THE ANALYSIS OF THE JUMPING SMASH IN THE GAME OF BADMINTON

Azmin Sham Rambely[1], Wan Abu Bakar Wan Abas[2] and Mohd. Safrulsahar Yusof[3]
[1]Centre of Mathematical Sciences, Faculty of Science & Technology, National University of Malaysia, Bangi, Selangor, West Malaysia
[2]Biomedical Engineering Department, Faculty of Engineering, University of Malaya, Kuala Lumpur, West Malaysia
[3]National Sports Council, Bukit Jalil, Kuala Lumpur, West Malaysia

An investigation on the prevalence of jumping smash in a badminton game is carried out using a six video camera system. The data was collected during the Thomas/Uber Cup 2000 competition, which was held in Kuala Lumpur, Malaysia. Thirteen male players in the single and double competitions were studied. The trials were digitized using the Peak Motus 2000 system. The result from the chi square analysis showed that majority of the jumps and landing occurred in only one foot. And from the correlation analysis, it was found that the angular velocity of the ankle at the maximum value prior to take off was strongly correlated with the center of mass vertical velocity ($r = 0.546$, $p = 0.001$).

KEY WORDS: jumping smash, statistical analysis, biomechanical analysis

INTRODUCTION: Jumping while performing a smash is a very popular technique in badminton games. It may contribute to the winning of a point if performed successfully. Thus players strive for a successful smash in order to accumulate points, besides the deceiving skill techniques that occur frequently in the games. Even though previous study has shown that height of jump does not correlate with a high velocity of the shuttlecock, players are overwhelmed with the jump smash (Rambely et al., 2005).

In the jumping smash, the jumping and landing sequence is commonly associated with injury. The majority of injuries occur in the lower extremity with the ankle and knee joint being particularly vulnerable, with 34 and 29 claims reported respectively (ACC Injury Statistic, 2004). Injuries to the ankle and knee joints are especially important because they are associated with more lost time from sport participation than other injuries cited (Solgard, et al., 1995). Perhaps the most serious knee injury during jumping is the rupture of the anterior crutiate ligament (ACL) while the most serious ankle injury is the calcaneal/Achilles tendon rupture.

It is hypothesized that repeated jumping and the deviations in jumping and landing technique during the games are the primary causes of injury. Furthermore a player puts greater force on the take-off foot in order to propel himself upward with a higher center of mass vertical velocity. However, no research exists regarding the jumping smash technique and its association with injury in badminton. Therefore the paper intends to investigate the jumping smash technique performed by the top ranking international badminton players and to determine the relative frequency of the jumping techniques.

METHODS: Video data were collected on badminton games during the men's singles and doubles semi-final and final events of the Thomas/Uber Cup 2000 competition held in Kuala Lumpur, Malaysia, from 11 May to 21 May 2000. Thirteen male players in the single and double competitions were studied. Nine of the players were right-handed and four were left-handed. The motion of a player during the jumping smash stroke is shown in Figure 1. The numbered points represent the shuttlecock and they are marked in accordance with the respective motions: preparation (1), back swing (2-4), forward swing (4-5), contact (5), and follow-through (6-9). The best smash strokes made by each player during the games were selected. The stroke referred to what was perceived, through manual observation, to produce the fastest shuttlecock speed. For each selected player, eight trials for the singles (number of players = 5) and three trials for the doubles (number of players = 8) in the semi-finals, and five trials for doubles during the finals (number of players = 4) were used in the analysis.

Thus a total of 84 trials were involved. Each trial consists of, on average, 60 frames starting from the action of getting ready to the landing position after the smashing stroke.

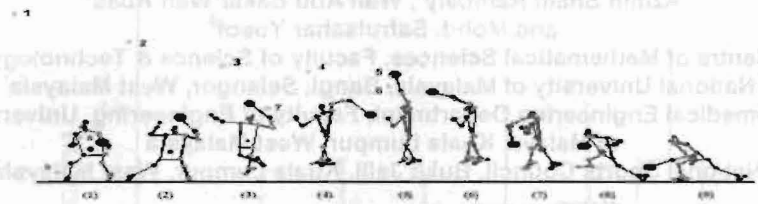

Figure 1 The motion of smash stroke.

The recording system consisted of 6 sets of 50 Hz shuttered CCTV cameras (WV-CP450/WV-CP454 Panasonic) with color S-video, genlock and 6x zoom capabilities, 6 time-code generators (Norita SR-50), six 9-system portable color televisions (CA688 Fumiyama), and 6 Peak-computerized and controlled VCR (NV-SD570AM Panasonic). For calibration, the cameras captured a reference structure (calibration frame) with 25 markers of known coordinates in space encompassing the whole court. The cameras were directly genlocked for video to provide shutter synchronization and identical frame rates.

Multiple cameras were used during the video capture. 2 cameras (C1 and C4) were positioned with the optical axes approximately perpendicular to the court and another 2 cameras (C2 and C5) were placed with their optical axes nearly parallel to the court to obtain the front (or back) view of the players. The other 2 cameras (C3 and C6) were placed approximately 45° to the court. Cameras 1, 2, and 3 were used to determine the three-dimensional coordinates for the right-hand side of the court while cameras 4, 5, and 6 to determine those for the left-hand side of the court.

The videotapes were edited using an industrial standard NTSC Panasonic AG-7350 VCR and an IBM-compatible personal computer. The Peak Motus 2000 software was used to digitize the trials.

Body segment parameters from the Dempster model were used but adjusted to include the shuttlecock and the badminton racket (rear and bottom) (Dempster, 1955). In each video image, 25 control points, 21 anatomical landmarks representing the endpoints of 24 segments, 1 point for center of mass, 2 points on the racket (top and rear), and 1 point for the shuttlecock were digitized manually. Subsequent to digitizing, the raw data were smoothed using the Butterworth digital filter with the cut-off frequency of 3Hz.

The relationship between lower limb angular kinematics and body centre of mass velocities was then analyzed using Pearson Product Moment Correlations. The data on the frequency of jumping and landing were analyzed using the SPSS software. The chi square analysis was performed to determine the frequency of jumping relative to racket arm, phase and foot pattern used. The racket arm is defined by the right-handed and left handed players. The phase is defined through the jumping and landing sequence, while the foot pattern is taken from the right foot, left foot or both feet. The jump is taken from the take-off foot (or the planting foot), while the landing is considered as the first foot land. Each factor is weighted in a categorical manner. The result is produced through the contingency table with confidence level of 0.05.

RESULTS AND DISCUSSION: Data for the lower limb are provided in Table 1. All tests are statistically significant ($p < 0.01$). During the performance of the jumping smash, a player usually jumps between the back swing and forward swing phases. From Figure 2, it can be seen that angular velocity of the ankle for the leg ipsilateral to the racket reached its maximum value before the take off foot is planted (denoted by the number 6); the mean peak ankle angular velocity recorded for the 84 trials is 355.6 deg/s occurred 0.15 s before impact. The angular velocity of the knee reached its maximum when the player is airborne. The average maximum angular velocity of the knee is 533.7deg/s occurred at 0.085 s before contact. The hip angular velocity also behaves similarly like the knee angular velocity. Its mean angular velocity is 338.8 deg/s occurred 0.06 s before impact. At contact the angular velocities of the hip, knee and ankle decrease in value, with 152.9deg/s, 240.8 deg/s, and –36.5 deg/s respectively. On the other hand, the linear velocities of the hip, knee, ankle, toe and heel are almost at their maximum values during the take-off event. In the landing phase, it is shown that the angular velocities are decreased.

Table 1 Lower limb maximum angular velocities.

	Mean Peak (deg/s)	Time Prior to Impact (s)	Impact (deg/s)
Hip	338.83	0.06	152.96
Knee	533.76	0.09	240.86
Ankle	355.64	0.15	-36.50

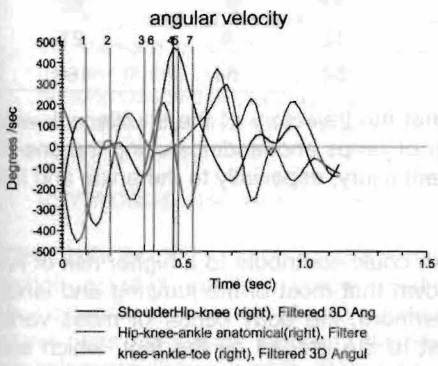

Figure 2 Angular velocity of hip, knee, and ankle of the leg ipsilateral to the racket during jumping while performing a smash.

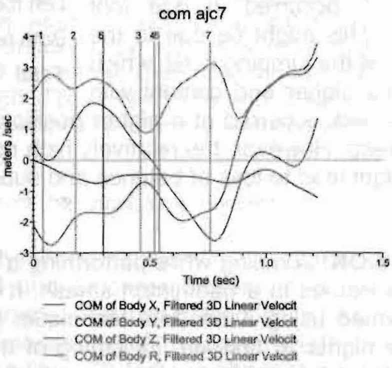

Figure 3 Typical variation in the velocities of the center of mass (com) of the body during a single trial from start position (1) to take-off position (6) and landing (7) in a jump smash.

Center of mass of frontal, sagittal and vertical velocities at take-off are 0.06 ± 1.5 ms^{-1}, 0.04 ± 1.4 ms^{-1}, and 1.9 ± 0.9 ms^{-1} respectively. No significant correlations were found between maximum pre-take-off hip and knee angular velocities and center of mass frontal, sagittal, and vertical velocities. However, there exists a significant correlation between peak ankle angular velocity before take-off and center of mass vertical velocity and sagittal velocity (r=0.546, p = 0.01 and r = 0.372, p = 0.05, respectively). When the leg contralateral to the racket maximum angular velocities are correlated with the center of mass velocities, there are also no significant correlations, but the knee angular velocity for leg contralateral to the racket is found to correlate with the center of mass resultant velocity (r = 0.314, p = 0.05). This finding is contradicted with finding of Coleman et al. (1993), who studied the jumping technique in spiking action in volleyball and found no correlation between the pre-take-off lower limb angular velocity and center of mass vertical and horizontal velocities.

At impact, the maximum angular velocity of ankle is found to correlate with center of mass resultant velocity (r = 0.332, p = 0.05). Also the angular velocity of knee of leg contralateral to the racket is found to correlate with center of mass frontal and resultant velocities (r = 0.349, p = 0.05 and r = -0.378, p = 0.05 respectively). Since the r values are relatively week, this seems to indicate that there is a very large variability between the techniques used by individual players.

The mean for center of mass resultant velocity is recorded at 2.8 ± 0.6 ms^{-1}, and the mean value for center of mass at impact is 1.9 ± 0.9 ms^{-1}, ranging from –2.7 ms^{-1} to 3.7 ms^{-1}. It is interesting to acknowledge that at take-off times, the vertical center of mass velocity in each trial is always at the maximum value and during landing; this vertical velocity is always at the minimum value, (Figure 3).

Majority of jumps were performed using only one foot either left or right foot, 44% and 41.7%, respectively. Interestingly, 61.9% of landing occurs in the left foot, 27.4% in the right foot and 10.7% utilizes both feet technique. Most of right-handed players (56.1%) perform the jump smash using their right-foot. However, majority of these players (78.9%) utilize a left foot technique landing. Similarly, majority of left handed players (81.5%) performing their jumping smash using their left foot and most of them (63%) land with their right foot. The distribution of jumps and landing are presented in Table 2.

Table 2 Distribution of jumps and landings in badminton smash.

Foot pattern	Phase		Total
	Jumping	Landing	
Right foot	35	23	58
Left foot	37	52	89
Both feet	12	9	21
Total	84	84	168

Even though jumping and landing using both feet are known to provide a wide base of support, most of the jumps and landings in jump smash performance occurred in one foot technique. This might be due to the objectives of the jumping itself, which are to jump higher and contact with the shuttlecock occurred at a higher position so that the trajectory of the shuttlecock would be very steep. However, the relatively high number of jumps and landings using the one-foot pattern might lead to loss of balance and subsequent injury, especially to the ankle and knee joints.

CONCLUSION: Jumping while performing a smash could contribute to a higher risk of knee and ankle injuries in a badminton smash. It is shown that most of the jumping and landing are performed using a one-foot technique. Furthermore, the body center of mass vertical velocity is higher at take-off, indicating of a thrust to the ground by the foot, which could damage the calcaneal bone. However, further kinetics analysis is required to fully quantify the biomechanical risks of performing this task.

REFERENCES:

Azmin Sham Rambely, Wan Abu Bakar Wan Abas, Nor Azuan Osman and Juliana Usman. Submitted for publication to the ISBS Conference in Beijing.

ACC Injury Statistics 2004. 3rd Edition. http://www.acc.co.nz/

Coleman, S.G.S., Benham, A.S. and Northcott, S.R. (1993). A three-dimensional cinematographical analysis of the volleyball spike. Journal of Sports Sciences, 11, 295-302.

Dempster, W.T. (1955). Space requirements of the seated operator. *WADC Technical Report* (pp. 55-159). Wright-Patterson, Air Force Base, OH.

Solgard, I. Nielsen, A.B., Moller-Madsen, B., Jacobsen, B.W., Yde, J. and Jensen, J. (1995). Volleyball injuries presenting in casualty: a prospective study. *British Journal of Sport Medicine*, 29(3), 200-204.