The anterior ground reaction force of cross-step footwork was significantly larger than the chasse step footwork. The lateral ground reaction force of cross-step footwork was significantly lower than the chasse step footwork. The vertical ground reaction force of cross-step footwork was significantly lower than the chasse step footwork.

Marsan et al. (2020) showed that Newton's second law could be a good estimation method for the ground reaction force value except for peak ground reaction forces[18]. In the results of this study, the displayed value of the ground reaction force is close to the value of the measurement observed by Marsan et al. (2020). This further supports the results of this study. A perfect stroke requires coordination of the whole body. The control of footwork patterns requires a coordinated sequence of body parts interacting with each other, and the optimal activation of all links is defined as the "kinetic chain"[11,19,20]. The lower limbs, as the starting point of the kinetic chain, transfer the best-activated energy from the lower limbs to the upper limbs through the continuous movement of the kinetic chain[9,21]. These include the integrity of the body when hitting the ball, as well as more full transmission of the lower limb kinetic chain.

The lateral ground reaction force of the chasse step hitting movement is significantly greater than the action of the cross-step hitting movement. Lam et al. (2019) observed the same results. The maximum horizontal force of the side-step was significantly higher than the one-step[22]. The chasse step hitting technique can be mastered by athletes through practice,

and the cross-step hitting technique has great variability compared with the chasse step hitting action. Therefore, with a lot of practice of the chasse step hitting, the lower limb kinetic chain transmission of the players could be more complete and smoother, so that the swing of hitting the ball in the process of the push force is more complete. The flow of the kinetic chain is conducive to an energy transfer from the lower limb to the upper limb, considerably influencing racket and ball speed in racket sports[22–25]. In general, in terms of the lateral ground reaction force, the chasse step hitting ball is higher than the cross-step hitting ball, which again confirms the results of this study regarding the vertical ground reaction force. Due to the variability and immediacy of the cross-step, the cross-step hitting technique cannot fully complete the swing action. Therefore, a greater push is required as a compensatory mechanism in the anterior direction. To compensate, the cross-step exhibits a greater anterior ground reaction force than the chasse step hitting technique. Shimokawa et al. (2020) investigated a similar result in the tennis forehand groundstroke. The peak anterior-posterior ground reaction force plays an influential role in affecting forehand post-impact ball speed[26]. However, a greater anterior ground reaction force may cause the center of gravity not to return to the initial position in time, thus affecting the beginning of the next movement. In the practical application of training and competition, athletes and coaches attempt to master the ability to control the center of gravity during cross-step footwork. Beginners should start from the chasse step footwork to hitting the ball. When the player has mastered the ability to control the center of gravity while hitting the ball, they can further learn to use the cross-step footwork.

There are several critical steps in the protocol. Firstly, the subject needs to accurately step on the center position of the force measuring table when executing the two footwork, to ensure that the ground reaction force data of the subject can be collected completely and accurately. Any data where the foot is placed outside the platform should be eliminated. Secondly, during the execution of the experiment, in order to accurately collect data, athletes need to execute actions after hearing the "start" command. The same experimenter is responsible for issuing the command. Third, in the process of data post-processing, the interpretation of the subjects' movements should be extremely rigorous.

The main limitations of this study were that the whole experiment was a real match environment as this will affect the practical application of the results of this study. Secondly, in this study, only the ground reaction force information of the two footsteps in the swing stage was measured. In future further research, experimental data should be collected in a situation that is as close to a real competitive environment as possible and the ground reaction force information of the racket lead stage should also be collected together.

By comparing the ground reaction force of two footwork techniques, the anterior ground reaction force of the cross-step footwork was significantly larger than the chasse step. The cross-step footwork is often used to recover the ball from a large distance, which may be a result of the timeliness of the cross-step. The time to return to the initial position changed the center of gravity and influenced the beginning of the next action. Athletes and coaches should pay attention to using cross-step footwork and having good control over the center of

gravity to avoid moving the weight forward too much and affect the next movement. At the same time, the player should adjust their step as soon as possible after the cross-step stroke to prepare for the next movement. The lateral and vertical ground reaction force of the chasse step was significantly larger than the cross-step footwork. The chasse step is an action that the athlete can learn through training to hit the ball. Enhancing the driving force of the lower limbs and optimizing the transmission of the lower limb power chain could increase the speed and power of the swing.

DISCLOSURES:

No potential conflict of interest was reported by the authors.

ACKNOWLEDGMENTS:

This work was supported by the National Natural Science Foundation of China (No. 81772423). The authors would like to thank the table tennis players who participated in this study.

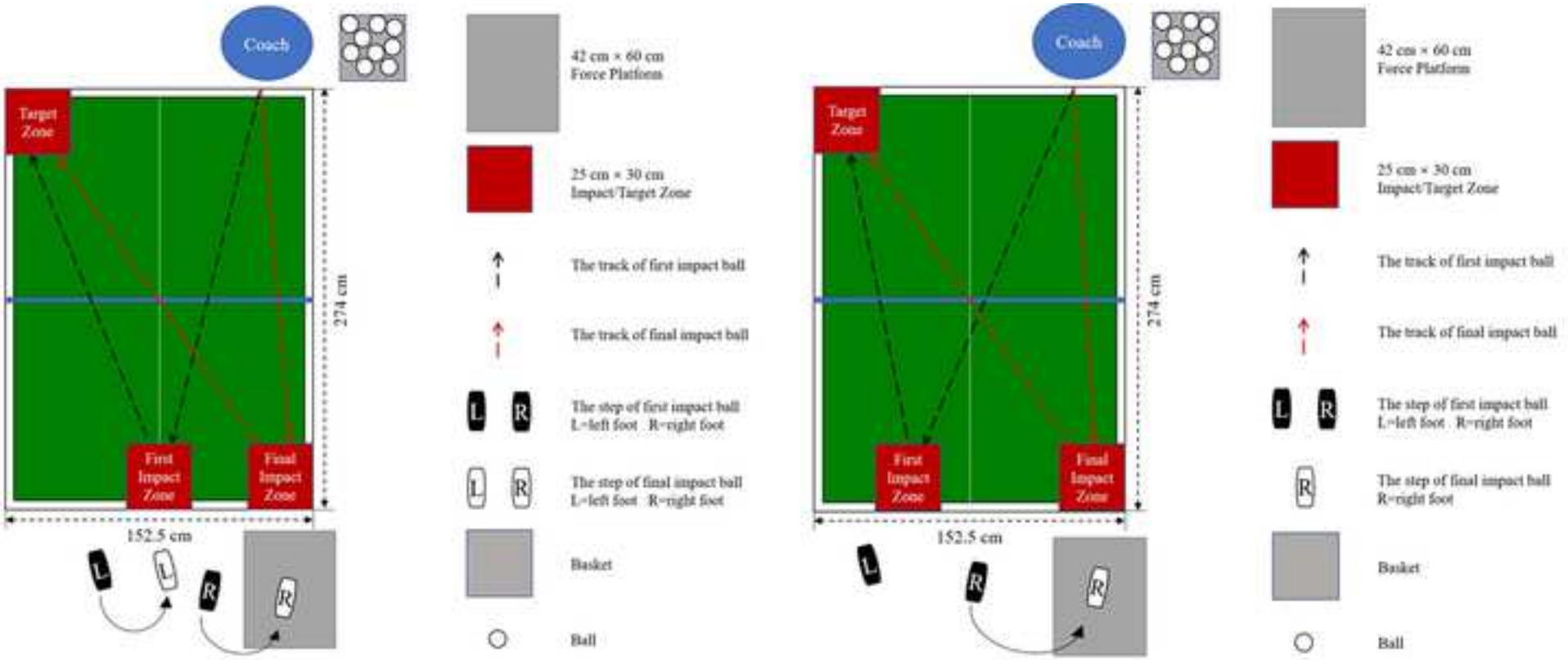
REFERENCES:

1. Kondrič, M., Zagatto, A. M., Sekulić, D. The physiological demands of table tennis: a review. *Journal of Sports Science & Medicine*. **12** (3), 362 (2013).
2. Mueller, F. F., Gibbs, M. R. A physical three-way interactive game based on table tennis. in *Proceedings of the 4th Australasian Conference on Interactive Entertainment*. 1–7 (2007).
3. Mueller, F. F.,Gibbs, M. A table tennis game for three players. in *Proceedings of the 18th Australia conference on Computer-Human Interaction: Design: Activities, Artefacts and Environments*. 321–324 (2006).
4. Furjan-Mandić, G., Kondrič, M., Tušak, M., Rausavljević, N., Kondrič, L. Sports students' motivation for participating in table tennis at the faculty of kinesiology in Zagreb. *International Journal of Table Tennis Sciences*. **6**, 44–47 (2010).
5. Wang, Y., Chen, M., Wang, X., Chan, R. H., Li, W. J. IoT for next-generation racket sports training. *Internet of Things Journal*. **5** (6), 4558–4566 (2018).
6. Muelling, K., Boularias, A., Mohler, B., Schölkopf, B., Peters, J. Learning strategies in table tennis using inverse reinforcement learning. *Biological Cybernetics*. **108** (5), 603–619 (2014).
7. Shao, S. et al. Mechanical character of lower limb for table tennis cross step maneuver. *International Journal of Sports Science & Coaching*. **15** (4), 552–561 (2020).
8. Malagoli Lanzoni, I., Di Michele, R., Merni, F. A notational analysis of shot characteristics in top-level table tennis players. *European Journal of Sport Science*. **14** (4), 309–317 (2014).
9. Qian, J., Zhang, Y., Baker, J. S., Gu, Y. Effects of performance level on lower limb kinematics during table tennis forehand loop. *Acta of Bioengineering and Biomechanics*. **18** (3) (2016).
10. Le Mansec, Y., Dorel, S., Hug, F., Jubeau, M. Lower limb muscle activity during table tennis strokes. *Sports Biomechanics*. **17** (4), 442–452 (2018).
11. Girard, O., Micallef, J.-P., Millet, G. P. Lower-limb activity during the power serve in tennis: effects of performance level. *Medicine and Science in Sports and Exercise*. **37** (6), 1021–1029 (2005).
12. Rajabi, R., Johnson, G. M., Alizadeh, M. H., Meghdadi, N. Radiographic knee

osteoarthritis in ex-elite table tennis players. *Musculoskeletal Disorders*. **13** (1), 1–6 (2012).
13. Malagoli Lanzoni, I., Bartolomei, S., Di Michele, R., Fantozzi, S. A kinematic comparison between long-line and cross-court top spin forehand in competitive table tennis players. *Journal of Sports Sciences*. **36** (23), 2637–2643 (2018).
14. Fu, F. et al. Comparison of center of pressure trajectory characteristics in table tennis during topspin forehand loop between superior and intermediate players. *International Journal of Sports Science & Coaching*. **11** (4), 559–565 (2016).
15. He, Y. et al. 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 & Medicine*. **19** (3), 522 (2020).
16. Wong, D. W.-C., Lee, W. C.-C., Lam, W.-K. Biomechanics of table tennis: a systematic scoping review of playing levels and maneuvers. *Applied Sciences*. **10** (15), 5203 (2020).
17. Yu, C., Shao, S., Baker, J. S., Gu, Y. Comparing the biomechanical characteristics between squat and standing serves in female table tennis athletes. *PeerJ*. **6**, e4760 (2018).
18. Marsan, T., Rouch, P., Thoreux, P., Jacquet-Yquel, R., Sauret, C. Estimating the GRF under one foot knowing the other one during table tennis strokes: a preliminary study. *Computer Methods in Biomechanics and Biomedical Engineering*. **23** (sup1), S192–S193 (2020).
19. Yu, C., Shao, S., Baker, J. S., Awrejcewicz, J., Gu, Y. A comparative biomechanical analysis of the performance level on chasse step in table tennis. *International Journal of Sports Science & Coaching*. **14** (3), 372–382 (2019).
20. Kibler, W., Van Der Meer, D. Mastering the kinetic chain. *World-Class Tennis Technique*. 99–113 (2001).
21. Elliott, B. Biomechanics and tennis. *British Journal of Sports Medicine*. **40** (5), 392–396 (2006).
22. Lam, W.-K., Fan, J.-X., Zheng, Y., Lee, W. C.-C. Joint and plantar loading in table tennis topspin forehand with different footwork. *European Journal of Sport Science*. **19** (4), 471–479 (2019).
23. Seeley, M. K., Funk, M. D., Denning, W. M., Hager, R. L., Hopkins, J. T. Tennis forehand kinematics change as post-impact ball speed is altered. *Sports Biomechanics*. **10** (4), 415–426 (2011).
24. Reid, M., Elliott, B., Alderson, J. Lower-limb coordination and shoulder joint mechanics in the tennis serve. *Medicine Science in Sports Exercise*. **40** (2), 308 (2008).
25. He, Y., Lyu, X., Sun, D., Baker, J. S., Gu, Y. The kinematic analysis of the lower limb during topspin forehand loop between different level table tennis athletes. *PeerJ*. **9**, e10841 (2021).
26. Shimokawa R.,Nelson A.,Zois J. Does ground-reaction force influence post-impact ball speed in the tennis forehand groundstroke? *Sports Biomechanics*. 1–11 (2020).

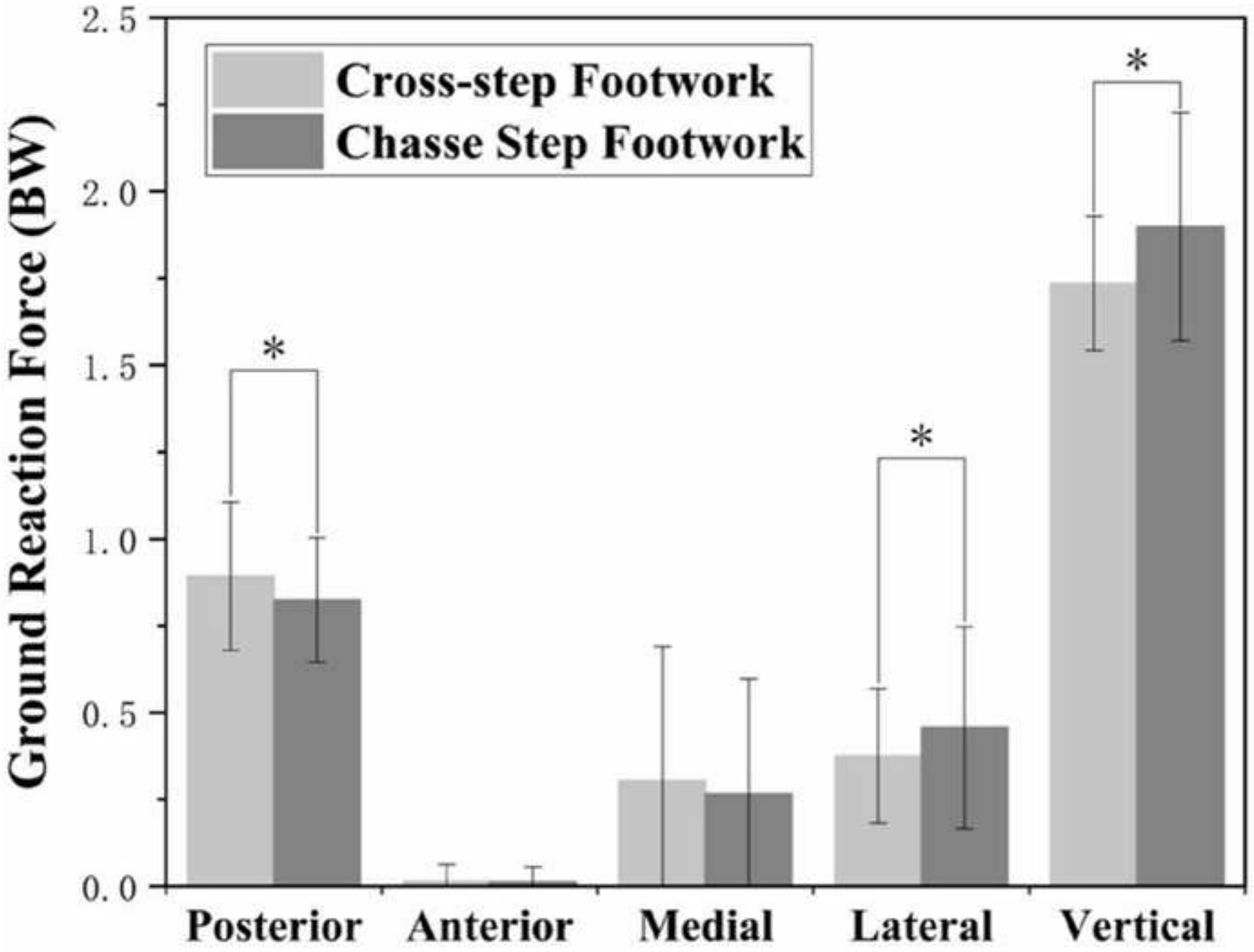
Figure

Click here to access/download;Figure;Figure 1.jpg



Figure

Click here to access/download;Figure;Figure 2.jpg



Participants (n)	Ages (years)	Height (cm)	Weight (kg)	Training Year (years)
16	20.75±2.06	173.25±6.65	66.50±14.27	12.50±2.08

Table 2

	Ground Reaction Force	Cross-Step Footwork Mean±SD	Chasse Step Footwork Mean±SD	P-value
Sagittal Plane	Posterior	0.89±0.21	0.82±0.18	0.014*
	Anterior	-0.02±0.05	-0.01±0.04	0.705
Frontal Plane	Medial	0.31±0.39	0.27±0.33	0.078
	Lateral	-0.38±0.21	-0.46±0.29	<0.001*
Horizontal Plane	Vertical	1.73±0.19	1.9±0.33	<0.001*

Comments and Responses

Dear Editors and Reviewers:

Thank you very much for your attention and comments concerning our manuscript entitled "Comparison of Kinetics Characteristics of Footwork During Stroke in Table Tennis: Cross-Step and Chasse Step". Those comments are all valuable and very helpful for revising and improving our paper, as well as the important guiding significance to our researches. We have studied comments carefully and made corrections which we hope meet with the final approval. Revised portion are highlighted in red in the paper. Here below is our description on revision according to the reviewers' comments.

Responses to the editorial comments

1. Please include a 50 word summary that specifies the goal of the experiment.

Response: Thank you very much for your remind. In fact, we have already stated the purpose of this study in the abstract and the main text. The content was as follows: This study presents a protocol to investigate the ground reaction force characteristics between cross-step and chasse steps during stroke in table tennis.

2. Please upload the Tables separately as xls/xlsx files.

Response: Thank you very much. We have uploaded the Tables according to your request.

Responses to the reviewers' comments

Reviewer 1

Manuscript Summary:

The aim of the study is to compare the ground force reaction characteristics of two classical footwork of table tennis: chasse step and cross-step. The authors found differences regarding the ground reaction forces of the two footworks. Most of the comments have been adressed by the authors but there are still a few modifications to make, especially in term of proof-reading and cheking for grammar and spelling

issues.

Response: Thank you very much for your help in improving our article. We have carefully modified it according to your requirements and expect to get your approval.

Major Concerns:

No major concern

Response: Thank you very much for your recognition. We will revise minor concerns more carefully.

Minor Concerns:

Introduction :

1. l. 47-48 replace "very important" by "of high interest"

Response: Thank you for your reminding. We have modified this part of content according to your suggestions.

2. l 134-167 : be careful with the tense used, it should be harmonized through the article

Response: Thank you very much for your reminding. In fact, we have tried our best to modify and check the language of the manuscript again. We apologize for any inconvenience this may have caused.

3. Table 1. Replace Weight (kg) by Mass (kg)

Response: Thank you. We have modified this part according to your suggestion.

4. l. 194 "NOTE: The table tennis table and balls are meet the standards of professional events." Rephrase "are meet", it does not sound right

Response: Thank you for your reminding. We have modified this sentence, which was as follows: The table tennis table and balls are up to the standards of professional events.

5. l. 230 "the ground reaction force in the posterior of cross-step footwork" should be "the posterior ground reaction force of the cross-step footwork"

Response: Thank you for your remind. We have re-edited this section, and the current content was as follows: As shown in Figure 2 and Table 2, compared with the chasse step footwork (0.82±0.18), the posterior ground reaction force of the cross-step footwork (0.89±0.21) was significantly larger (P=0.014). However, the lateral ground reaction force of cross-step footwork (-0.38 ± 0.21) was significantly lower (P<0.001) than the chasse step footwork (-0.46±0.29). As well as the vertical ground reaction force of cross-step footwork (1.73±0.19) was significantly lower (P<0.001) than the chasse step footwork (1.9±0.33). No differences were observed between the medial or anterior ground reaction forces between the cross-step and the chasse step footwork during stroke in table tennis (P > 0.05).

6. l.230-234 Rephrase for all this paragraph

Response:Thank you very much. We have re-edited this section, and the current content was as follows: As shown in Figure 2 and Table 2, compared with the chasse step footwork (0.82±0.18), the posterior ground reaction force of the cross-step footwork (0.89±0.21) was significantly larger (P=0.014). However, the lateral ground reaction force of cross-step footwork (-0.38 ± 0.21) was significantly lower (P<0.001) than the chasse step footwork (-0.46±0.29). As well as the vertical ground reaction force of cross-step footwork (1.73±0.19) was significantly lower (P<0.001) than the chasse step footwork (1.9±0.33). No differences were observed between the medial or anterior ground reaction forces between the cross-step and the chasse step footwork during stroke in table tennis (P > 0.05).

7. l. 265-266 "Because the chasse step hitting technique can be mastered by the athletes through a lot of practice" I do not understand why this sentence is here.

Neither is the "however" after. Just

Response: Sorry for the confusion this section caused. We have re-edited and explained this section, and the current content was as follows: The lateral ground reaction force of the chasse step hitting movement is significantly greater than the action of the cross-step hitting movement. Lam et al. (2019) observed the same results. The chasse step hitting technique can be mastered by the athletes through a lot of practice, and the cross-step hitting technique has great variability compared with the chasse step hitting action. Therefore, with a lot of practice of the chasse step hitting, the lower limb kinetic chain transmission of the players could be more complete and smoother...

8. l. 246 same remark that l. 230

Response: Thank you very much for your reminding. We have reedited this section. The contents was as follows: The key finding of this study is that: 1) the posterior ground reaction force of cross-step footwork was significantly larger than the chasse step footwork. 2) the lateral ground reaction force of cross-step footwork was significantly lower than the chasse step footwork. 3) the vertical ground reaction force of cross-step footwork was significantly lower than the chasse step footwork.

9. l. 264-265 "The lateral ground reaction force of the chasse step hitting action is significantly greater than the action of the cross-step hitting action". Too many "action", rephrase.

Response: Thank you for your advice. The sentence has been modified according to your requirements. The content was as follows: The lateral ground reaction force of the chasse step hitting movement is significantly greater than the action of the cross-step hitting movement.

Reviewer 2

Manuscript Summary:

This paper compares the ground reaction force between chasse step and cross-step in table tennis forehand. The authors found some differences between the two steps. The topic may be interesting for relevant scientists, coaches and players.

Response: Thank you very much for your suggestions on optimizing this article. We have carefully revised the manuscript according to your requirements and hope it can conform to your requirements.

Major Concerns:

First, how the participants performed the two types of footwork is unclear. How did the participants hit the firstly served ball? With forehand or backhand? After hitting the second served ball, what were the participants asked to do? Were they required to get back to the ready position? The description of the footwork is critical in this study and should be crystal clear. Second, the ground reaction force means the force acting on the foot from the ground. You observed the posteriorly directed GRF, suggesting the body was accelerated backward during the swing. This seems odd. Please verify and explain this.

Response: Thank you very much for your remind. We totally agree with your suggestion. And we have add the detail of stroke in the protocol section. As follows: Then hit the firstly and second served ball by forehand with maximum force. And back to the ready position after finished the secondly stroke task.

Besides, we feel sorry for the confusion. The two words of posterior and Anterior are reversed, we have check the manuscripts and data again to ensure there is correct about the result. We have rectify the table and sentence of the study. Thank you very much for your remind.

Minor Concerns:

1. L26 The planes have two independent directions. I think it is sufficient simply to put "the forces in the anteroposterior, medio-lateral, and vertical directions".

Response: Thank you very much. In order to more clearly express the results of this study, we have modified this section according to your opinions. The

contents was as follows: The ground reaction force in the anterior-posterior, medial-lateral, and vertical directions of the participant was measured by a force platform.

2. L27 Please delete "Three-dimensional".

Response: Thank you. We have deleted this part of content according to your suggestion.

3. L66 What is a level of serving movement? A level of serving skill?

Response: Sorry for the confusion in this section. The content of this part has been modified as: serving skill.

4. L86 You did not measure lower limb kinetics. Ground reaction forces are the resultant reaction from the whole-body movement not from the lower limb only. Please consider rephrasing this part: "the ground reaction force characteristics" instead of "the lower limb kinetics characteristics".

Response: Thank you very much for your suggestions. We have re-edited this section according to your suggestions. The contents was as follows: The first hypothesis of this study is that the chasse step and cross-step have different ground reaction force characteristics.

5. L87 better performance? You need to define the performance here. You also need to consider the above comment for the second hypothesis.

Response: Thank you very much for your remind. We fully agree with your suggestions. In order to facilitate readers to understand this study, we have deleted this section.

6. L122 I think the calibration T-wand is a more popular word than the T-frame.

Response: Thank you very much. We have modified this section according to your suggestions. The content was as follows: Then wave the T-wand in the

capture range.

7. L146 Please clarify " to study right-handed race-holding"

Response: Sorry for confusion, we have delete the sentence, and the sentence was reedited as follows: Because there are few of left-handed racket user, it is easier to find enough right-handed racket user to participate in this experiment.

8. L166 The "experiment" should be referred to as the whole process. Please revise this part: for example, "The formal data collection began."

Response: Thank you very much. We have modified this section according to your suggestions. The content was as follows: The formal data collection began.

9. L196 bein?

Response: Thank you very much. We have modified this section. The content was as follows: Ask the participant to hold the ready position.

10. L197 finally?

Response: Sorry for the confusion. We have modified this section. The content was as follows: the first and final impact area.

11. L203 You seemed not to randomize the order of data collection for the two footwork. Why?

Response: Thank you very much. In fact, we have explained the sequence of data collection. In order to facilitate the subjects' feet to accurately step into the force platform, the test sequence was specified in the protocol section. The content was as follows: Also, the participants were asked to first use the chasse step footwork to complete 5 times successful strokes, and then use the cross-step footwork to complete 5 times successful strokes.

12. L256 "support our results" is unclear. Usually, data support a claim or a

hypothesis.

Response: Thank you very much for your reminding. We have modified this section. The content was as follows: This further supports the results of this study.

13. L272 cross step.the cross step?

Response: Sorry for the confusion. And Thank you very much for your reminding. We have modified this section. The content was as follows: Due to the variability and immediacy of cross-step, the cross-step hitting technique cannot fully complete the swing action.

14. L276 Please check the grammar. I think "in the vertical direction" not "in the sagittal plane" is more appropriate if I understand appropriately. Please note that the sagittal plane includes the anteroposterior and vertical directions.

Response: Thank you very much for your reminding and suggestions. We totally agree with you. We have reedited this section as follows: Therefore, the greater push is required a compensatory mechanism in the anterior direction.

15. L305 "Because no time ..." is unclear. Please be accurate and precise for this is a scientific paper.

Response: Sorry for the confusion. We have modified this section. The content was as follows: Haven’t in time to go back to the initial position...

16. L315 I cannot understand this sentence.

Response: Sorry for the confusion. We have reedited the sentence, and the content was as follows: Enhancing the driving force of the lower limbs and optimizing the transmission of the lower limb power chain could increase the speed and power of the swing.

17. Table 2 I think "ground reaction force in three anatomical directions" is more

appropriate than "The ground reaction force in three planes"

Response: Thank you very much. We fully agree with your suggestions and have modified this section according to your suggestions. The contents was as follows: Table 2. The ground reaction force information of chasse step footwork and cross-step footwork in three anatomical directions during stroke in table tennis.

18. Table 2 "BW means …": BW should appear before this sentence in the Table.

Response: Thank you very much for your advice. We have changed it in the details of Table according to your suggestion.

Reviewer3

The manuscript provides interesting data in relation to table tennis and some biomechanical aspects related to some of the main movement "patterns". The information provided is novel and specific, but some changes need to be made in writing quality and structure.

Response: Thank you very much for your comments and suggestions. We have carefully revised the manuscript according to your requirements and hope that it can conform to the requirements of publication.

Major Concerns:

n/a

Response: Thank you very much.We have carefully revised the minor concerns, hoping to conform to the requirements of publication.

Minor Concerns:

The structure and set up of the way the methodology is written.

Firstly, I would again like to congratulate the author/s on conducting this research and preparing the manuscript, understanding and appreciating the challenges that come with applied research. I have provided recommendations to help with the clarity of the manuscript and have provided some specific comments below.

Response: Thank you very much for your suggestion to improve this article. We have carefully revised the minor concerns, hoping to conform to the requirements of publication.

Abstract:

Line 27 to 33: Change for clarity to:

The key finding of this study is that: the ground reaction force in the posterior of the cross-step footwork (0.89 ± 0.21) shows significantly larger (P=0.014) when compared with the chasse step footwork (0.82±0.18).

However, the ground reaction force in the lateral of cross-step footwork (-0.38±0.21) shows a significantly lower (P<0.001) than the chasse step footwork (-0.46±0.29). it is showing significantly lower what???? Occurrence? Performance?

In addition, the cross-step footwork (1.73 ± 0.19) shows a significantly lower (P<0.001) ground reaction force in vertical compared to chasse step footwork (1.9± 0.33).

Response: Thank you very much for your advice. We have re-edited this part of content, and the modified content was as follows: The ground reaction force in the anterior-posterior, medial-lateral, and vertical directions of the participant was measured by a force platform. The key finding of this study is that: the posterior ground reaction force of cross-step footwork (0.89 ± 0.21) was significantly large (P=0.014) than the chasse step footwork (0.82±0.18). However, the lateral ground reaction force of cross-step footwork (-0.38 ± 0.21) was significantly lower (P<0.001) than chasse step footwork (-0.46±0.29). As well as the vertical ground reaction force of cross-step footwork (1.73 ± 0.19) was significantly lower (P<0.001) than chasse step footwork (1.9±0.33).

Introduction:

Line 43 change In the table tennis . . . to In table tennis competition . . .

Response: Thank you very much. We have modified this sentence according to your suggestions. The contents was as follows: In table tennis competitions,

players need good strategies to try to win the match.

Line 52 - change There are differences in the step of table tennis players from a different region . . .to There are differences in the step of table tennis players from different regions

Response: Thank you very much. We have modified this sentence according to your suggestions.

Line 55 - change get enough time to have enough time

Response: Thank you very much. We have modified this section according to your suggestions.

Line 81 - change it to this

Response: Thank you very much. We have modified this section according to your suggestions.

Line 83 - take-out 16 as you mention this in your methodology so no need for participant number in introduction

Response: Thank you very much. We have modified this section according to your suggestions.

Protocol

Line 101 - do you have the details of the force platform? What force platform was used. If you do great to put into the protocol details.

Response: Thank you very much for you suggestion. We have add the details of the force platform in the protocol section, the content as follows: AMTI, Watertown, USA, sampling frequency of 1000 Hz.

Line 112- adjustment change to adjust

Response: Thank you very much. We have modified this section according to

your suggestions.

Line 116 - change to Place the T correction rack in the center of . . . . .

Response: Thank you for your remind. We have modified this section according to your suggestions.

Line 124 - change to Then observe the progress bar . . . .

Response: Thank you very much. We have modified this section according to your suggestions.

Line 132 - add a space after 1.8 and after SET VOLUME ORIGIN

Response: Thank you for your remind. We have add the space according to your suggestions.

Line 136 - All of them belong to . . . .

Response: Thank you very much. We have modified this section according to your suggestions.

Line 141 and line 149 - add a space after 2.2 and 2.3, respectively. Check this throughout line 172, 174, 196, 205, ...

Response: Thank you for your remind. We have add the space according to your suggestions.

Line 168 - heading for table needs to come above the table not below and please reference this in line 135 instead of providing mean ± SD (see Table 1) after Sixteen healthy male national levels table tennis players

Response: Thank you for your remind. We have modified these parts according to your suggestion. The contents was as follows: Sixteen healthy male national levels 1 table tennis players volunteered to participate in the experiment (Ages:

20.75±2.06 year; Height: 173.25±6.65 cm; Weight: 66.50±14.27 kg; Training Year: 12.50±2.08 year).

Line 222 - The Shapiro-Wilks test was performed . . .

Response: Thank you very much. We have modified these parts according to your suggestion. The contents was as follows: The Shapiro－Wilks tests were performed to check the normal distribution for all variables.

Line 223 - A paired t-test was used to . . . .

Response: Thank you for you suggestion. We have modified these parts according to your suggestion. The contents was as follows: A paired t-test was used to compare kinetics characteristics of chasse step footwork and cross-step footwork during table tennis stroke.

Line 225- The significance level was set at . . .

Response: Thank you very much. We have modified these parts according to your suggestion. The contents was as follows: The significance level was set at $p < 0.05$.

Results

Line 231 - was significantly larger

Response: Thank you very much. We have modified these parts according to your suggestion.

Line 232 - 233 - The cross step footwork (1.73±0.19) also showed . . . .

Response: Thank you for your remind. We have modified these parts according to your suggestion. The contents was as follows: As well as the vertical ground reaction force of cross-step footwork (1.73 ± 0.19) was significantly lower ($P<0.001$) than the chasse step footwork (1.9±0.33).

Line 234 - No differences were observed . . . . .

Response: Thank you very much. We have modified these parts according to your suggestion. The contents was as follows: No differences were observed between the medial or anterior ground reaction forces between the cross-step and the chasse step footwork during stroke in table tennis (P > 0.05).

Discussion

Line 251 to 254 - make this 2 sentences for clarity as it is too long

Response: Thank you very much. We have modified the sentence, the content was as follows: Marsan et al. (2020) investigated the estimation value of the ground reaction force based on Newton’s second law could be a good estimation method for except the peaks ground reaction forces

Line 238 to 249 - can you integrate this with some of your findings please.

Response: Thank you very much. As your suggestion, we add the content was as follows: The lateral ground reaction force of the chasse step hitting movement is significantly greater than the action of the cross-step hitting movement. Lam et al. (2019) observed the same results. The Maximum horizontal force of side-step was significant higher than the one-step.

Line 255 - change that of Masran to observed by Masran. Also add in the year of publication so, Masran et al. (2020)

Response: Thank you very much for your suggestion. We have modified these parts according to your suggestion. The contents was as follows: In the results of this study, the displayed value of ground reaction force is basically close to the value of the measurement observed by Marsan et al. (2020).

Line 251 to 268 - same as the above, please integrate some of your findings to agree/disagree with this.

Response: Thank you very much. As your suggestion, we add the content as

follows: Shimokawa et al. (2020) investigated the similar result in the tennis forehand groundstroke. The Peak anterior-posterior ground reaction force play a most influential role to affecting forehand post-impact ball speed. However, a greater anterior ground reaction force may cause the center of gravity not return to the initial position in time, thus affecting the beginning of the next movement.

Line 267-268 - why should beginners start with this?

Response: Thank you very much. In fact, we have explained this in the manuscript. Because the anterior ground reaction force of cross-step footwork was significantly greater than the chasse step footwork, this probably means that the athlete shows a greater forward weight transfer during cross-step footwork, which may affect the timely return of center of gravity. So you can practice chasse step footwork to enhance the control ability of the center of gravity, and then practice the cross-step footwork.

Line 272 - change influences to influencing

Response: Thank you very much. We have modified these parts according to your suggestion.

Line 275 - re-read and re-word as there is a full stop in the middle of the sentence

Response: Thank you for your remind. We've double-checked the manuscript to make sure no similar problems arise.

Line 276- change to as a compensatory. . .

Response: Thank you for your suggestion. We have modified these parts according to your suggestion.

Line 280 -282 - re-word for clarity, I get what you mean but the sentence is badly structured.

Response: Thank you very much for you remind. And sorry for the confusion.

We have re-edited this part, the specific content was as follows: In the practical application of training and competition, athletes and coaches should pay attention to master the ability of control center of gravity during cross-step footwork.

Line 289 - full stop after accurately. New sentence: Any data where the foot is placed outside the platform should be eliminated.

Response: Thank you very much for you remind. We have re-edited this section according to your requirements, the details were as follows: Any data where the foot is placed outside the platform should be eliminated.

Line 295 - The main limitations of this study were . . . .

Response: Thank you very much. We have re-edited this section according to your requirements, the details were as follows: The main limitations of this study were that, Firstly, the whole experiment was not in a real match environment, this will affect the practical application of the results of this study to some extent. Secondly, in this study, only the ground reaction force information of the two footsteps in the swing stage was measured. In future further research, experimental data should be collected in a situation that is as close to the real competitive environment as possible. And the ground reaction force information of the racket lead stage should also be collected together.

After you state limitations state future research

Response: Thank you very much for you suggestion. We have re-edited this section according to your requirements, the details were as follows: The main limitations of this study were that, Firstly, the whole experiment was not in a real match environment, this will affect the practical application of the results of this study to some extent. Secondly, in this study, only the ground reaction force information of the two footsteps in the swing stage was measured. In future further research, experimental data should be collected in a situation that is as

close to the real competitive environment as possible. And the ground reaction force information of the racket lead stage should also be collected together.