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COMPARISON OF PLAYER'S CENTER OF MASS MOVEMENT BETWEEN HIGH AND LOW IMPACT POSITIONS IN TENNIS FOREHAND STROKE

Chih-Yu Lin[1], Kuo-Cheng Lo[2], Hwai-Ting Lin[3] and Lin-Hwa Wang[1]

Institute of Physical Education, Health & Leisure Studies, National Cheng Kung University, Tainan, Taiwan[1]
Physical Education Office, Kun Shan University, Tainan, Taiwan[2]
Department of Sports Medicine, Kaohsiung Medical University, Kaohsiung, Taiwan[3]

During the tennis forehand stroke, the displacement of body center of mass (COM) changes with the body movement. The COM movement influences the recovery from one stroke to the next. Therefore, the purpose of this study is to investigate the differences of COM movement and joint kinematics between high and low-impact positions on different skilled players. This study adopted a 3-D motion analysis system for recording and tracing the advanced (n = 5; level 3-4) and intermediate (n = 7; level 5-6) athletes' motion of whole body during high and low-impact positions in tennis forehand stroke. The results showed that significant difference was not found between both impact positions and level groups in ball velocity. Advanced group showed greater anterior/posterior displacement than the intermediate group in low-impact position that increased the kinetic energy.

KEY WORDS: strategy, displacement, velocity.

INTRODUCTION: The forehand stroke is an essential and basic skill in tennis. A powerful stroke, correct stroke location and fast movement are the key elements to win the game (Douvis, 2005; Johnson, et al., 2006). With the rapid development of sports science, the sports training nowadays emphasizes the scientific methods and determines the best conditions of a great athlete through experiment. Most analysis of forehand stroke focuses on kinematics (Elliott & Marsh, 1989; Knudson, 1990) and kinetics (Bahamonde &Knudson, 2003; Wang, 2005) of stroke action and the electromyography (EMG) (Morris, et al., 1989) during stroke., Those research focus on the action of single swing, however, the athletes' reaction before and after they swing has not been fully evaluated. The quantitative analysis of the movement of COM is still not unclear during tennis stroke.
The displacement of body COM has been applied frequently in research of the gait analysis, body migration, balancing control (Smith, Lelas & Kerrigan, 2002), and measurement of patient body balance (Cherng, Su, Chen & Kuan, 1999). One study applied the concept of displacement of COM in the analysis of baseball pitching (Lin, Su, Nakamura & Chao, 2003), but few related research utilizes the concept of body COM in sports performance analysis. Therefore, the purpose of the research is to investigate the differences in action and the strategy adopted while athletes are trying to maintain the body balance and performing forehand stroke at the different impact heights positions.

METHODS: According to the standards of International Tennis Federation (International Tennis Number, ITN), subjects are divided into different levels. Level five to six is considered as the intermediate group (IG; n = 7; ages: 24 ± 4.93 yrs; height: 175.57 ± 5.62 cm; weight: 76.43 ± 12.46 kg) and level three to four is the **advanced** group (AG; n = 5; ages: 35.4 ± 10.14 yrs; height: 174.6 ± 4.22 cm; weight: 74.8 ± 12.46 kg). The Eagle® motion system (Motion Analysis Corp., Santa Rosa, CA, USA) with eight cameras was used in this study for the tennis forehand stroke motion collection at a sampling rate of 500 Hz. Twenty-eight reflective markers were placed on human anatomical positions. The segments' motion trajectory and ball impact condition were derived when the two groups used the forehand stroke with different heights of stroke. The serve machine was used to keep the balls at the same speed (14 m/sec) when stroke was performed. The players waited for the ball served by the machine after they were ready. One stroke was collected from backswing phase, acceleration phase, impact in two different positions (high-impact position: stroke above the waist; low-impact position: stroke below the waist) to follow-through phase. Ten successful trials were collected for data analysis. The positions of the segmental center of mass were determined using the anthropometric data of Dempster (1955). The collected motion data were traced and identified by Evart software, and smoothed with cut-off frequency 7.12Hz. The MATLAB program was applied to find out the change of joint angles by Euler analysis and the COM movement was presented by a cycle of one stroke. The ANOVA-repeated measures with a significant level of 0.05 were used to analyze the differences in heights of impact positions at different skilled levels during tennis forehand stroke.

RESULTS: In the high-impact position, the ball speed after stroke was 32.90±2.15 m/sec in the AG and 30.04±4.14 m/sec in the IG and 31.01±1.35 m/sec and 29.49±1.14 m/sec in the low-impact position, respectively. The AG showed larger ball velocity which did not reached statistical significant difference in both impact positions and level groups.
Regardless of the backswing phase (*p*=.009) or the acceleration phase (*p*=.004), the AG had a significantly greater COM anterior/posterior displacement than the IG (Table 1). In the anterior/posterior displacement, no matter in the high or low position, the AG had more posterior component of COM displacement than in the IG from acceleration phase (*p*=.043) to follow-through phase. In the COM right/left displacement, players stroking in high-impact position had more right component of COM displacement than in low-impact position during acceleration phase. In the vertical component of COM, it was found that the high-impact position showed greater upward component of COM displacement than the low-impact position during acceleration phase, but it might be observed in the follow-through phase and significant differences were observed (*p*=.039) (Figure 1).

Table 1
Significant difference in the displacement of COM between different skill groups and stroke positions

Direction	Source	*p-value*	Result
Backswing phase			
Anterior/posterior	Low-impact position	.009	AG>IG
Acceleration phase			
Anterior/posterior	Level	.043	AG>IG
Anterior/posterior	Low-impact position	.004	AG>IG
Follow-through phase			
Upward/downward	Position	.039	High>Low

DISCUSSION: Our present findings illustrated the displacement of COM in both advanced and intermediate players during tennis forehand stroke. It was found that two different positions did not cause significant differences in ball velocity, but the AG's ball velocity was larger than that of the IG, and the ball velocity in higher impact position was larger than in lower impact position. Higher impact position needs only flat stroke, but lower impact position requires backswing movement to increase the acceleration distance so that the ball in lower position can cross the net and turn out to be a top-spin ground stroke. The researches in the past indicated that the flat stroke generated larger velocity than the top-spin ground stroke.

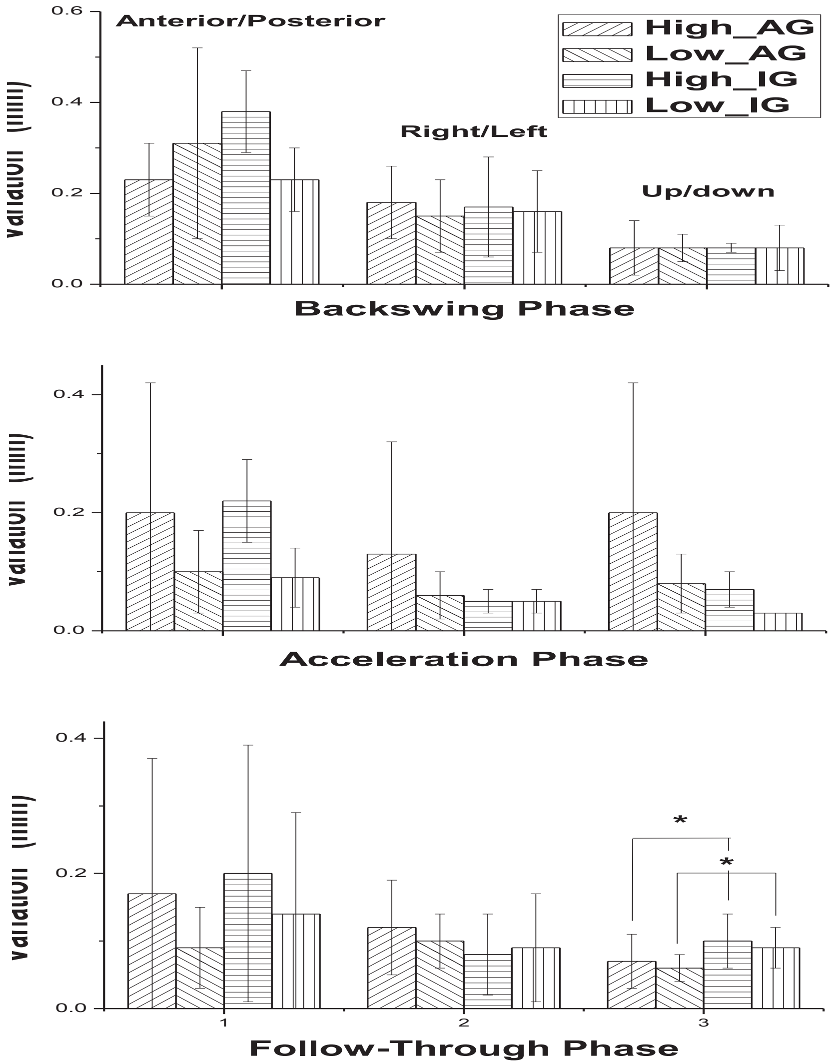

Figure 1: The variation of displacement of COM between skill groups and stroke positions in tennis forehand stroke. * $p < .05$

In the anterior/posterior displacement, whether in high or low position, the AG had more posterior component of COM displacement than the IG from acceleration to follow-through phases. AG is good at using the strategy of forward and backward body movement to produce kinetic energy to increase the stroke power. In the right/left displacement, players stroking in high-impact position had more right scope of COM than in low-impact position during acceleration phase. The players' stroke in high-impact position had better predictive ability and was more stable. In the vertical directions, it was found that the high-impact position showed greater upward component of displacement of COM than the low-impact position during acceleration phase, but it was the opposite of the follow-through phase and significant differences were observed. In the follow-through phase, the player's body moves upward with the racket, and COM moves up indirectly, too. The result conforms to the application of different movement strategies to generate different performance (Liao & Lin, 2008).

CONCLUSION: No significant difference was found between both impact positions and level groups in ball velocity, but the AG showed larger ball velocity in both impact positions and level groups. The AG had a significant greater anterior/posterior displacement than the IG in both backswing position and acceleration phase to contribute to the generation of kinetic energy. Our investigation reveals that hitting in the different impact positions, players have different stroke performances and strategies of COM movement. Further investigation is required in order to determine whether it is possible to improve the strategy of COM movement in the IG by regulating the stroke action.

REFERENCES:

Bahamonde, R., & Knudson, D. (2003). Kinetics of the upper extremity in the open and square stance tennis forehand. *Journal of Science and Medicine in Sport,* 6(1), 88-101

Cherng, R. J., Su, F. C., Chen, J. J., & Kuan, T. S. (1999).Performance of static standing balance in children with spastic diplegic cerebral palsy under altered sensory environments. *American Journal of Physical Medicine & Rehabilitation,* 78, 336-343.

Dempster, W.T. (1955). *Space requirements of the seated operator WADC-TR-55-159*. Wright-Patters on Air Force Base, Ohio.

Douvis, S. J. (2005). Variable practice in learning the forehand drive in tennis. *Perceptual and Motor Skills,* 101, 531-545.

Elliott, B., & Marsh, T. (1989). A biomechanical comparison of the topspin and backspin forehand approach shots in tennis. *Journal of Sports Sciences*, 7, 215-227

Johnson, C. D., McHugh, M. P., Wood, T., & Kibler, B. (2006). Performance demands of professional male tennis players. *British Journal of Sports Medicine,* 40, 696-699.

Knudson, D. V. (1990). Intrasubject variability of upper extremity angular kinematics in the tennis forehand drive. *International Journal of Sport Biomechanics,* 6, 415-421.

Liao, C. F., & Lin, S. I. (2008). Effects of different movement strategies on forward reach distance. *Gait & Posture,* 28, 16-23.

Lin, H. T., Su, F. C., Nakamura, M., & Chao, E. Y. S. (2003). Complex chain of momentum transfer of body segments in the baseball pitching motion. *Journal of the Chinese Institute Engineers,* 26(6), 861-868.

Morris, M., Jobe, F. W., Perry, J., Pink, M., & Healy, B. (1989). Electromyographic analysis of elbow function in tennis players. *American Journal of Sports Medicine,* 17, 241-247.

Smith, L., Lelas, J., & Kerrigan, D. (2002). Gender differences in pelvic motions and center of mass displacement during walking: stereotypes quantified. *Journal of Women's Health & Gender-based Medicine,* 11, 453-458.

Wang, L. H., & Lin, H. T. (2005). Momentum Transfer of Upper Extremity in Tennis One-Handed backhand drive. *Journal of Mechanics in Medicine & Biology,* 5, 231-141.

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