GROUND REACTION FORCE AND KINEMATICS OF FOREHAND JUMPING SMASH AMONG ELITE MALAYSIAN BADMINTON PLAYERS

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This study identified the contribution of lower and upper extremity biomechanical parameters towards high velocity and accuracy of the shuttle in forehand straight jumping smash. A total of 19 Malaysian elite badminton players performed a forehand straight jumping smash to a designated area at the opposite area of the court.Multiple corelation test was performed to determine the contributions of each variable in all three phases.Maximal Ground Reaction force (r=.548,p< 0.05), Maximum jump height (r=.0505, r<0.05),Wrist angular velocity during back swing phase to contact phase (r=0.745,p<0.05) and Racket head speed(r=0.724,p<0.05). Wrist angular velocity of the racket hand shows the highest correlation followed by racket head speed during back swing phase to contact phase. Higher jumping height with shorter time duration will emphatically produce higher shuttle velocity and accuracy.

KEYWORDS: badminton, jumping smash, biomechanics.

INTRODUCTION: Badminton is the most popularly played sports in Malaysia in 2018 according to an online survey("Malaysia - kinds of sports regularly participated in 2018," 2019).In badminton there are many techniques in gaining an upper hand over the opponent. The jumping smash is one of the many techniques used by players. This technique when used correctly can add strength for the players that require the usage forehand and overhead jumping smash. A jumping smash is performed in mid-air to create steeper angle and thus it is the most powerful shot in badminton. The fastest ever badminton hit was recorded in Tokyo, during the Japan Open on 24th September 2017. It was attributed to Lee Chong Wei at speed of 417km/h (256mph)("Guinness World Records," 2019)
Several studies have been published focusing on the badminton jumping smash. These include two-dimensional (2D) sagital plane analytical techniques(Ii, 1998),(wolf gawin, 2007),(Huang, Shaw-Shiun, & Tsai, 2002),(David B. Waddell, 1991) and three-dimensional (3D) kinematics data. However, they are limited to simple descriptions of joint ranges or motion(ROM) and segmental orientation at key phases("Biomechanical Analysis of the Upper Extremity in Three," 1979),(Hirza Mohammad Ariff & Sham Rambely, n.d.). In addition, according to (Rusdiana, Ruhayati, Korea, & Korea, 2016), the racket velocity at contact is 84.6±1.27 and 68.33±3.39 m/s respectively for elite male and female players in forehand jump smash. The objectives of the study were to determine those kinetics and kinematics of upper and lower body variables that significantly contribute to shuttle velocity in forehand striaght jumping smash.

METHODS: Nineteen Malaysian elite badminton players were used for the purpose of the study with their age ranging 23± 4 years, mass 69.9± 8.2kg, height 1.748 ±0.0056m, subject includes 12 right handed and 7 left handed.
Experimental procedure:
The experimental procedure was as follow as for each participant: Firstly, instruction on the test was explained and consent form was signed. The system was then calibrated and 60 reflective markers were attached to the body which consist of 15 segments, 9 markers were attached on the athlete's own racket. One 20 mm (diameter) sized retro reflective marker was attached on the head of the shuttlecock (Aerosensa 30). Player's were given time to familiarise with the court condition, lighting and shuttle launcher. Data collection (Kinematics) was then conducted with 25 unit cameras Qualisys AB 411 05n goteberg, sweeden at 700 fps and 3

units of Kistler force plate at 700 hz were used to collect ground reaction force. Shuttle launcher was set to launch shuttlecock directly at above the force plate where the player is required perform the jumping smash. 20 forehand straight jumping smash trials were recorded for each player. From these trials, one trial which generates the highest shuttle velocities with accurately landing on the designated area at the opposite court was selected for further analysis.
The whole jumping smash action was divided into three phases. First phase is the Preparation phase (PP) which happens at the moment where the participation is at minimal racket leg knee angle and also the lowest CG. The second phase, Back swing phase (BSP) are defined at the frame where the racket hand shoulder is at hyper flexion position. The third phase, Contact phase (CP) was defined during the first frame of the racket head is at contact with the shuttle. Multiple correlation tests were used to identify the variables which contribute to the performance of forehand straight jumping smash; the selected variables were tested at the 0.05 significance level.

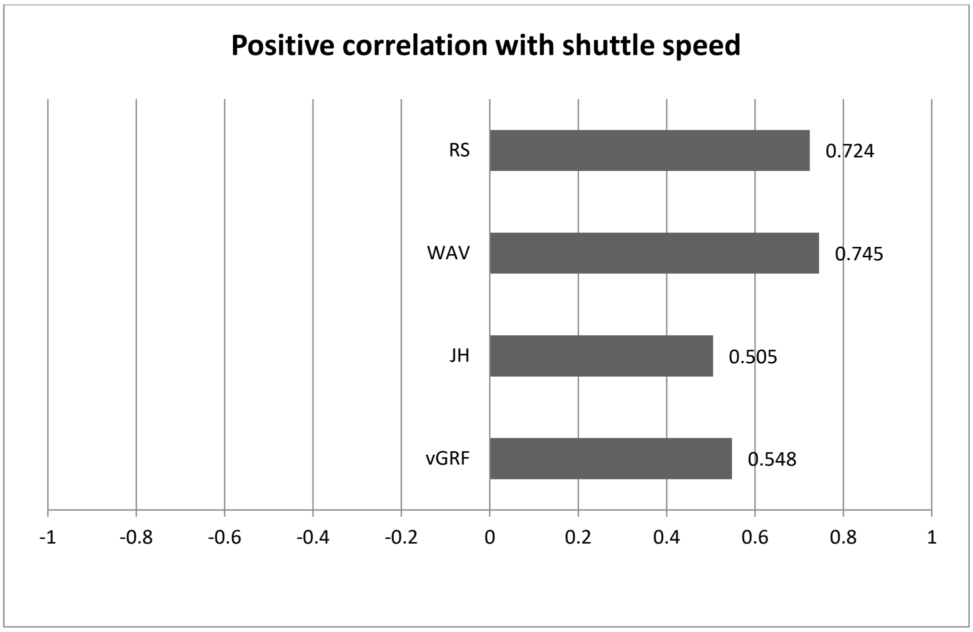
RESULTS: The nineteen elite badminton players participating in this study had a shuttlecock velocity of 321.53±25.82 km/h. The mean, standard deviation and multiple correlations of the kinetic and kinematic variables are shown in Table 1.

Table 1: Descriptive and Correlation analysis results for forehand straight jumping smash.

No.	Independent variables	Mean	±SD	r	sig
1.	PP, Racket leg Knee angle (°)	109	8.9	-0.031	0.898
2.	PP, Non-Racket leg Knee angle(°)	105	9.3	-0.077	0.753
3.	PP, Racket leg ankle angle(°)	69	6.4	-0.400	0.900
4	PP, Non-Racket leg ankle angle(°)	77	10.3	-0.247	0.307
5.	PP, Vertical Ground reaction force, GRF(BW) vGRF	2.95	0.42	0.548**	0.008
6.	PP-BSP, Racket leg Knee angular Velocity(°/s)	765	45.4	-0.033	0.893
7.	PP-BSP, Non-Racket leg Knee angular Velocity(°/s)	745	73.9	0.344	0.149
8.	PP-BSP, Racket leg ankle angular Velocity(°/s)	778	85.5	0.245	0.313
9.	PP-BSP, Non-Racket leg ankle angular Velocity(°/s)	598	142.8	0.285	0.237
10.	PP-BSP, Time taken for CG Min to Max(s)	0.51	0.12	0.555	0.14
11.	PP-BSP, height of CG Min to Max(cm) JH	49	4.7	0.505*	0.027
12.	BSP, Racket Hand elbow angle(°)	63	11.2	-0.02	0.934
13.	BSP, Racket Hand wrist angle(°)	109	8.1	0.291	0.227
14.	BSP-CP, Racket hand elbow angular Velocity(°/s)WAV	1726	132.4	0.226	0.351
15.	BSP-CP, Racket hand wrist angular Velocity(°/s)	1091	101.3	0.745**	0.00
16.	BSP-CP, Racket leg Knee angular Velocity(°/s)	797	277.9	0.356	0.135
17.	BSP-CP, Non-Racket leg Knee angular Velocity(°/s)	861	343.2	0.364	0.126
18.	BSP-CP, Racket head speed, RS (m/s)	279	28.8	0.724**	0.00
19.	CP, Racket Hand elbow angle(CPEA) (°)	146	4.7	0.252	0.299
20.	CP, Racket hand wrist angle(CPWA) (°)	144	2.9	0.248	0.306

** Correlation is significant at the 0.01 level of confidence.
*Correlation is significant at the 0.05 level of confidence

The multiple correlation analysis demonstrates that four factors were associated with high shuttle velocity and accuracy. Maximal ground reaction force r= 0.548, p<0.008; jumping height from min cg to maximum r=0.505,p<0.027; maximal wrist angular velocity during back swing phase to contact phase r=0.745,p<0.00 and maximal racket head speed during backswing phase to the contact r= 0.724, p<0.00.



Correlation is an effect size and so we can verbally describe the strength of the correlation using the guide that Evans (1996) suggests for the absolute value of *r.* Figure 1 shows the variables which correlated “moderately” to “very strong”. The highest correlation among twenty independent variables was from the racket hand, wrist angular velocity 0.745 (1091±101.3km/h) during back swing phase to contact phase followed by racket head speed 72.4% (279±28.8km/h) which occur in between of shoulder hyper flexion at airborne (BSP) to contact phase when the shuttle at first contact with racket head. Another important variable which were correlated is Maximal Ground reaction force during the take-off phase where the participants will anticipate the shuttle and perform push-off from force plate 54.8% (2065±362.8km/h) and lastly jumping height 50.5%(49±4.7cm) from the minimal cg during the preparation phase to maximal cg right before the back swing phase.

DISCUSSION: Previous studies have reported relationship between shuttlecock velocity and a variety of kinematics and kinetics factors of the different badminton jump smash technique. Fewer attempts have been made to find the impact of lower body kinematics in terms of determining the shuttlecock velocity during jump smash. This study used multiple correlation analysis to determine whether a linear relationship existed between lower and upper body kinematics with shuttle velocity.

From the study, the strongest relationship was found between shuttlecock velocity and wrist angular velocity, which occur in between back swing phase to contact phase. This is in agreement with previous literature, where wrist angular velocity evaluated by (Huang et al., 2002) is 37.25% higher than the finding in this study 1091±101.3 deg/s. This could be caused by high degree of variability in the wrist angle (Miller, 2016).

Tang et al. (1995) suggested in the contact phase wrist is one of the contributory factors in attaining greater racket head speed. This study shows that there is significant correlation between racket head maximal speed in between back swing phase to contact phase with a 72.4% contribution and is concurrent with other studies by (A. S. Rambely, Osman, Usman, & Wan Abas, 2005).

Vertical Ground reaction force found to be moderately correlated with 0.548 to high shuttle velocity within the principles of kinetic chain. When performing a jump smash, the force that is needed to produce high velocity of the shuttle with accuracy is transferred through the lower extremity of the foot. (Rasmussen, 2012).

Li et al found that the distance from the lowest centre of mass during preparation phase to the centre of mass at contact was not significantly different between elite and college players.

However, elite players have shorter jumping time with higher jumping height from preparation phase to contact phase. Thus elite players achieved higher upward velocity than the collegiate players causing them to achieve higher shuttle velocity in both smash strokes (Ii, 1998). This study revealed that the maximum jumping height from preparation to contact phase has moderate correlation 50.5% (49±4.7cm) to performing the fastest forehand straight jumping smash similar to (Ii, 1998). Elite athletes generally have better Stretch Shortening Cycle compared to others so they are able to achieve this (A. Rambely, 2008).

CONCLUSION: Even though the standard among the players are almost the same, there were few players could perform faster jumping smash compared to others. This study found that Improving power and the flexibility of the racket hand wrist will give an advantage on due to wider range of motion during preparation phase to contact phase. Including staggered stance concentric squad during strength training will improve the lower body explosive power and help with height of jump. In future, lower body kinetics should be included in the study. Further study will be needed to fully understand why some players can smash faster than others.

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