A COMPARISON OF LOWER LIMB KINEMATICS BETWEEN SUPERIOR AND INTERMEDIATE PLAYERS IN TABLE TENNIS FOREHAND LOOP

Yan Zhang[1], Jan Awrejcewicz[1], Marcio Goethel[1], Ievgen Levadnyi[1], and Yaodong Gu[2]

Department of Automation, Biomechanics and Mechatronics, The Lodz University of Technology, Lodz, Poland[1]
Research Academy of Grand Health Interdisciplinary, Ningbo University, Ningbo, China[2]

Understanding of biomechanics is important in sports performance enhancement since each skill has a fundamental mechanical structure. The purpose of this study was to investigate the effect of performance level on lower limb kinematics in table tennis forehand loop. 13 male superior players (SPs) and 13 intermediate players (IPs) participated in this test. A VICON motion analysis system was used to capture joint motions of lower limbs. Participants were asked to execute single forehand loop against topspin ball with full effort. Compared with IPs, SPs showed significantly larger hip flexion and knee external rotation at the event of backward-end, and larger hip internal rotation and extension at forward-end. SPs also showed significantly larger ankle and hip angular changing rate during forward swing.

KEY WORDS: Performance. Table tennis, forehand loop, lower limb kinematics

INTRODUCTION: Forehand loop stroke requires both flexibility and stability lower limb joints to achieve high racket speed and to prevent injury. How to coordinate motion pattern to improve forehand loop technique is one of the most common concerns for table tennis coaches and athletes.
It has been documented that energy generated at lower limb can be transferred to shoulder and upper limb through sequential movements of body segments (Elliott, 2006). Therefore, lower limb drive considerably influences racket and ball speed (Elliott, 2006; Seeley et al., 2011). With assistance of lower limb movements (Girard, Micallef & Millet, 2007), such as normal knee flexion-extension, ball speed showed to be higher than under the condition of knee-restricted. Seeley et al. (2011) noted that players increased the peak angular velocity of hip and ankle to achieve higher post-impact ball speed in tennis. Knowledge of performance level effect on lower limb motion pattern will provide substantial information on how to improve technical movements effectively. Coaches and players need to understand the basic biomechanical principles and how to apply them to the different components or phases of strokes. The purpose of this study, therefore, was to identify the differences in lower limb kinematics between superior players (SPs) and intermediate players (IPs) while performing forehand loop against topspin balls.

METHODS: 26 professional male players from Ningbo University table tennis team volunteered to participate in this test. 13 of them are the National Division I players (age: 20.1 ± 0.9 years; height: 174.8 ± 2.5 cm; body mass: 66.9 ± 5.1 kg; training experience: 13.4 ± 1.2 years) categorized as the superior group, and the rest are the National Division II players (age: 21.2 ± 1.6 years; height: 175.2 ± 2.4 cm; body mass: 69.1 ± 4.1 kg; training experience: 10.2 ± 1.9 years) categorized as the intermediate group. All participants were right-handed style with no previous lower limb and foot diseases or deformity, and were free from injury for at least six months prior to the test.
The test took place in Ningbo University table tennis training gymnasium. The floor is made of wood which is commonly used in daily training and competitions. A ball machine placed 1.2 m away from the opponent's court was used to project topspin balls directly to the foreside of the subjects' court. Settings including projecting angle, radian, velocity and frequency were consistent for all balls. All subjects were informed of the test procedures and dropping position and spin direction of the balls. Sufficient time was given to warm up and familiarize themselves with the experimental environment. Subjects were asked to perform

single crosscourt forehand loop in situ (Fig. 1) with full effort wearing the unified training footwear. A 8-camera Vicon motion analysis system (Oxford Metrics Ltd., Oxford, UK) was used to capture joint motions at a frequency of 200 Hz. 16 reflective markers (diameter: 14 mm) were attached on bilateral lower limb landmarks according to the model of PlugInGait. Each subject performed at least five successful attempts. Data were collected separately for the five attempts (Not five consecutive strokes). Motion smoothness was judged by players themselves and the quality of the balls' effect was supervised by their coaches.

Figure 1: Definition of key events of one stroke.

The entire forehand loop motion was divided into two phases of backswing and forward swing. Backswing phase referred to the period between two certain events of neutral position (NP) and backward-end (BE, maximum knee flexion) and forward swing phase referred to the period between events of BE and forward-end (FE, maximum hip internal rotation) (Fig. 1). Variables of the dominant side as joint angle at BE and FE, joint range of motion (ROM) and joint angular changing rate during forward swing (R_f) were processed for analysis.

All statistical analyses were performed using Stata 12.0 (Stata Corp, College station, TX). Initial Shapiro– Wilk tests validated that the data were normally distributed. To examine the differences between two performance levels, independent t-test was taken for each variable including the time of entire motion, joint angle at BE and FE, joint ROM, and R_f. Statistical results were considered significance if $p < 0.05$.

RESULTS: The time to perform one forehand loop was 0.87±0.06 s and 1.04±0.09 s for SPs and IPs respectively with significant difference. Compared with IPs, SPs showed significantly smaller ankle dorsiflexion with larger hip flexion and knee external rotation at BE and significantly larger ankle internal rotation, hip extension and internal rotation with smaller knee internal rotation at FE (Table 1). SPs showed significantly larger ROM of the ankle in the sagittal plane and ROM of the hip in the sagittal and transverse planes, while significantly smaller knee ROM in the sagittal plane (Table 2). R_f at the ankle and hip for SPs was clearly larger than that of IPs in the sagittal plane, while R_f at the knee was slightly smaller for SPs (Figure. 2). In the frontal and transverse planes, R_f of all joints showed to be larger for SPs. Differences only in the ankle and hip reached to statistical significance (Figure. 2).

Table 1
Comparison of joint angles at key events between IP and SP, mean ± SD

Event		Ankle		Hip		Knee	
		IP	SP	IP	SP	IP	SP
BE	X	12.1±1.9	1.4±4.3*	57.1±1.8	74.2±8.1**	54.7±5.0	54.5±3.6
	Y	0.2±0.7	0.6±1.6	–9.0±8.4	–4.8±6.7	2.8±12.0	9.8±4.4
	Z	0.3±4.3	–0.7±7.5	6.4±8.9	8.7±5.3	9.2±3.3	15.6±1.9***
FE	X	17.9±4. 3	18.8±2.1	–5.6±3.3	–12.8±5.1**	34.8±4.1	32.1±9.1
	Y	2.7±2.0	5.8±2.9	–21.2±3.9	–20.5±0.8	11.6±13.2	1.9±1.7
	Z	–15.1±10.7	–33.1±4.6*	–7.2±9.9	–19.1±7.6**	–7.0±1.2	0.9±5.4***

Note: x – the sagittal plane; y – the frontal plane; z – the transverse plane.
* P < .05, significant difference at the ankle. ** P < .05, significant difference at the hip. *** P < .05, significant difference at the knee.

Table 2
Joint ROM during the entire motion, mean ± SD

	Ankle		Hip		Knee	
	IP	SP	IP	SP	IP	SP
X	11.7±3.2	20.4±4.1*	65.5±3.0	89.4±3.8**	33.7±4.4	25.5±6.3***
Y	4.7±0.5	5.8±2.0	28.0±4.9	32.1±4.5	20.6±3.8	18.0±3.8
Z	29.5±3.8	35.1±9.9	23.5±1.2	31.9±6.6**	18.5±2.1	18.3±4.1

Note: x – the sagittal plane; y – the frontal plane; z – the transverse plane.
* P < .05, significant difference at the ankle. ** P < .05, significant difference at the hip. *** P < .05, significant difference at the knee.

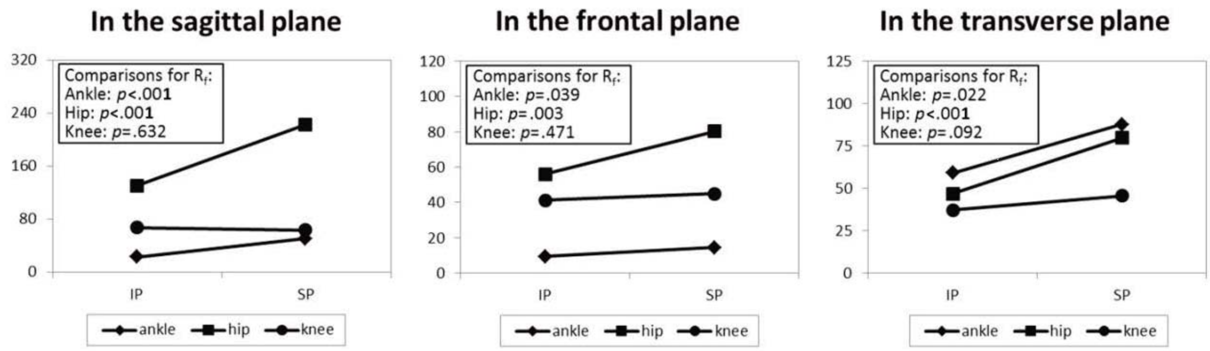

Figure 2: Angular changing rate during forward-swing phase.

DISCUSSION: A thorough understanding of lower limb motion pattern of players with different skilled levels has important implications on sports performance enhancement and injury prevention. This study investigated the differences in lower limb kinematics during forehand loop against topspin ball between superior and intermediate players. Key phases (backward swing and forward swing) and technique events (backward-end, BE and forward-end, FE) were identified for in-depth analysis. Findings suggested that SPs could complete one forehand loop within less time than IPs. In table tennis competitions, SPs are able to execute a stroke in less time so that they have enough time to prepare for the next stroke. Moreover, forward swing phase for SPs accounted for less time in an entire motion cycle. The ability to accelerate the racket rapidly during forward swing should be an important factor for increasing ball speed (Iino & Kojima, 2009).

At the event of BE, SPs showed significantly larger hip flexion compared with IP. Based on the theory of stretch-shortening cycle that the utilization of elastic energy stored in muscle-tendon complex during eccentric phase (stretch) could partially enhance concentric performance (shorten) (Komi & Bosco, 1978; Walshe, Wilson & Ettema, 1998), it is possible to infer that the increased hip flexion may enhance muscle output of gluteus maximus during forward swing, which is a potential factor to increase racket velocity. Similarly, the significantly larger knee external rotation with smaller ankle dorsiflexion of SPs at BE may contribute to stretching the internal rotator, resulting in enhanced contraction effect during forward swing. SPs presented more flexible ankle motion with larger ankle rotation ROM and larger internal rotation at FE, which potentially contributes to footwork performance. SPs also showed significantly larger hip ROM in the sagittal and transverse planes and larger extension and internal rotation at FE. This may be associated with greater weight transfer range to facilitate momentum generation (Ball & Best, 2007). In contrast, the knee internal rotation of IPs was larger than that of SPs at FE, which may lead to knee injury such as anterior cruciate ligament rupture for IPs. Compared with IPs, SPs showed a more sound lower limb motion pattern with obviously larger R_f of the ankle and hip as Seeley et al. (2011) reporting that velocity of hip extension and ankle plantar flexion displayed positive correlation with post-impact ball speed.

As observed, a general difference between SPs and IPs exists in the time to complete the forward-swing in forehand loop. In addition to accelerating forward-swing, increasing joint motion flexibility and velocity of ankle and hip during forward swing could potentially improve forehand loop performance. Moreover, appropriate increases of hip flexion and knee rotation at BE may also contribute to the performance. For IPs, it is also important to control knee rotation at FE to reduce the risk of knee injuries.

CONCLUSION: This study evaluated the effect of performance level on lower limb kinematics during table tennis forehand loop. SPs performed the forehand loop within less time and showed relatively sufficient hip and knee motion during backswing, which is a possible strategy to utilize elastic energy. During forward swing, SP showed significantly larger joint motion flexibility and velocity of ankle and hip. This may contribute to momentum generation and transference from the lower limb to the trunk and upper limbs. Larger joint motion of IPs only presented in knee rotation at FE. Knowledge of this study suggest coaches and intermediate players paying attention to enlarging hip flexion during backswing, increasing joint motion velocity of ankle and hip and reducing knee rotation during forward swing to improve forehand loop technique without undue risk of injuries.

REFERENCES:

Ball K. & Best R. (2007). Different centre of pressure patterns within the golf stroke II: Group-based analysis. *Journal of Sports Science*, 25, 771–779.

Elliott B. (2006). Biomechanics and tennis, *British Journal of Sports Medicine*. 40, 392–396.

Girard O., Micallef J.P. & Millet G.P. (2007). Influence of restricted knee motion during the flat first serve in tennis. *The Journal of Strength & Conditioning Research*, 2, 950–957.

Komi P. & Bosco C. (1978). Utilization of stored elastic energy in leg extensor muscles by men and women. *Medicine and Science in Sports and Exercise*, 10, 261–266.

Iino Y. & Kojima T. (2009). Kinematics of table tennis topspin forehands: effects of performance level and ball spin. *Journal of Sports Science*, 27, 1311–1321.

Seeley M.K., Funk M.D., Denning W.M., Hager R.L. & Hopkins J.T. (2011). Tennis forehand kinematics change as postimpact ball speed is altered. *Sports Biomechanics*, 10, 415–426.

Walshe A.D., Wilson G.J. & Ettema G.J. (1998). Stretch-shorten cycle compared with isometric preload: contributions to enhanced muscular performance. *Journal of Applied Physiology*, 84, 97–106.