CONTACT TIME AND TAKE-OFF SPEED RELATIONSHIP IN DETERMINING HEIGHT OF JUMP IN JUMPING BADMINTON SMASH

Azmin Sham Rambely and Wan Abu Bakar Wan Abas*

School of Mathematical Sciences, Faculty of Science & Technology, Universiti Kebangsaan Malaysia, Bangi, Selangor
***Biomedical Engineering Department, Faculty of Engineering, University of Malaya, Kuala Lumpur**

The paper investigates the relationship between the foot contact time with the ground during the planting of foot phase and the horizontal and vertical velocities before take-off to determine an attainable height of jump during a jumping smash performance. World class badminton players were chosen as subjects. Results showed that contact time was found to be about 0.22 s to generate the greatest forward momentum and there was a greater need to convert the horizontal velocity to vertical velocity, as the vertical velocity determines the attainable height of jump.

KEYWORDS: Jumping smash, badminton smash, take-off speed, height of jump,

INTRODUCTION:

By definition, jumping is a projection of the body into the air by means of a force made by the feet against a surface. Literature contains many biomechanical studies related to jumping, which have concentrated on either vertical jumping (for example, high jump and counter movement jumping) or horizontal jumping (long jump) which were done by Bobbert & van Soest (1994), Linthorne et al. (2002), Hatze (1981), and Pandy et al. (1990). In vertical jumping, researchers have been interested in the contribution of the human lower limb with height of jump (Bobbert & van Soest, 1994) and parameters that can guarantee the height performance (Greg & Yeadon, 2000), whilst in the long jump activity, researchers have looked at jumping performance, such as optimal take-off angle (Lees et al., 2000; Linthorne et al., 2002) running speed (Bridgett et al., 2002; Hay, 1993) and jump techniques (Hay et al., 1986).

In badminton, a jump is considered as a sudden vertical jump, and the take-off may be made from either one or two feet. Rambely et al. (2005) found that professional players prefer to use a one-foot take-off to perform the jump smash. So far little research has been done relating to factors in determining a jumping performance in badminton. Thus the objectives of this paper are to investigate the relationship between the foot contact times with the ground during the planting of foot phase and at the factors that determine an attainable height of jump during a jumping smash performance.

METHOD:

Video data were collected during badminton games of 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. The phases during the jumping smash stroke are described as follows: preparation, back swing, forward swing, contact, and follow-through, and four events are identified, which are the planting of foot, toe-off, airborne and landing. The best smash strokes of each player during the games, which were those with the highest shuttlecock speed, were selected for analysis. 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.

The recording system consisted of 6 sets of 50 Hz shuttered CCTV cameras (WV-CP450/WV-CP454 Panasonic), 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 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 (top and rear) (Dempster, 1955). In each video image, 25 control points, 21 anatomical landmarks representing the endpoints of 24 segments, 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.

RESULTS AND DISCUSSION:

Usually, in a jump the quality is determined by the distance or the height of jump (HOJ). In a jumping smash in badminton games, the quality of jumping is determined by the reasonable height attained at the right spot to strike the shuttlecock and to produce the greatest speed shuttle possible in performance of a badminton smash. HOJ is defined as the difference between the maximum and minimum values of the center of mass. The minimum value center of mass is taken at the moment of take-off, while the maximum value center of mass occurs at the maximum height of jump. Yet, the take-off speed is another factor involved in the quality of a jump, including the jump smash.

A body cannot generate force to increase velocity or change direction without foot contact. Thus contact time is important as well. Contact time is the period of time in which a foot or feet are in contact with the ground during the pre-takeoff activity or the planting of foot phase. Thus from an impulse-momentum relationship,

Impulse = *Change in momentum*,

or the equation breaks up into

Force x *Time* = *Mass* x *Change in velocity.*

During the planting of foot phase, a player aims to produce the greatest momentum while on the ground, thus he could attain the desirable height. The contact time starts in this phase and it ends before the toe-off phase. Hence, the average contact time is about 11 frames. Thus the duration of contact time is found to be about 0.22 s in order to generate the greatest momentum in a badminton smash.

Referring to the impulse-momentum relationship, a player must apply a force over the contact time period (i.e. impulse) to change velocity. Change of velocity considers both in numerical value and a change in direction. Table 1 shows that during the planting of foot phase, a player has a horizontal thigh velocity of 0.021 m/s and positive vertical velocity of 0.675 m/s. During the toe-off phase, the horizontal velocity is a negative 0.296 m/s and the vertical velocity increases to 0.796 m/s, resulting in a take-off angle of about 70° (Figure 1).

Table 1 Linear Velocity of the lower limb before take-off

Phase	Linear Velocity (m/s)			
	Ipsilateral Thigh		Ipsilateral Leg	
	horizontal	vertical	horizontal	vertical
Initial	0.475	0.684	0.417	0.511
planting of foot	0.021	0.675	-0.143	0.487
toe-off	-0.296	0.796	-0.308	0.509

A similar pattern is observed for the ipsilateral leg with the horizontal velocity is a negative 0.143 m/s and positive vertical velocity of 0.487 m/s in the planting of foot phase, and increasing to a horizontal velocity of a negative 0.308 m/s and an positive vertical velocity of 0.509 m/s, resulting in a take-off angle of almost 90°. All of this may happen in 0.22 seconds. Graphic illustrations for the change of linear velocity of thigh and lower leg are shown in Figure 2.

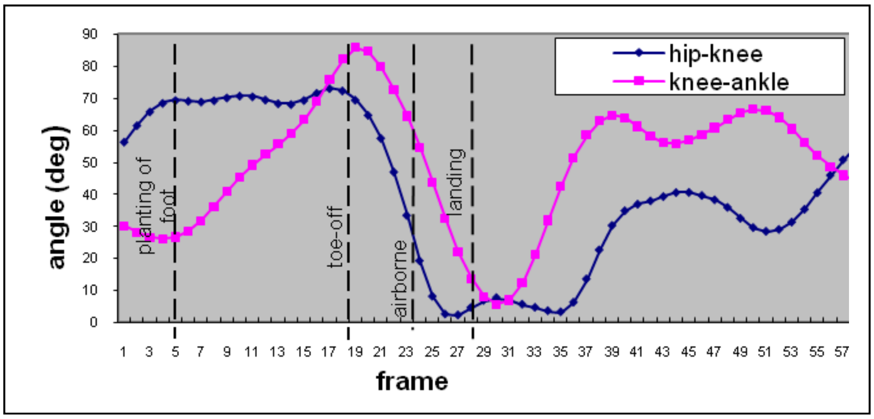
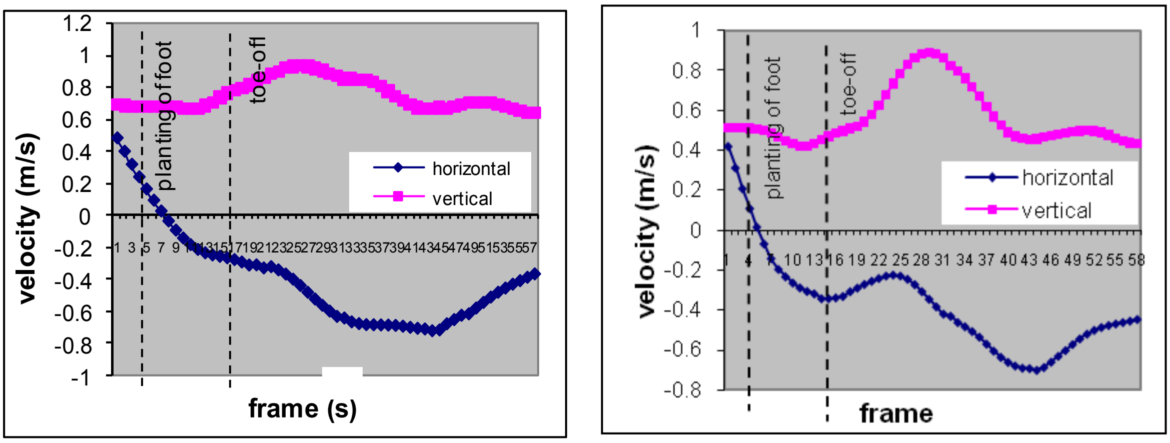


Figure 1 Segment angle on the ipsilateral leg during a jumping smash performance



(a) **(b)**

Figure 2 Linear velocity of the ipsilateral thigh (a) and lower leg (b)

During the planting of foot before toe-off, few things occur at the ipsilateral thigh and lower leg. Firstly, the horizontal velocity increases in value but changes its direction from positive to negative, and vertical velocity increases in value. These changes occur because of the ground reaction forces acting on the body. In the horizontal direction, a player produces a force against the direction of motion. In the vertical direction, the speed increases in the direction of motion and before toe-off and the body produces positive velocity to gain lift. It is interesting to acknowledge that during this period, the vertical linear velocity in each trial is always at the minimum value and after contact this vertical velocity achieved its maximum value, Figure 2.

In Figure 1, it can be seen that the angle at take-off (during toe-off phase) increases to the maximum range of motion for both thigh (hip-knee angle) and lower leg (knee-ankle angle), which indicates that there is a greater need to convert the horizontal velocity to vertical velocity, as the vertical velocity determines the attainable height of jump. Therefore the foot needs to be on the ground long enough to generate a sufficient ground reaction force in order to convert to vertical velocity.

The mean HOJ for the group was recorded as 0.54 m and the mean speed of the shuttle after impact was recorded as 57.4 ms^{-1}. It is found that there is no definite correlation between the HOJ during a smash and the post-impact shuttlecock velocity (Figure 3). A similar scatter is obtained for any individual player. Analysis on the tactics of play may be able to shed more light on this phenomenon.

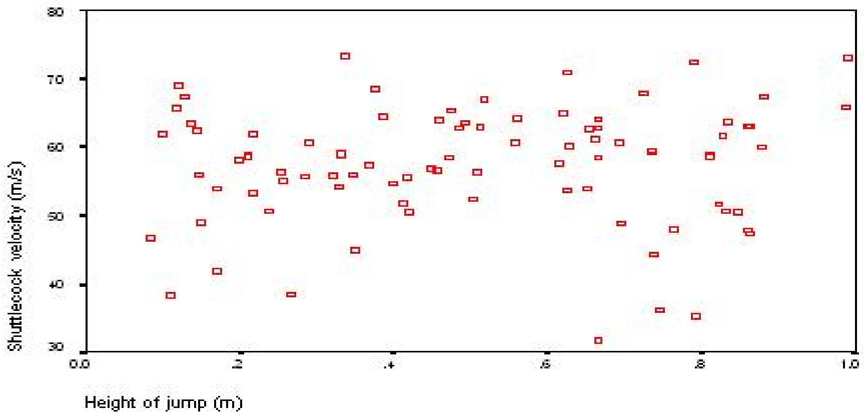


Figure 3 Correlation between height of jump (HOJ) during a smash and shuttlecock velocity

CONCLUSION:

The foot contact time during the planting of foot is found to be about 0.22 s to generate the greatest momentum. However, it should be taken into consideration that vertical jumps can be practiced in a short stretch-shortening cycle (SSC) which lasts less than 0.2 s There are athletes who obtain their individual greatest jumping height in a short SSC and others in a long SSC (contact time > 0.2 s). Thus, to deal these effects more carefully further study to look at the mean (± SD) of contact time and to distinguish between athletes with short and long SSC (contact times less or more than 0.2 s) have to be done.

REFERENCES:

Bobbert, M. F.& van Soest, A.J. 1994. *Effects of muscle strengthening on vertical jump height: A simulation study,* Med. & Sc. in Sports & Ex. 26, pp. 1012-1020.
Bridgett, L.A., Galloway, M. & Linthorne, N.P. 2002. *The effect of run-up speed on long jump performance*. In: Gianikellis, K.E., 20th Int. Sym. on Biomechanics in Sports, pp 80-83. Universidad de Extremadura, Spain.
Dempster, W.T. (1955). Space requirements of the seated operator. *WADC Technical Report*, p. 55-159. OH: Wright-Patterson, Air Force Base.
Greg, M.P. & Yeadon,M.R. 2000. *The influence of touchdown parameters on the performance of a high jumper.* J. of App. Biomech. 16, pp. 367-378.
Hatze, H. 1981. *A comprehensive model for human motion simulation and its application to the take-off phase of the long jump*. J. of Biomech. 14, pp. 135-142.
Hay, J.G. 1993. *Citius, altius, longius (faster, higher, longer): the biomechanics of jumping for distance.* J. of Biomech. 26(Suppl. 1), pp. 7-21.
Hay, J.G., Miller, J.A. & Canterna, R.W. 1986. *The techniques of elite male long jumpers*. J. of Biomech. 19, pp. 855-866.
Lees, A., Fowler, N. & Derby, D. 2000. *Optimum take-off techniques and muscle design for long jump*. J. of Exp. Bio. 203, pp. 741-750.
Linthorne, N.P., Guzman, M.S. & Bridgett, L.A. 2002.*The optimum takeoff angle in the long jump*. In: Gianikellis, K.E., 20th Int. Sym. on Biomechanics in Sports, pp 126-129. Universidad de Extremadura, Spain.
Pandy, M.G., Zajac, F.E., Eunsup, S. & Levine, W.S. 1990. *An optimum control model for maximum-height human jumping*, J. of Biomech. 23, pp. 1185-1198.
Rambely, A.S., Wan Abas, W.A.B. & Yusof, M. S. 2005. *The analysis of jumping smash in the game of badminton.* In: Wang, Q. (ed.) *Sc. Proc. of the XXIIIth Int. Sym. on Biomech. in Sports,* Beijing. Vol. 2 pp 671-674.

Acknowledgement
The research is funded by the FRGS grant (UKM-ST-02-FRGS0002-2006) from the Ministry of Higher Education, Malaysia.