INTRA-INDIVIDUAL VARIATION IN THE JUMP SMASH FOR 19 MALAYSIAN ELITE BADMINTON PLAYERS

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The badminton jump smash is a key skill that is crucial for winning rallies in badminton, but players can have substantial variations in smash performance. In this study the intra-individual variation in the badminton jump smash was investigated. Twenty-five jump smashes were recorded using a 3D motion capture system for 19 elite badminton players with the three fastest and three slowest jump smashes per participant selected, analysed and categorised into FAST and SLOW groups (95.0 ± 3.6 $m{\cdot}s^{-1}$ and 85.8 ± 5.8 $m{\cdot}s^{-1}$). Post impact shuttlecock speed, racket head speed at contact and longitudinal impact location were found to have a significant difference between the two groups. To achieve a consistent smash coaches should encourage a consistent fast racket head speed and positioning of the racket relative to the shuttlecock at impact in their training strategies.

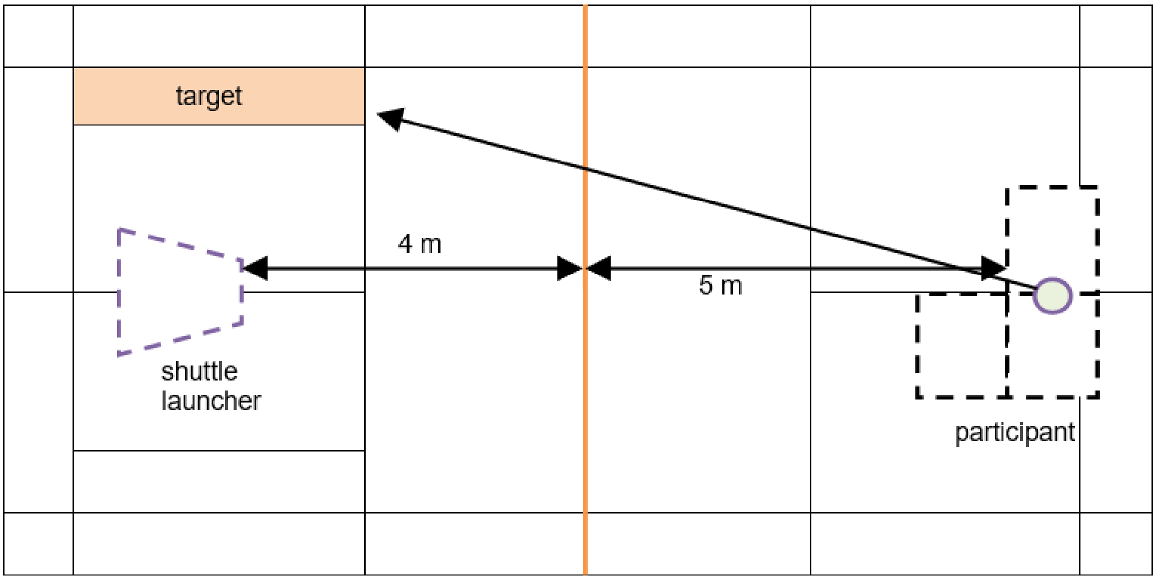
KEYWORDS: variation in intra-individual, overhead technique, performance racket

INTRODUCTION: The forehand smash was reported as the last shot played in 29.0% and 21.6% of the men’s and women’s singles rallies at the 2008 Beijing Olympic Games (Abian-vicen et al., 2017). Studies conducted across various projectile-hitting sports have emphasised the significance of the impact location. Off-centre impacts have been found to lead to reduced speeds and launch angles deviating further from the normal orientation of the racket or bat face (Elliott et al., 1995; Knudson & Bahamonde, 2001; McErlain-Naylor et al., 2020; Peploe et al., 2018). It has also been suggested that different racket weights have an effect on neuromuscular control strategies in advanced players compared to beginner (Pan et al., 2024). A higher velocity in the smash is commonly associated with specific characteristics at the moment of racket-shuttlecock contact. This includes the effect of the racket-shuttlecock impact location on shot outcome (McErlain-Naylor et al., 2020). However, to the authors’ knowledge, no study to date has conducted any intra-individual analysis to investigate why a given player’s shuttlecock speed may vary between smash strokes. The aim of this study was to quantify the intra-individual variation in shuttle smash speed, racket head speed and impact location among Malaysian elite players. Understanding how variables associated with the racket cause reductions in the shuttlecock speed at an individual level will allow the coaches and practitioners to better advise the players on how to best position the racket at contact to produce the fastest smash.

METHODS: Nineteen-elite male Malaysian badminton players were recruited for this study (age 20.2 ± 0.7 years, mass 71.7 ± 4.5 kg, height 1.77 ± 0.06 m; mean ± SD). All data were collected on an instrumented standard full-size badminton court at the Sports Biomechanics Laboratory in National sports Institute, Malaysia using a 25 Oqus 7+ series infrared cameras (Qualisys AB 411 05, Goteborg, Sweden) recording at 700 Hz with reflective tape attached to the shuttlecock and racket (Ramasamy et al., 2021) (Figure 1). Twenty-five maximum jump smashes aimed at a designated area on the opposite side of the court (Figure 1b) were performed by each participant. Trials that did not land in the designated area were excluded. The three fastest and three slowest jump smashes (identified by the post-impact shuttlecock speed) for each participant were selected for further analysis and categorised into FAST and

SLOW groups, respectively, for further analysis. For each smash shuttlecock speed and racket head speed at the instant of racket-shuttlecock contact were calculated using a curve-fitting methodology (Peploe et al., 2018) that was adapted for badminton (McErlain-Naylor et al., 2020). Medio-lateral impact location and longitudinal impact location of the shuttlecock relative to the centre of the stringbed on the racket at contact were also calculated (Li et al., 2016; Zhu, 2013). The reliability of each variable for both FAST and SLOW groups were analysed using integrated pointwise indices (intra-Class Correlation, ICC) test. Paired T-test and integrated pointwise indices using ICC (type: consistency) test were performed in IBM SPSS Statistics 26 (IBM, Armonk, NY, USA).


a.



b.

Figure 1. (a) Data collection set-up, with three force plates and target area highlighted in black (shuttle path shown from shuttle machine to striking location through to target area); (b) Set-up from above with 3.88 m x 0.4 m target area shown.

RESULTS: The overall range of shuttlecock smash speeds was 75.8 – 100.6 m/s, with the largest variation for an individual being 13.4 m/s (13% difference) and the smallest difference for an individual being 3.3 m/s (3% difference). Across all 19 participants, significant differences were observed (Table 1) between the FAST and SLOW groups in post-impact shuttlecock speed (95.0 ± 3.6 $m{\cdot}s^{-1}$ vs 85.8 ± 5.8 $m{\cdot}s^{-1}$, $p < 0.0005$), racket head speed at contact (66.3 ± 3.4 $m{\cdot}s^{-1}$ vs 64.3 ± 3.7 $m{\cdot}s^{-1}$, $p < 0.0005$) and longitudinal impact location (8.5 mm vs -2.6 mm, p = 0.027). There was no significant difference in the medio-lateral impact location (Table 1).

Table 1. Paired samples T-Test results for the comparison between FAST and SLOW trials

variable	unit	mean (SD)		*p*-value
		FAST	SLOW	
post-impact shuttlecock speed	ms^{-1}	95.03 ± 3.58	85.79 ± 5.83	**<0.0005***
racket head speed at contact	ms^{-1}	66.25 ± 3.43	64.32 ± 3.72	**<0.0005***
medio-lateral impact location	mm	-15.31 ± 8.12	-19.57 ± 18.56	0.209
longitudinal impact location	mm	8.46 ± 15.65	-2.58 ± 27.74	**0.027***

Note. *denotes statistically significant difference between the groups, impact locations measured relative to the centre of the stringbed with positive distances being towards the top of the racket for longitudinal impact locations and closer to the player for medio-lateral impact locations.

DISCUSSION: The intra-individual variation in shuttlecock smash speed across the 25 trials for each participant varied from 3.3 – 13.4 m/s with significant differences between the FAST and SLOW groups for both post-impact shuttlecock speed and racket head speed. A maximum difference of 3.3 m/s (3%) across 25 trials could be considered a small difference and perhaps what might be expected for elite players, but 13.4 m/s (13%) is over 3 times as much and for an elite player perhaps surprising. It is beyond the scope of this study to understand specifically why there is such variation across elite players, but this should be the topic of further investigations. It is not surprising that both post-impact shuttlecock speed and racket head speed were different as previous work has found a high correlation between smash speed and racket head speed ($r = 0.90$; King *et al.,* 2020). Overall participants performed smashes with greater longitudinal impact locations (11 mm closer to the racket tip) in the FAST group compared to the SLOW group. It is not obvious why this difference in impact location occurred across a group of elite players, but it could indicate that coordinating the timing of the racket shuttle impact was challenging even for elite players. Having an impact location closer to the tip of the racket does result in a faster speed of the racket at the point of impact on the racket and therefore it makes sense that the fastest shuttlecock speeds came from impacts slightly closer to the tip of the racket. The combination of a faster racket head speed and an impact location closer to the racket tip appear to be the main factors that explain the difference in shuttlecock speed with there no clear difference in medio-lateral impact location. Variation in the medio-lateral impact location may be perhaps linked more closely to variability in the direction of the smash rather than the smash speed.

CONCLUSION: Considerable intra-individual variation in smash speed was found (up to 13.4 m/s) and that seems to be explained by intra-individual variation in racket head speed and longitudinal impact location across a range of trials. These observations may have practical value for informing coaches on the areas to focus on to achieve a consistent smash speed. The present study was limited to shuttlecock smash speed, racket head speed and impact location. Future work should investigate the changes in technique which cause the differences in racket head speed and impact location and establish if some techniques cause less variation in racket head kinematics at impact. Furthermore, investigations with non-elite populations, or different age groups are warranted to investigate this topic area further, as well as longitudinal studies to see what technique changes are made as players progress through various stages and performance groups, thereby highlighting which technique factors are important for consistently developing greater racket head speed and shuttlecock smash speed.

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