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ORIGINAL SCIENTIFIC PAPER

Movement Mechanism Differences of Badminton Overhead Forehand and Backhand Smash Stroke Techniques during Teaching Learning in Human Movement Science

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Abstract

This study aims to analyze the movement of backhand and forehand smash stroke techniques in three dimensions using a kinematics approach in badminton. The results were analyzed using a descriptive and quantitative approach. Furthermore, 24 male badminton players from the University Student Activity Unit with an average age of 19.4±1.6 years, a height of 1.73±0.12m, and a weight of 62.8±3.7kg were used. The study was conducted using 3 Panasonic Handycams, a calibration set, 3D Frame DIAZ IV motion analysis software, and a speed radar gun. The data normalization from the kinematics values of the shoulder, elbow, and wrist joint motion was calculated using the inverse dynamics method. Also, the one-way Anova test was used to determine the differences in the kinematics of motion in the two different groups. The results showed that the speed of the shuttlecock during the forehand smash was greater than the backhand. In the maximal shoulder external rotation phase, two variables were found with the best results during the forehand smash, namely the velocity of shoulder external rotation and wrist palmar flexion. The velocity of shoulder internal rotation, elbow extension, and forearm supination in the maximum angular velocity phase showed greater results when making a forehand smash.

Keywords: *badminton, overhead smash, biomechanics, kinematics, three dimensions*

Introduction

According to Kuntze, Mansfield and Sellers (2010), stroke techniques are categorized into three types considering the position of the racket. They include underarm, sidearm, and overhead strokes. The attack technique often used is the overhead smash stroke technique (Chow, Seifert, Hérault, Chia, & Lee, 2014). Similarly, there are two types of smash technique skills, namely forehand and backhand smash. These are powerful attack weapons to kill opponents and get as many points as possible by contributing 39.8% (Barreira, Chiminazzo, & Fernandes, 2016). Furthermore, a smash is a fast stroke that relies on the strength, velocity, and flexion of the wrist with the shuttlecock swooping down towards the opponent's field area (Lam, Wong, & Lee, 2020).

The world record for smash speed is held by Fu Haifeng, a Chinese doubles player. This medalist paired with Cai Yun with a shuttlecock speed of 332 km/h at the June 2005 Sudirman Cup championship (Martin et al., 2020). The speed of the shuttlecock exceeded those of other racket sports by reaching 493 km/h. This was played by a Chinese player Tan Boon Heong while testing a new racket product (Yonex ArcSaber Z-Slash) in 2017 (Rusdiana et al., 2020). Meanwhile, the fastest backhand smash was conducted by Taufik Hidayat, an Indonesian player with a gold medal at the 2004 Athens Olympics with a shuttlecock speed of 206 km/hour (McErlain-Naylor et al., 2020).

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The backhand smash is an overhead stroke using the rear racket head. When making this, the body's position needs to back to the net by prioritizing the wrist joint flexion motion which is directed to swoop backward (Sakurai & Ohtsuki, 2010). This is because the transfer of body weight to the pedestal is the same as the position of the hand while holding the racket. The upper extremity rotates rapidly when the shuttlecock moves to the front of the player. Sequentially, it continues with the rotation of the hip, shoulder, and elbow joints (Li, Zhang, Wan, Wilde, & Shan, 2016). Same with a forehand smash, the shuttlecock needs to be hit at the highest possible position. Furthermore, the flexible and strong wrist flexion motion is a major factor in producing a hard and targeted stroke (Miller, Felton, Mcerlain-Naylor, Towler, & King, 2013). The reason for applying the motion mechanics principles is the key to producing a smash that provides maximum strength, speed, and accuracy to kill the opponent's movements and generate points (Ooi et al., 2009).

Due to the lack of backhand smashes, different studies tried to connect with almost the same motion patterns to add broader insights on tennis sports such as serve, smash, backhand, and forehand drive techniques. According to Abian-Vicen, Castanedo, Abian, & Sampedro (2013), a one-handed backhand drive is not only supported by the velocity of the trunk rotation. However, it is determined by the amount of momentum and force movement generated from the shoulder and wrist joints. This drive involves the motion of body segments such as the legs, hips, trunk, upper arms, forearms, and hands (Alexandros, Christina, Nikolaos, & Konstantinos, 2013).

The velocity of maximal shoulder external rotation and the backswing of the upper arm are the main factors in generating a greater force when making a backhand drive (Kolman, Kramer, Elferink-Gemser, Huijgen, & Visscher, 2019).

Genevois, Reid, Rogowski and Crespo (2014) reported that in the advanced player group, the maximum speed of the racket is obtained from the strength of the upper arm force. Meanwhile, in the novice group, the maximum speed is obtained from the motion of the wrist and elbow. During the one-handed backhand drive, the velocity of hip rotation makes a significant contribution to that of the other upper limb joints (Wu, Gross, Prentice, & Yu, 2001). Meanwhile, the forehand smash requires harmonious coordination of body motions from the strength generated by the trunk, shoulders, arms, and wrists (Mavvidis, Metaxas, Riganas, & Koronas, 2005). To produce an effective smash, the biomechanics principles should be implemented in the phase of motion sequences. These include the preparation phase, backswing, forward swing, racket impact with the shuttlecock, and follow-through motion phase (Phomsoupha & Laffaye, 2014). Nesbit, Elzinga, Herchenroder and Serrano (2006) stated that the importance of wrist flexion, forearm pronation, and upper arm rotation. In addition, the "kinetic chain movement" principle will produce an effective and efficient smash. The study of Taha, Hassan, Yap and Yeo (2016) reported that these joints and segments have an effect on one another during movement. When one is in motion, it creates a chain of events that affects the movement of neighboring joints and segments. Furthermore, the optimal performance in conducting a forehand smash depends on the motion of the body segments that work in a harmonious motion chain sequence (Abian-Vicen et al., 2013).

Based on the background explanation, this study aims to analyze the movement of backhand and forehand smash techniques in three dimensions with the motion kinematics approach in badminton.

Method

Method and Design

The method used is descriptive and a quantitative approach. Descriptive is a method that aims to systematically describe facts accurately about certain symptoms that are the center of attention.

Participants

The sample used was 24 male badminton players that joined the University Student Activity Unit with high skills with an average age of 19.4±1.6 years, a height of 1.73±0.12m, and a weight of 62.8±3.7kg. Furthermore, purposive sampling was used, and all participants gave their consent on the form that had been given previously and were confirmed not to be injured. Before the test, they received technical explanations related to the implementation procedures in a comprehensive manner. The data collection test was conducted in the badminton field sports hall building, Faculty of Sports and Health Education, Indonesia University of Education.

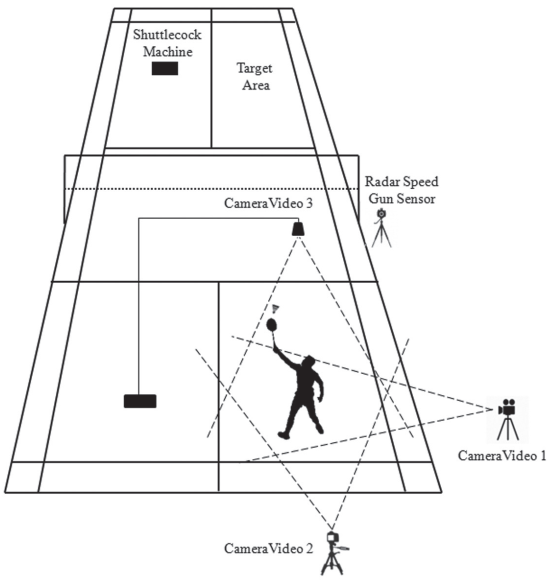

FIGURE 1. Schematic of collecting view data from behind the field

Instrument

The instrument used three video cameras (Panasonic Handycam HC-V100 Full HD, Japan), a three-dimensional calibration, a 3D motion analysis software (Frame DIAZ IV, Japan), one set manual marker, and a radar speed gun (Bushnell Speed gun 101911, Italy).

Procedure

Before the test, the participants engaged in a warming up for about 15 minutes. This was followed by performing overhead backhand and forehand smashes using their racket to be more comfortable and adapt fast. Figure 2 describes the scheme for field data collection, where ball speed is measured using a radar speed gun with a shutter speed of 100 Hz. It was placed near the net with a distance of 45 cm outside the field line. In addition, video camera 1 was placed on the right side of the field with a distance of 2.5 m perpendicular to the position of the subject standing. Video camera 2 was positioned behind the field line parallel to the subject area with a distance of 3m from the player's position. Video camera 3 was placed above the subject standing in a perpendicular position parallel to the subject area. The three video cameras were set by users according to the needs of the study characteristics. This includes a frame rate of 100 Hz, a shuttle speed of 250 s, and an exposure time of 1/1200 s. Meanwhile, calibration and data processing analyzed in three dimensions were conducted using the direct linear transformation structure method developed by Aziz Abdel (Hong, Wang, Lam, & Cheung, 2014).

Data Analysi

This study uses the SPSS version 22.0 application. (SPSS Inc., Chicago, IL), where the average and standard deviation were calculated as initial data for further calculations of normality, homogeneity, and hypothesis tests. To test the hypothesis, a one-way analysis of variance approach was used. This analysis helped to calculate the level of difference between the backhand and forehand overhead smash with an alpha confidence level of 0.05. The three-dimensional coordinate data of the signs affixed to each part of the player's joints were adjusted using the Butterworth low-pass filter method approach. This was carried out with a cut-off frequency of 15 Hz and determined by the residual analysis technique (Iino & Kojima, 2011).

Kinematics Parameters

To obtain the kinematic parameters of an overhead smash motion, a model is made following the anatomical principles of the body in Figure 2.

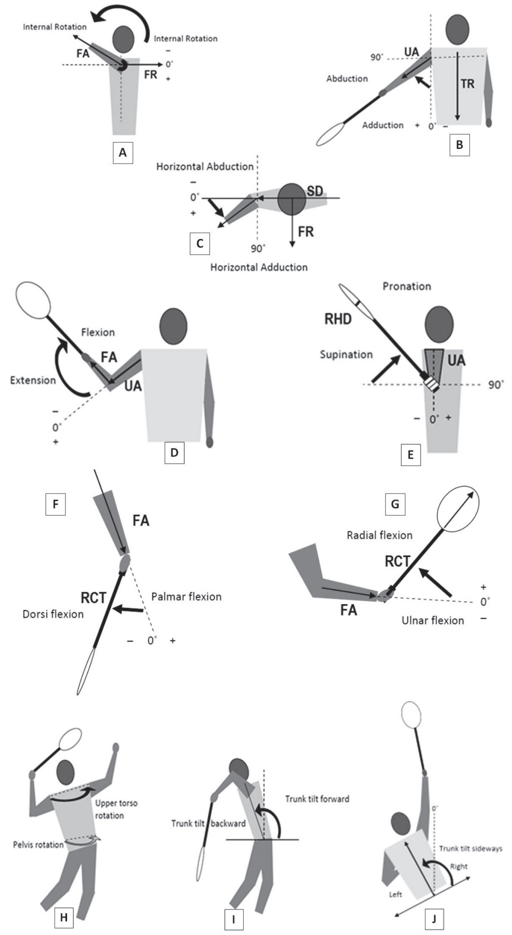

FIGURE 2. Kinematic parameters of motion in the upper limbs joint (source: Rusdiana et al., 2020)

Initially, the shoulder joint consists of three movements, namely internal-external rotation (A), abduction-adduction (B), and horizontal abduction-adduction (C). Furthermore, the elbow joint consists of two movement characteristics, namely flexion-extension (D) and forearm pronation-supination (E). The wrist joint consists of two movements, namely the palmar-dorsiflexion (F) and the radial-ulnar flexion (G). The next movements are upper torso rotation and pelvis rotation (H), trunk tilt forward and trunk tilt backward (I), as well as trunk tilt left and right sideways (

Result

Table 1 showed the data on the difference in ball speed and changes in the kinematics of motion during backhand and forehand smashes.

Table 1. Kinematic parameters during maximal shoulder external rotation

Kinematic Parameter Analysis	Backhand	Forehand
	Means±SD	Means±SD
Shuttlecock velocity (km/h)*	112±5.7	158±3.5
Shoulder external rotation (deg)*	-122±3.5	-169±4.2
Shoulder abduction (deg)	101±1.2	106±1.4
Shoulder horizontal adduction (deg)	7±0.83	9±0.96
Elbow flexion (deg)	94±1.1	102±1.3
Radio-ulnar Pronation (deg)	1±1.1	12±1.3
Wrist palmar flexion (deg)*	-23±2.1	-47±2.4
Trunk tilt backward (deg)	21±3.5	24±3.1
Trunk tilt sideways left (deg)	19±1.4	21±1.6

Legend: * - Significance difference at the 0.05 level

Table 1 showed the significant differences in three variables of the nine kinematic parameters analyzed in the maximal shoulder external rotation phase. These include shuttlecock velocity (p=0.035), shoulder external rotation (p=0.048), and wrist palmar flexion (p=0.037). From these results, the three variables at the forehand smash have a greater value than the backhand.

Table 2. Kinematic analysis parameters in the maximum angular velocity phase

Kinematic Parameter Analysis	Backhand	Forehand
	Means±SD	Means±SD
Shoulder internal rotation (deg/s)*	1623±3.5	2111±4.2
Upper torso rotation (deg/s)	761±1.2	782±1.4
Pelvis rotation (deg/s)	421±0.8	429±0.9
Elbow extension (deg/s)*	523±1.1	995±1.3
Supination (deg/s)*	642±1.1	494±1.3
Wrist dorsi flexion (deg/s)	763±2.1	855±2.4
Trunk tilt forward (deg/s)	185±3.5	199±3.1

Table 2 showed the significant differences in three variables of the seven kinematic parameters analyzed in the maximum angular velocity phase during the forehand smash. These include the speed of the shoulder internal rotation (p=0.042), elbow extension (p=0.035), and forearm supination (p=0.024). From these results, the three variables at the forehand smash have a greater value than the backhand.

Discussion

The results showed a significant difference in the maximum speed of the shuttlecock produced during the forehand smash compared to the backhand. Others showed a positive contribution between shuttlecock speed and wrist angular velocity when making backhand and forehand smashes. Meanwhile, the sequence pattern of upper limb joint rotation at the beginning of the backswing phase up to the moment of impact has similarities in the two smash techniques. The shoulder joint rotation velocity showed a greater result than the elbow joint. The wrist flexion angular velocity showed a smaller result than the elbow angular velocity. This is consistent with Creveaux, Dumas, Hautier and Rogowski (2013), where the upper limb motion sequence starts from the rotation of the shoulder, elbow, and wrist joints during backhand drives in tennis. According to Rota, Morel, Saboul, Rogowski and Hautier (2014), one major contribution of racket speed is obtained from the forearm supination rotation motion. Rogowski, Creveaux, Chèze, Macé and Dumas (2014) stated that the combination of shoulder internal rotation and forearm supination provides approximately 53% support for the shuttlecock speed during an overhead forehand smash. The result is related to the backhand smash technique. This shows that the forearm supination and upper arm lateral rotation provide the maximum bearing capacity to the speed of the racket swing before impact occurs (Fu, Ren, & Baker, 2017).

The series of motion patterns from the overhead forehand and backhand smashes require linear and circular velocity as well as an acceleration of the body movement, shuttlecock, and racket swing. There is very little study on badminton that explains the movements of forehand and backhand overhead smash stroke techniques. However, the study by Gordon and Dapena (2006) analyzed the contribution of upper limb joint rotation velocity during the tennis serve. It was stated that the backward maximal shoulder external rotation is the initial momentum to produce a larger forward shoulder internal rotation force. This results in a greater racket speed as represented in figure 3.

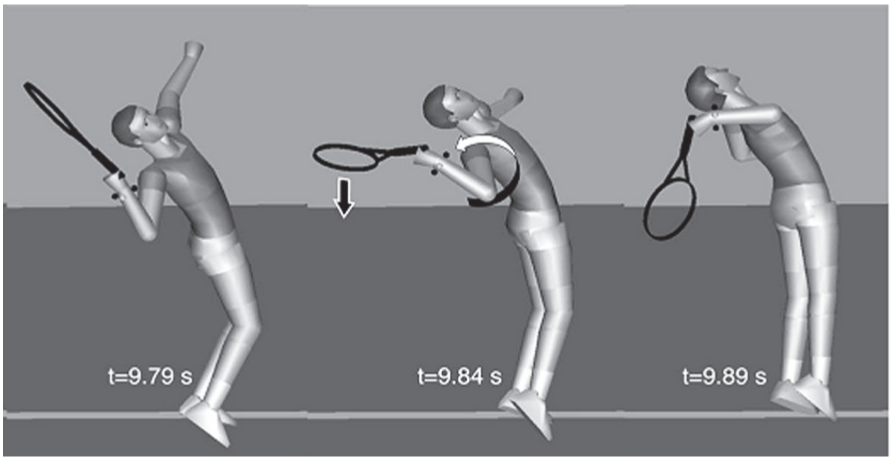

FIGURE 3. Contribution of shoulder maximal external rotation when the racket is swinging backward (Gordon, & Dapena, 2006).

During maximal shoulder external rotation, the racket head position needs to be close to the hip joint. This helps to minimize the moment of inertia by a large amount depending on the distance to the axle of the shoulder rotary axis. The smaller the resulting moment of inertia, the greater the rotation speed. Therefore, it creates an impact on the forward racket swing to be faster until the ball impact occurs (Maeda et al., 2017).

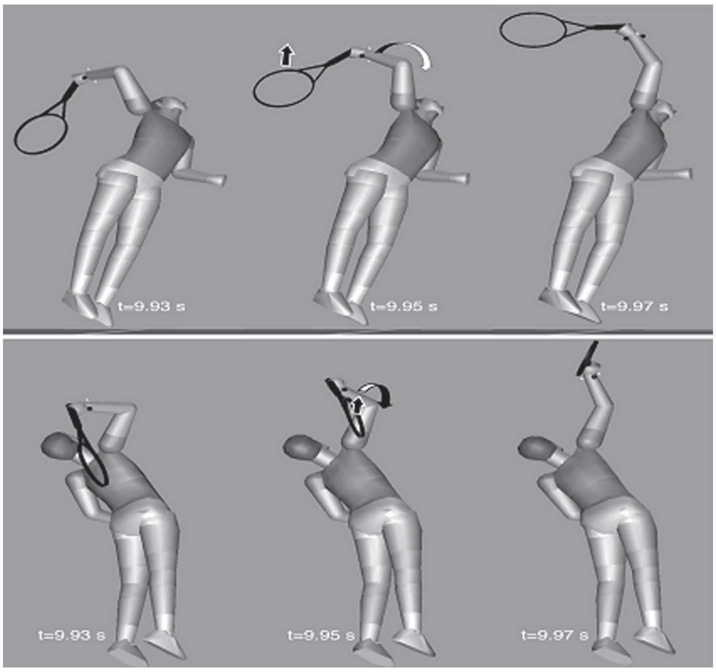

FIGURE 4. Elbow flexion-extension movement (Gordon, & Dapena, 2006).

Furthermore, the joint velocity in elbow extension shows a significantly greater result, especially during the forehand smash. This is consistent with the study conducted by Reid, Elliott, & Crespo (2013) on the tennis serve. It was reported that the elbow joint provides positive support for racket speed. In the elbow extension motion, the faster it rotates, the more the production of a large force on the motion of the upper arm and racket. This happens before the occurrence of its impact on the shuttlecock as shown in Figure 4. Furthermore, the elbow extension motion contributes about 30% to the racket speed (Martin et al., 2021).

Another joint rotation that has an important role in racket speed is the arm velocity in the radio-ulnar pronation motion (Gordon, & Dapena, 2006). This motion shows the movement pattern, especially in the group of players with high technical skills. Meanwhile, for the novice, this motion is usually almost non-existent. Therefore, it is not surprising that professional players produce shuttlecock speeds, which are much greater than amateurs.

Conclusion

From the results, it is concluded that the speed of the shuttlecock during the forehand smash is greater than the backhand smash. During maximal shoulder external rotation, the forehand smash has a significant difference in three variables, including shuttlecock velocity, shoulder external rotation, and wrist palmar flexion. Furthermore, shoulder internal rotation, elbow extension, and forearm supination at maximum angular velocity showed greater results when performing a forehand smash. The shoulder internal rotation and elbow joint velocity as well as forearm supination make a very significant contribution to the shuttlecock speed when performing the two-stroke techniques.

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Conflict of interest
The authors declare that there are no conflicts of interest.

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