Computer Methods in Biomechanics and Biomedical Engineering, 2014
Vol. 17, No. S1, 140–141, http://dx.doi.org/10.1080/10255842.2014.931550

Shuttlecock velocity during a smash stroke in badminton evolves linearly with skill level

M. Phomsoupha* and G. Laffaye

UR CIAMS – Motor Control and Perception Group, Sport Sciences Department, Bât, 335, Université Paris-Sud, 91405 Orsay, France

Keywords: aerodynamic; racket sport; ecological approach; expertise; sport performance

1. Introduction

Highly ranked badminton players seem to have a different stroke technique compared to lower ranked players (Sørensen 2010). Up to now, no studies have analysed the evolution of this velocity with expertise. So, in this study it is hypothesised that the maximal velocity of the shuttlecock during a smash evolved linearly until a plateau corresponding to the optimal smash movement. Moreover, the aerodynamic of the trajectory was investigated to understand how this velocity evolves during the whole trajectory.

2. Methods

In total, 77 players participated in this study. Their skills were reflected in the French ranking system (FFBad 2014) and are labelled as followed: elite (top players and A-ranking), high skilled (B-ranking), advanced (C-ranking), intermediate (D-ranking), novice (no ranking) and untrained (non-players) (Table 1). The velocity was recorded using a Doppler radar gun Stalker Sport system (Plano, TX) at a frequency of 250 Hz and an accuracy of ±0.027 m/s located 3 m behind the player in the player–target axis at a height about 2m50 (Chelly and Denis 2001). Only smashes hitting the target were recorded. The maximum velocity was recorded for the statistical analysis as well as the evolution of the velocity during the trajectory.

Table 1. Sample characteristics.

Variables	Age (years)	Height (cm)	Body mass (kg)
Untrained ($n = 11$)	25.6 ± 6.6	180.1 ± 5.7	76.5 ± 5.7
Novices ($n = 15$)	24.1 ± 9.1	178.9 ± 6.0	71.7 ± 8.0
Intermediate ($n = 23$)	27.3 ± 9.1	179.3 ± 6.0	72.6 ± 8.8
Advanced ($n = 13$)	25.0 ± 10.2	178.8 ± 5.3	73.7 ± 7.1
High skilled ($n = 7$)	24 ± 1.9	180 ± 4.2	75 ± 8.1
Elite ($n = 8$)	26.1 ± 4.46	180.5 ± 3.5	77.3 ± 6.6
F(5,71)	0.36	0.17	0.71
p-value	0.88	0.97	0.61

A skilled player was set to throw shuttles from the serve area in a rising trajectory towards the middle of the court. For each subject, 15 successful forehand smash strokes were recorded with a 30 s rest time, after a standardised warm-up and advice on the smash movement from a professional trainer. The subjects were asked to perform the smash stroke and to hit as hard as possible in a target located in front of him (2 m × 2 m).

The best three performances were kept for reliability and averaged for statistical analysis. Reliability was assessed (Atkinson and Nevill 1998) with intra-class correlation coefficient (ICC) and coefficient of variation (CV) and the difference between samples with an analysis of variance with Fisher *post hoc* (STATISTICA 10) with $p < 0.05$. Participants gave written informed consent to participate in this study.

3. Results and discussion

The result shows a high reliability of the method used with an ICC = 0.96 and a CV < 4.3%. The range of values is between 24.44 m/s and 81.66 m/s.

Moreover, there is an effect of expertise ($F(5,71) = 86.79$; $p < 0.0001$) with difference between all samples (all $p < 0.05$). That means when raising the level of expertise, players are able to strike the shuttle more quickly. The unexpected result is that no plateau (especially between high skilled and elite) was found within our sample, showing that elite players optimise biomechanical principles to be highly efficient (Figure 1).

On the basis of the literature, this increase of the velocity (+138%) with expertise could be explained by four biomechanics principles previously identified (Waddell and Gowitzke 2000):

(1) The addition of velocity in a sequential proximo-distal joint action during the forehand stroke increases the head velocity of the racket from proximal joints (hip and intervertebral) to the distal one (elbow extension and radioulnar pronation).

---

*Corresponding author. Email: michael.phomsoupha@u-psud.fr

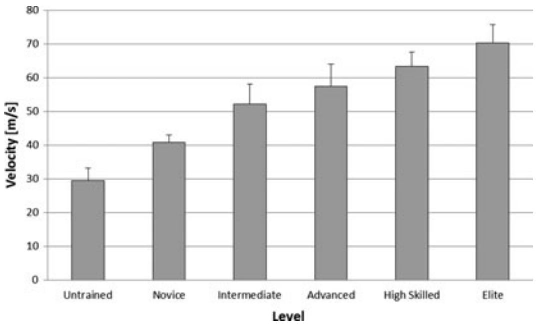

Figure 1. Difference between samples in the shuttlecock velocity during smash.

(2) The stretch-shortening cycle increases the efficiency of the force production. High skilled players stretch quickly their forearm during the eccentric phase of the movement (hyper-supination of the forearm), which is followed by a rapid concentric action (pronation of the forearm) without delay.

(3) The impulse principle: best players increase the impulse by producing the higher force as possible in the shortest time by a high acceleration of the distal joint.

(4) Lastly, the mechanism of the racket deflection influences the terminal velocity of the shuttlecock (Kwan et al. 2010).

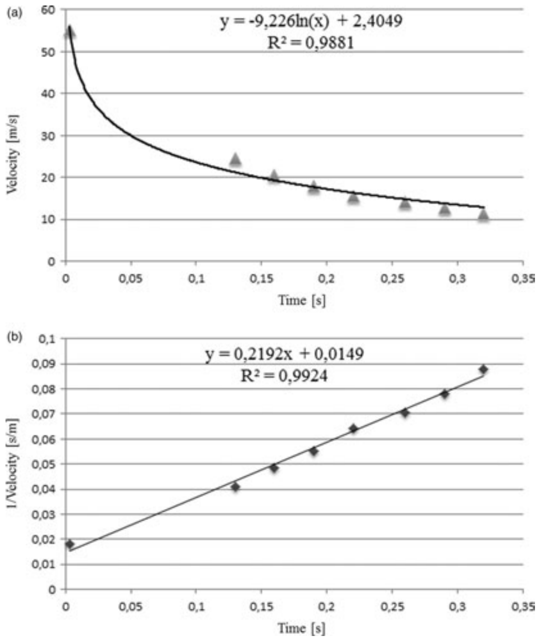

Figure 2. Evolution of the current velocity with time during a typical smash (A) and linearity of the relationship between inverse velocity and time (B).

Moreover, the study of the current velocity during the trajectory reveals a high deceleration of the shuttlecock, due to the high aerodynamics constraints. Figure 2(A) shows that the shuttlecock velocity decreases to half about after 0.05 s and has only one-fifth of its initial velocity after 0.25 s.

Moreover, according to the theoretical approach of Cohen et al. (2014), it is expected that there is a linear relationship between $1/V$ and the time. The straight line found between $1/V$ and the time (Figure 2B, $r^2 = 0.98$) confirms that the aerodynamic constraints the velocity. The origin of the equation corresponds to the launch velocity ($1/V_0$) and the gradient characterises the shuttlecock as $1/L$ with $L = 2M/\rho SC_D$, where L is the aerodynamic length, M the shuttlecock mass (0.005 kg), ρ the air density (1.2 kg/m^3), S the cross-sectional area of the projectile and C_D the drag coefficient (0.64). In our example, the gradient is about 0.22, which is exactly the theoretical gradient found by Cohen et al. (2011).

4. Conclusions

This study shows that the shuttlecock velocity evolved linearly with skill levels. Future researches to explain differences between high skilled and elite should be focused on the optimisation in the use of the deflection of the racket.

References

Atkinson G, Nevill AM. 1998. Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. Sports Med. 26:217–238.

Chelly S, Denis C. 2001. Leg power and hopping stiffness: relationship with sprint running performance. Med Sci Sports Exerc. 33:326–333.

Cohen C, Darbois-Texier B, Dupeux G, Brunel E, Quéré D, Clanet C. 2014. The aerodynamic wall. Proc R Soc A. 470:20130497.

Cohen C, Darbois-Texier B, Clanet C. 2011. Physics of badminton shuttlecocks. Part 1: aerodynamics. Bull Am Phys Soc. 56.

Kwan M, Skipper Andersen M, Cheng C-L, Tang W-T, Rasmussen J. 2010. Investigation of high-speed badminton racket kinematics by motion capture. Sport Eng. 13:57–63.

Sørensen K. 2010. A biomechanical analysis of clear strokes in badminton executed by youth players of different skill levels [thesis]. Aalborg: Sports Science, Aalborg University.

Waddell DB, Göwitzke BA. 2000. Biomechanical principles applied to badminton power stroke. In: Hong Y, Johns DP, Sanders R, editors. 18 International Symposium on Biomechanics in Sports. Hong Kong, China, June 25–30. p. 1–6.