REPORTING THE LOADING AND MOVEMENT PROFILES OF CHASSE-STEP AND ONE-STEP FOOTWORK IN TABLE TENNIS

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This study aimed to analyze the biomechanical characteristics of athletes with two typical table tennis footwork. Eighteen elite athletes performed chasse-step and one-step. Kinematic and kinetic data were collected using the Vicon and AMTI. Hip joint flexion during one-step increased significantly in the backward swing ($p=0.045$) while knee joint extension with chasse-step increased greatly ($p<0.001$) in the forwarding swing. The hip joint contact force of one-step increased in the ant-post direction ($p<0.001$), though the chasse step contact force of the hip joint increased in the med-lat direction ($p<0.001$). The findings suggested that the chasse-step had greater quality performance and preparation for the next successive stroke while the one-step showed faster performance which tended to direct score. This information may help coaches develop training programs, athletes improve performance, and prevent injuries.

KEYWORDS: Table Tennis; Footwork; Lower Limb; OpenSim; Musculoskeletal Modelling

INTRODUCTION: As one of the major racket sports, table tennis has been included in Olympic programs since 1988. Technical and tactical skills are considered to be important performance factors in table tennis. The positive technical progress of table tennis performance has placed higher requirements on the technical and tactical skills of the player. These skills include footwork (one-step chasse, slide, cross-step, and pivot) and strokes (forehand, backhand, smash, service, push, top, top countertop, and others) (Yang et al., 2022). A high-leveled techniques indicates that table tennis athletes can use proper footwork, control their power, and stroke the ball with adequate speed and spin (Yang et al., 2022). Some researchers have investigated and emphasized the importance of footwork in table tennis performance. By investigating the one-step, chasse-step, and cross-step of 15 male table tennis players, higher joint loadings in the chasse-step and cross-step than one-step may provide useful insights into injury mechanisms and training program development for table tennis (Lam et al., 2019). Malagoli Lanzoni et al. (2014) compared the footwork of international and national players and found that Asians used footwork more frequently than Europeans. In 2020, Malagoli Lanzoni et al. (2020) also collected data from male and female table tennis athletes and found that usage of chasse-step was equally 20%.
Despite the popularity of table tennis, little was known about the characteristics required for different table tennis footwork. The objective of this study was to investigate the effect of chasse-step and one-step on kinematics and kinetics in elite table tennis athletes. It was hypothesized that there would be significant differences between chasse-step and one-step in kinematic and kinetic of the lower limb. Biomechanics approaches for table tennis may provide a comprehensive basis for the development of footwork training plans and athletic performance of table tennis athletes during competitions.

METHODS: The study recruited 18 male elite table tennis athletes (National Level I in China). All the participants were right-handed, which was determined with the racket hand. Each of the participants was required to sign the informed consent form. The protocol of this study was approved by the Ethics Committee.

An eight-camera motion capture system (Oxford Metrics Ltd., Oxford, UK) was used for kinematic data collection at 200 Hz, for the analysis of hip and knee joint kinematics during gait. An in-ground force platform (AMTI, Watertown, MA, USA) was used for GRF collection at 1000Hz (Figure 1). All participants with 52 marker sets (diameter: 14 mm) were informed of the experimental requirements and procedures. After warming up, participants were asked to stroke with chasse-step and one-step from the impact zone to the target zone (diagonal side), as they would in a formal match. Each participant completed at least five trials during data collection that were judged by the same professional coach serving balls in the test. Hip and knee joint angles, joint moments, and joint contact forces were calculated using OpenSim (v4.2) and analyzed the footwork stance phase (first backward swing phase and then forwarding swing) by independent sampled t-tests. The SPM 1D analysis was performed for statistical analysis using MATLAB R2019a (The MathWorks, Natick, MA, USA).

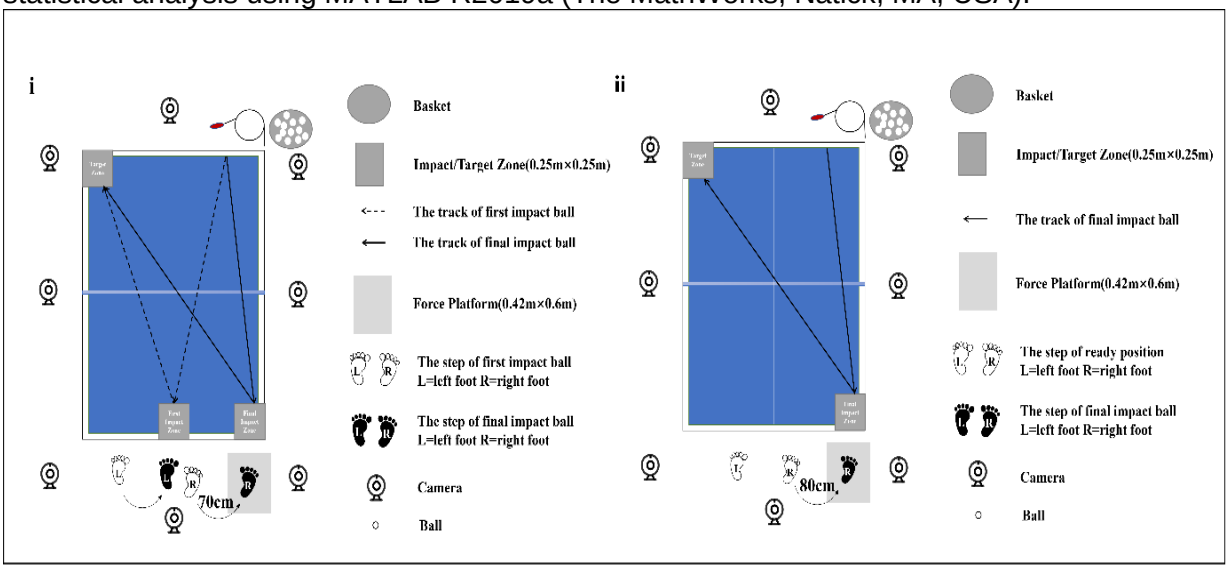

Figure 1: Experimental set-up of chasse-step (i) and one-step (ii).

RESULTS: Figure 2 presents the comparison of hip and knee angles during chasse-step and one-step. As for the hip joint, one-step flexion increased at 0%-5% ($p=0.045$) and 59%-60% ($p=0.049$) (Figure2i_a), but abduction increased between15% and 50% ($p<0.001$) (Figure 2i_b). Internal rotation of one-step increased at 20%-25% ($p=0.0045$) (Figure2i_c). The knee joint angle of the chasse-step decreased flexion between 40% and 85% ($p<0.001$) and from 99% to 100% ($p=0.049$) (Figure 2ii_a). Nevertheless, there were no significant differences in knee joint angles in the other two planes (Figure 2ii_b, c).

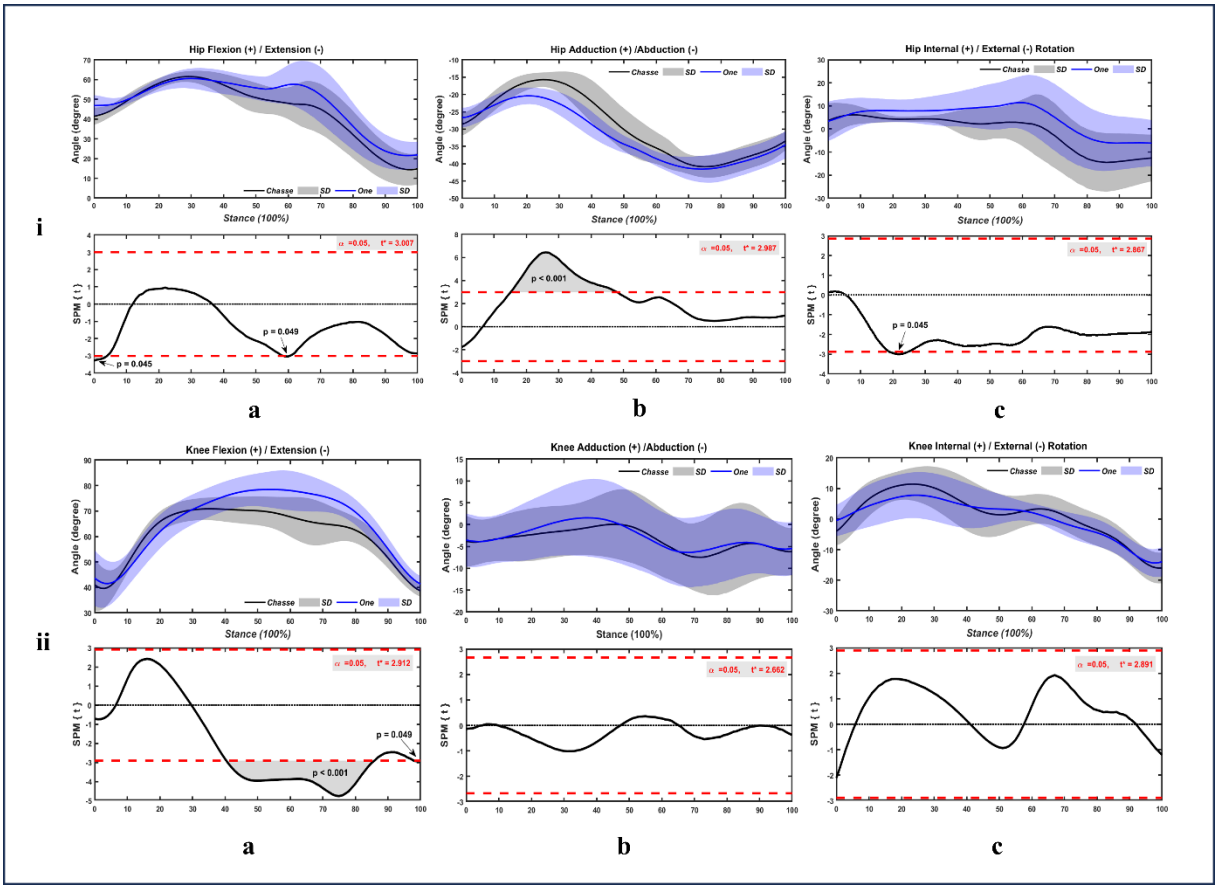

Figure 2: Hip (ia-c) and knee (iia-c) joint kinematics angles with SPM1d in chasse-step (gray) and one-step (blue).

The contact forces of the hip and knee joint were observed in Figure 3. In the ant-post-direction, the hip joint contact force of one-step had a significant increase at 15%-35% ($p<0.001$) and 53%-85% ($p<0.001$) (Figure 3i_a). The contact force of the chasse-step was increased across stance at 0-2% ($p=0.049$), 8%-12% ($p=0.004$), and 20%-28% ($p<0.001$) in the med-lat direction, while it decreased at 57%-63% ($p<0.001$) in the med-lat direction (Figure 3i_b). Additionally, hip joint contact force had a significant increase in the sup-inf direction at 35%-48% of chasse-step ($p<0.001$) and 55%-75% of one-step ($p<0.001$) (Figure 3i_c). As for the ant-post-direction, the knee joint contact force increased at 0-1% ($p=0.049$) in the chasse-step, but between 45% and 75% ($p<0.001$) in one-step (Figure 3ii_a). The contact force of the chasse-step knee joint showed a significant increase at 8%-10% ($p=0.042$) in the med-lat direction (Figure 3ii_b). Chasse-step the contact force of knee joint was increased from 6% to 9% ($p=0.032$) and from 18% to 22% ($p=0.05$) in the sup-inf direction. Nevertheless, the contact force of one step increased from 55% to 75% ($p<0.001$) in the same direction (Figure 3ii_c).

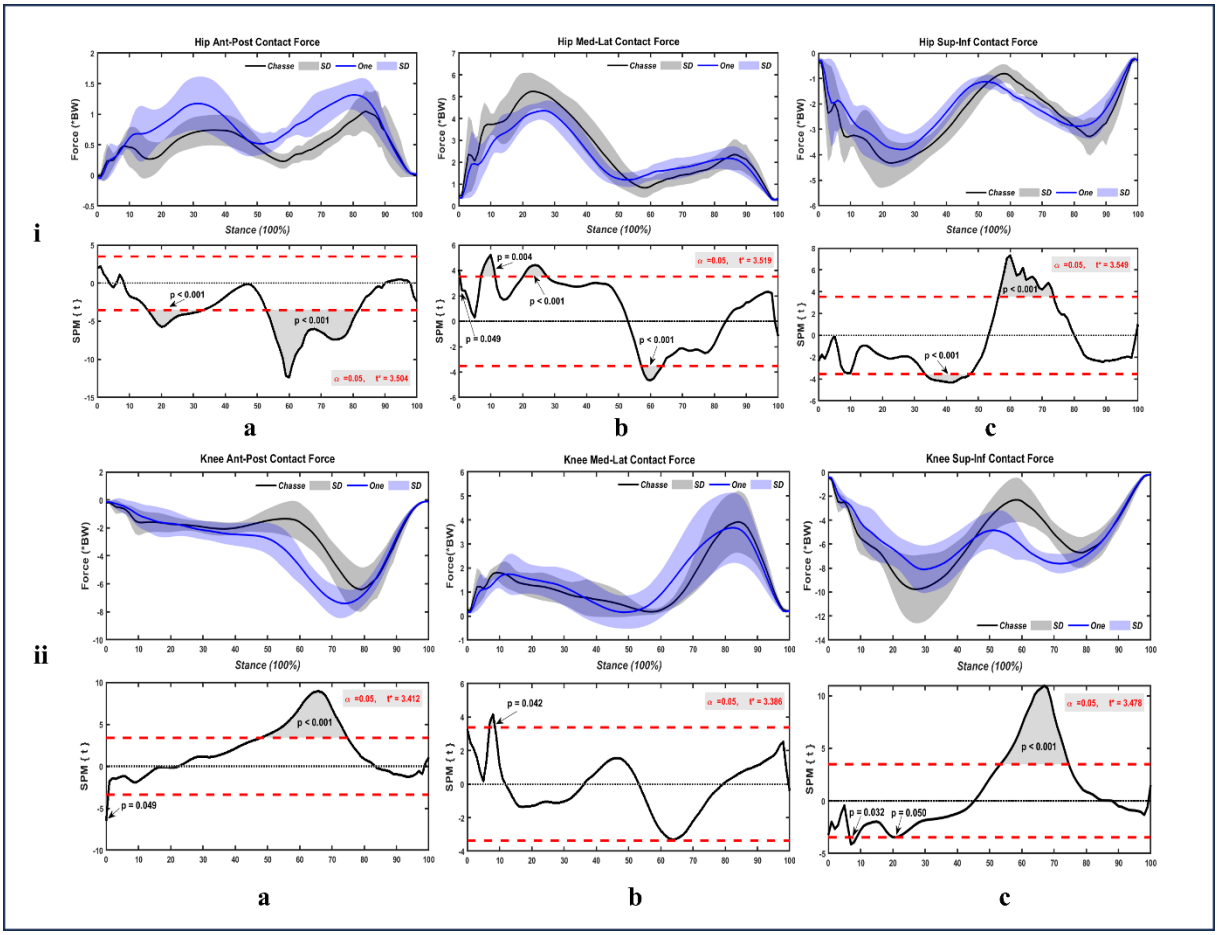

Figure 3: Hip (ia-c) and knee (iia-c) joint contact force with SPM1d in chasse-step (gray) and one-step (blue).

DISCUSSION: The findings supported the hypothesis that there was a significant difference in the biomechanical profiles between chasse-step and one-step. Specifically, it was found that the hip joint flexion angle of one-step increased greatly in the backward swing. During the stance, the hip joint contact force during one-step increased in the ant-post direction while the hip joint of the chase-step increased in the med-lat contact force. Additionally, the knee joint extension angle of the chasse-step increased greatly and the hip contact force increased in the med-lat direction.

As reported, the hip angle in the sagittal plane was related to the forehand motion velocity. The mechanical work in the hip joint was highest on the forehand drive (Marsan, 2019). During the backward swing phase, the hip flexion angle of one-step increased greatly, which could infer the contribution of a faster stroke. Greater hip contact force in the ant-post direction may allow table tennis athletes to better forward swing the ball. Similarly, an increase in the forward component of certain joint ranges of motion facilitated the impact-hitting force. It was found that the increased forward bending of the torso may improve the power of the forehand topspin (Bánkosz & Winiarski, 2018). By discussing the accelerating loop technique of forehand in elite table tennis athletes, it was reported that the forward velocity of the first-ranking athlete was greater than the second-ranking and the rest (Zhang & Shi, 2000), which may suggest that one-step may employ the movement to improve the performance of direct scoring.

Hip contact force in the med-lat direction increased during the chasse-step. It can be inferred that the chasse-step was employed to use med-lat direction movement to move to the right position to prepare for the next stroke. The chasse-step was considered one of the most commonly used forms of table tennis footwork (Yang et al., 2022). Through the video analysis of the singles match in the African badminton Championships, it was concluded that the footwork movements during each match were the most frequently used chasse-step (Abdullahi & Coetzee, 2017). The knee extension angle was significantly increased during the forward

swing phase with the chasse-step. Knowledge of the range of knee extension was sufficient to determine leg drive quality. Potential athletes may use the greater leg drive to achieve the transfer of inertia from the truck to the upper limbs (Elliott et al. 2003). The lower limb of the forward swing phase would have a larger extension, which may suggest that the chasse-step of table tennis footwork could be stretched out to produce a higher quality stroke.
As a limitation of this study, the upper limbs or the whole body shall be investigated and discussed as a whole-body chain, not simply the lower extremities, which may be noted in future studies. Furthermore, this study only selected the analysis dominant side without considering the influence of the non-dominant side.

CONCLUSION: This study identified the hip flexion and knee extension joint angles, as well as hip contact force in the ant-post and med-lat direction of elite table tennis athletes during chasse-step and one-step. One-step may have a faster performance to direct score and chasse-step may have a high-quality stroke that tends to continue next strokes. The findings could be used by coaches to develop footwork training programs for athletes to improve performance. Furthermore, the information in this study may be used to prevent lower limb injury for table tennis athletes.

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