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Kinetics Analysis of Overhead Standing Smash in Badminton

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Abstract

The purpose of this study was to analyze the joint motion kinetics of the shoulders, elbows, and wrists of skilled player group and unskilled player group when performing overhead standing smash in badminton game. The samples involved were 26 samples. The samples included 13 male badminton players joining Student Activity Unit who had achieved many achievements and had a high skill, while the other 13 samples were unskilled players, involving students who had just studied under one year. The mean of the participant age was 19.4 ± 1.6 years, height was 1.73 ± 0.12m, and body weight was 62.8 ± 3.7kg. This study used 3 Panasonic Handycams, a calibration set, 3D Frame DIAZ IV motion analysis software, and a speed radar gun. Normalization of the kinetic motion score of the shoulder, elbow, and wrist joints was calculated using the inverse dynamics. The t-test was used to determine the significance of motion kinetic differences of the two different groups. The results presented that the shuttlecock speed of the skilled player group, during the overhead standing smash, showed a significant difference. Meanwhile, the joint motion of the inferior shoulder force, shoulder anterior force, shoulder internal rotation torque, shoulder horizontal abduction torque, elbow anterior force, and wrist flexion torque were higher in the skilled player group than the unskilled player group.

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INTRODUCTION

Biomechanical research, especially the study of motion kinetics related to badminton overhead standing smash, is limited, but a number of studies of other sports similar to the smash movement had been published, such as tennis serve and smash, an overarm throw handball, overarm throw cricket, and a pitcher overarm throw, which can help provide an insightful study of the overhead smash kinetic motion in badminton (Rusdiana, 2020). Smash is an overhead shot aimed to the opponent's area in a dive movement and performed at the full power. This type of shot is identical as an attacking shot, because it aims to defeat the opponent (Hong et al., 2014). In addition, this shot is characterized by a fast shuttlecock rate (Mei et al., 2016). The speed of the shuttlecock resulting from a smash exceeds the speed of a ball in other racket sports, which could reach a 493 km/h maximum speed did by a Chinese player, Tan Boon Heong, when testing a new racket product. (Yonex ArcSaber Z-Slash) pada tahun 2013 (Barreira et al., 2016). In addition, a Chinese men's doubles player, Fu Haifeng, could reach around 332 km/h shuttlecock speed at the 2005 Sudirman Cup championship (Chow et al., 2014). Moreover, an Indonesian men's singles player, Taufik Hidayat, could reach a 305 km/h shuttlecock speed at the 2006 World Championship (Taylor et al., 2014).

The smash shot technique can be done while standing or jumping; the types of smash shots found in the badminton game are full smash shots, cut smash shots, backhand smash shots, and overhead circular smash shots (Abián et al., 2017). An overhead standing smash requires the strength of the legs, shoulders, and arms muscles and the flexibility of wrists as well as a harmonious coordination of body movements (Li et al., 2017). Besides that, a smash requires various elements which are essential for optimizing the technique. For an effective overhead standing smash shot, biomechanical principles must be considered for each motion sequence, such as preparation, backswing, forward swing, impact, and follow through (Abián et al., 2017) illustrated in Figure 1.

Soubeyrand et al., (2017) reported the importance of the combination of wrist flexion, forearm pronation, and upper arm rotation with the biomechanical motion principles, which can result in a maximal force of smashes in badminton. The optimal smash performance depends on the various movements of the body segments working in a sequence of harmonious movement series known as a kinetic chain movement (Valldecabres et al., 2020). According to Phomsoupha & Laffaye (2014), a kinetic chain is the notion of joints and segments which have an effect on one another during the movement. When one is in motion, it creates a chain of events that affects the movement of neighboring joints and segments. The application of biomechanical principles is the key to producing a smash with a maximum strength, speed, and accuracy to defeat the opponent's movements and earn points (Gomez et al., 2019).

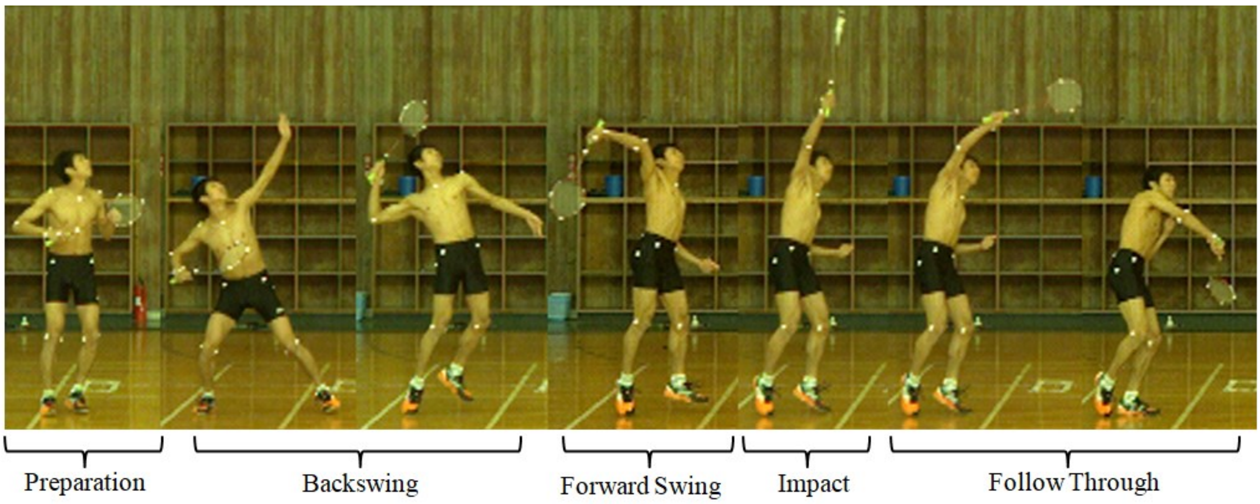

Figure 1. Phase of Badminton Overhead Standing Smash Movements

Furthermore, during the preparation phase, the position of the body must be balanced by stretching the two arms, opening both legs shoulder-width apart, and bending both knees slightly to create a stable center of gravity and mass (Rota et al., 2014). In the backswing phase, when the load is moved backwards, push the body with the legs to move the center of gravity to the backswing position. After that, stretch the racket arm to back as far as possible to provide an optimal momentum for a greater speed and acceleration of the forward swing (Rusdiana et al., 2020). The optimal speed of the forward swing movement depends on the occurring inertia moment, including the distance of the racket head must be closer to the hips, the further the position of the racket arm behind the body, the greater the generated momentum and speed of angular velocity; the application of this principle will certainly increase a greater sum of force during the impact point by involving major muscle movements followed by a series of minor muscle movements (Maeda et al., 2017). It is in line with the tennis service research reported by (Phomsoupha & Laffaye, 2015) that “Force summation is an important biomechanical principle for optimal tennis serve techniques. When performing the serve, it is important to use the largest muscles first, followed by the smallest muscles while sequentially accelerating each body part to maximise momentum. The more joints involved in the technique will produce greater acceleration and promote optimal tennis serve”.

Based on the explanation of the previous studies above, this study was aimed at analyzing the joint motion kinetics of the upper limb joints, especially the shoulder, elbow, and wrist joints of the skilled player group and the unskilled player group when performing an overhead standing smash in badminton game.

METHODS

The method used in this research was a descriptive method with a quantitative approach. Descriptive method is a research method that aims to systematically and accurately describe facts about certain symptoms that becomes the center of the researcher's attention.

Participants

The samples involved were 13 skilled male badminton players who joined the Student Activity Unit at university level who had gained a lot of achievements and 13 unskilled player students with under one year of study period. The means of age, height, and body weight were 19.4 ± 1.6 years, 1.73 ± 0.12m, and 62.8 ± 3.7kg. The total number of participants were 26 people.

All participants gave their consent on the form that had been previously given. All participants were also confirmed not being injured. Then, before the test was administered, they received a comprehensive technical explanation related to the procedure implementation. The test for the data collection was carried out in a badminton field at FPOK sport hall, Universitas Pendidikan Indonesia.

Instruments

The instrument of this study were three video cameras (Panasonic Handycam HC-V100 Full HD, Japan), a three-dimensional calibration set, a set of 3D motion analysis software (Frame DIAZ IV, Japan), a set of manual markers, a speed gun radar (Bushnell Speed gun 101911, Italy), and an automatic shuttlecock throwing machine (Flypower).

Test Procedures

Before the test, the participants did a warm up for 15 minutes which was followed by performing overhead standing smash using their own racket to make the participants comfortable and quick to adapt.

Figure 2 explains the field data collection scheme. The measurement the speed of the ball utilized a radar speed gun and a 100 hz shutter speed which were placed near the net with a 45 cm distance outside the field line. Video camera 1 was placed at the right side of the field side line with 1.5m distance perpendicular to the subject standing position. The video camera 2 was put behind the field line parallel to the subject area with 2m distance from the player standing position. Meanwhile, the video camera 3 was placed above the subject standing position, which was vertically perpendicular to the subject area position. The three video cameras were adjusted according to the needs of the research characteristics. The frame rate was 100 hz; the shuttle speed was 250s; and the exposure time was 1 / 1200s. Meanwhile, for the calibration purposes and data processing, the three-dimensional analysis was carried out using the Direct Linear Transformation Calibration Structure Method developed by (Hamill et al., 1999).

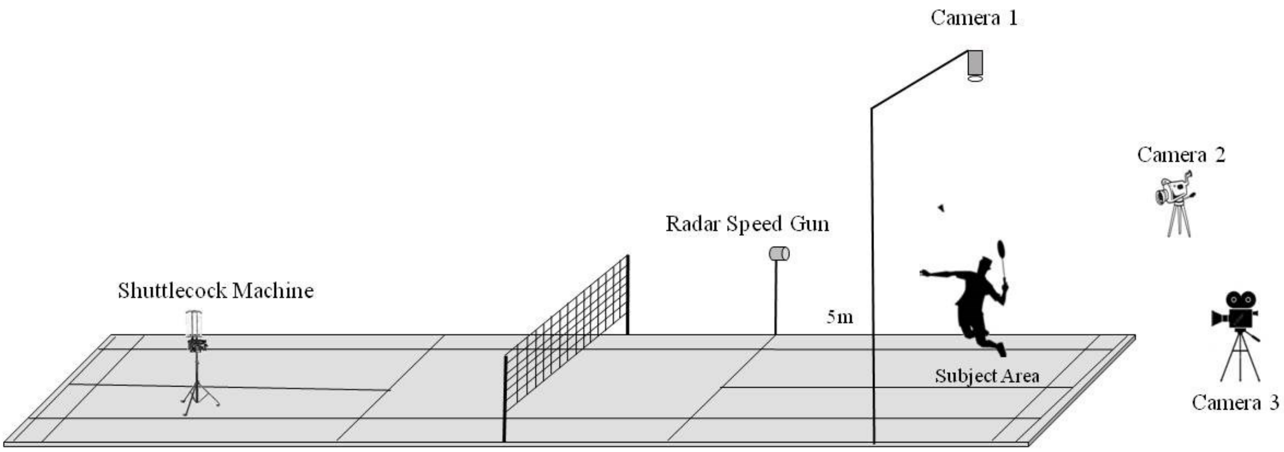

Figure 2. Phase of Badminton Overhead Standing Smash Movements

Motion Kinetic Parameters

To determine the kinetic characteristics of standing smash, a model was made according to the motion anatomy principles, including the shoulder joint which consisted of three movement characteristics, consisting of internal external shoulder rotation (A), shoulder abduction-adduction (B) and shoulder horizontal abduction-adduction (C). Elbow joint consists of two characteristics of movement, namely elbow flexion-extension (D) and forearm pronation-supination (E) movements. The wrist joint consists of two characteristics of movements, namely the palmar-dorsi flexion (F) and radial-ulnar flexion (G) movements.

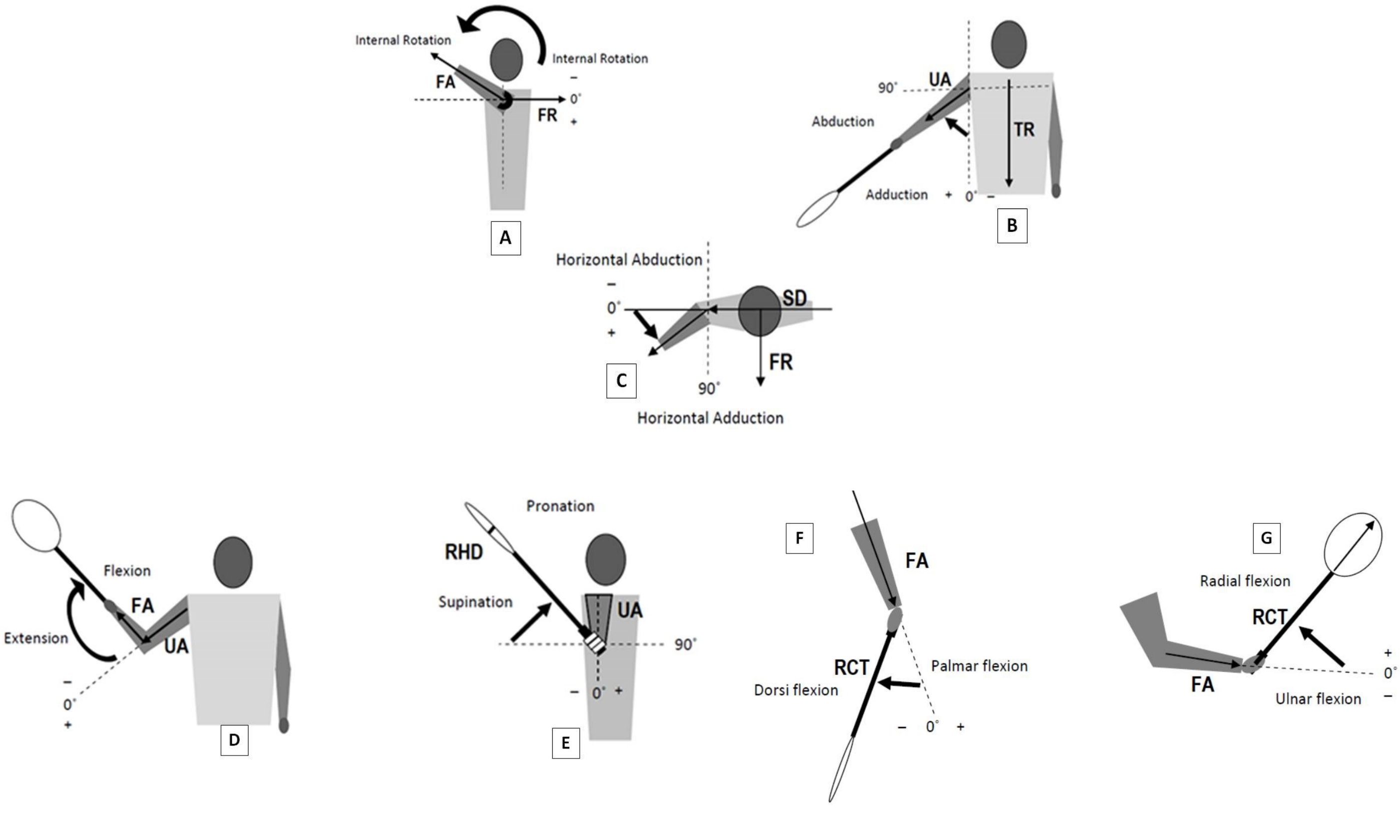

Figure 3. Motion Kinetic Parameters of the Upper Limb Joints (source: Rusdiana, 2020)

Data Analysis

This study used the SPSS version 22.0 application (SPSS Inc., Chicago, IL). The mean and standard deviation were calculated as the initial data for further calculations, namely normality test, homogeneity test, and hypothesis test. To test the hypothesis, a non-parametric t-test approach was used (Mann-Whitney tests) because the normality of data was not fulfilled. This test aimed to calculate the level of difference between the two groups (skilled and unskilled player groups) with an alpha confidence level 0.05. The 3D coordinate data from the player markers were refined using the Butterworth low-pass filter method with a 15 Hz cut off frequency, which was determined by residual analysis (Iino & Kojima, 2011). All kinetic values were calculated using Matlab 8.5 software (Mathworks, Natick, USA).

RESULT

The peak values of normalized joint kinetics are shown in Table 1. The results showed that the six sub-indicators of the 14 analyzed parameters during the overhead standing smash were significantly different between the skilled and unskilled player groups. The shoulder inferior force (P = 0.002), shoulder anterior force (P = 0.014), shoulder internal rotation torque (P = 0.016), shoulder horizontal abduction torque (P = 0.029), elbow anterior force (P = 0.003), and wrist flexion torque (P = 0.031) movements of the skilled player group showed a significant difference.

Meanwhile, the maximum kinetic values of the shoulder proximal force, shoulder horizontal adduction torque, elbow medial force, elbow proximal force, wrist anterior force, wrist medial torque, wrist proximal force, wrist anterior torque, wrist medial torque, wrist proximal force, wrist flexion torque, and wrist radial torque movements showed no significant difference between the two groups.

Table 1. Kinetic Parameter Maximum Values of Badminton Overhead Standing Smash

Variables	**Skilled**		**Unskilled**		**P-Value**
	Mean ± SD		**Mean ± SD**		
Shoulder Force (N/BW)					
Shoulder Inferior Force*	2.9	0.5	4.2	0.7	0.002
Shoulder Anterior Force*	2.6	0.7	3.4	0.4	0.014
Shoulder Proximal Force	5.7	0.8	5.4	1.2	0.215
Shoulder Torques (Nm/BW x H)					
Shoulder Internal Rotation Torque*	35.2	8.1	21.6	7.1	0.016
Shoulder Horizontal Adduction Torque	56.8	12.3	58.3	11.8	0.945
Shoulder Horizontal Abduction Torque*	20.4	7.2	28.9	10.4	0.029
Elbow Force (N/BW)					
Elbow Anterior Force*	1.8	0.4	3.9	0.9	0.003
Elbow Medial Force	2.8	0.7	4.2	0.9	0.165
Elbow Proximal Force	6.2	1.5	6.5	1.4	0.236
Wrist Force (N/BW)					
Wrist Anterior Force	2.6	0.5	2.7	0.4	0.225
Wrist Medial Force	0.8	0.3	0.11	0.5	0.342
Wrist Proximal Force	3.6	0.8	3.9	0.6	0.242
Wrist Torque (Nm/BW x H)					
Wrist Flexion Torque*	15.3	2.9	24.4	3.6	0.031
Wrist Radial Torque	13.4	3.4	15.6	3.8	0.654

Significance Value P < 0.05
N = Newton, BW = Body Weight, Nm = Newton meter, H = Height

DISCUSSION

The purpose of this study was to compare the joint motion kinetics of the shoulders, elbows, and wrists between the skilled players and unskilled players when performing an overhead standing smash in badminton. The findings of this study indicated that there was a significant difference of the shuttlecock speed during the overhead standing smash between the skilled player group and the unskilled player group. The results of this research are relevant with other study investigating a sport with a similar motion with the overhead standing smash, namely tennis serve between professional players and advanced tennis players (Johnson & McHugh, 2006). Furthermore, the results of this study also explain that an efficient service movement mechanism allows players to maximize the ball speed with a low joint load and reduce the risk of joint injury. The results of the present study indicate that the overhead standing smash of the unskilled player group was less "efficient" due to the overload of shoulder and elbow torque compared to the skilled player group who gained a higher ball speed (Yeh et al., 2019). This problem occurred in the unskilled player group so that it can be related to the kinetic chain movement theory principle when the movement is not harmonious. It indicates that any disturbance in the kinetic motion chain caused by improper mechanics could result in an overload upper limb joint, resulting in a lack of coordination of the appropriate motion sequences (Herbaut et al., 2018).

The movement series of the overhead jumping smash require a linear and circular velocity and acceleration of the body movement, shuttlecock, and racket swing. There is a limited research on badminton games explaining the movement of the forehand overhead stroke technique, especially the standing smash. However, according to Bahamonde & Knudson (2003), in their research analyzing the contribution of the upper body joint rotation speed on tennis serve, the maximum movement of the shoulder joint when the racket is swinging backwards is the initial phase to produce a faster shoulder forward rotation speed to get a higher ball speed. This result is in line with the finding of (Rogowski et al., 2014) in tennis serve that the elbow joint contributes significantly to the velocity of the ball after the impact. The fast elbow extension movement rotation will produce a strong push from the upper arm and the forward swing before the impact with the shuttlecock (Gordon, 2006).

In addition, the results of other studies show that the flexion and extension movements of the elbow joint contribute significantly (up to 30%) to the speed of the racket swing (Song et al., 2020). The rotation speed of other joints that have an important role on the racket swing speed is the forearm pronation-supination motion (Gordon, 2006). This joint movement, especially the rotational speed of the forearm supination before an impact with the shuttlecock, provides a great support to the racket speed. This movement is clearly seen in the high technical skill player group. Meanwhile, for unskilled players, these movements usually hardly happen. Therefore, it is not surprising if a professional player's smash produces a higher shuttlecock speed compared to an amateur player.

Moreover, the research conducted by (Kolman et al., 2019), related to the wrist motion kinetic data during tennis service, showed that the wrist force and torque provided a higher support compared to the tennis forehand stroke. It shows that the tennis serve movement is a skill having a risk of wrist injury. Further results of study from (Yeh et al., 2019) reported that the majority of wrist pain occurred due to repetitive overloads during the tennis serve caused by the shoulder proximal force and stress of joint torque. In addition, (Johnson & McHugh, 2006) reported that the short duration of backswing would result in a higher anterior shoulder force in the backswing phase. Therefore, to prevent shoulder and elbow injuries due to overload movements, the player should pay attention to the maximum shoulder back swing in a chain (Genevois et al., 2020).

CONCLUSION

The results and discussion conclude that the shuttlecock speed of the skilled player group, when performing overhead standing smash, was higher compared to the unskilled player group. Furthermore, there were significant differences in the shoulder inferior force, shoulder anterior force, shoulder internal rotation torque, shoulder horizontal abduction torque, elbow anterior force, and wrist flexion torque joint motions between the skilled player group and the unskilled players group. Due to the limitations of the study, it is suggested that the next discussion focuses on the kinetic and momentum changes of the body segment movement in analyzing jumping smash in Badminton.

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