HITTING TO DIFFERENT SPOTS ON THE COURT: THE BALL KINEMATICS OF THE PROFESSIONAL TENNIS SERVICE

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Of the component parts of the service (toss and swing) the swing has received disproportionate research attention. Consequently, the age-old question of whether players serve to different parts of the court from the same toss remains unanswered. A 22 camera, 250Hz VICON MX motion analysis system tracked six professionally ranked players as they hit first serves (FS) and second serves (SS) to three 2X1m target areas reflecting the landing locations of T, body and wide serves respectively, on the deuce court. The displacements of the front foot, ball zenith and ball impact were significantly different in the FS, while kinematics across SS were consistent. Front foot position was closer to the centre mark in the T serve and players impacted the ball further left in the wide serve compared to the T serve. Implications are practical for serving and returning.

KEYWORDS: biomechanics, coaching, skill development.

INTRODUCTION: The two most important strokes in tennis are service (hereafter serve) and return. The key parameters describing the performance of both during match play are known to improve with professional ranking (Reid, Mcmurtrie and Crespo, 2010). Logically, where servers endeavour to limit the time and information available to returners to make appropriate decisions and responses, returners desire the opposite. Some coaching texts encourage servers to use the same toss for every serve (Yandell, 1999), practically constraining the information on offer to returners to manufacture a quality return. In contrasting vein, coaches implore returners to attend to the ball toss in an effort to help determine the tactical intent of the server (Crespo and Miley, 1998). The 'competing interests' of the server and returner when it comes to the ball toss are captured by former world number 1, Jim Courier (2010): "you can see a server's tendencies if they toss the ball in a certain spot" yet "the best servers don't give anything away ... with the same toss they can hit three spots on the court: out wide, into the body and then down the middle". The inference is then that lesser servers exhibit some perceptible variation in their ball toss. Indeed, as expert players are capable of picking up useful anticipatory information from the kinematics of an opponent's tennis movement pattern (Shim et al., 2005), consistent toss kinematics would seem advantageous for the server. A key question then becomes to what extent do the spatial characteristics of the toss change with serve location among high performance players? As abovementioned, players able to serve to different court locations while controlling for or only encountering subtle changes in ball toss should theoretically hold a competitive advantage. However with limited literature available on ball toss kinematics or serving to different locations, namely in a match play environment, the validity of this concept remains unknown. This study will therefore provide an insight in to the effect of three common serve locations on the toss kinematics of both the first and second serve. From a practical perspective, it considers whether players "hit different serves off the same toss".

METHODS*:* Six internationally-ranked male right-handed players participated in the study. They were aged 18-24 years old and 1.83±0.06m tall. Players provided informed consent in line with the relevant human research ethics approval. Players performed their regular pre-match warm-up before hitting three successful, maximal effort first serves (FSs) and second serves (SSs) to three target areas on the deuce court. The target areas were 2m long x 1m wide and reflected the landing locations of T, body and wide serves of right-handed players serving against right-handed opponents (see Figure 1). Players used their own rackets to complete the protocol. Each player hit serves in a standardised sequence (FS T, FS body, FS wide, SS T, SS body, SS wide) and were provided two minute rest between each block of 10 serves. Testing was undertaken on a full-size tennis court constructed at the Australian Institute of Sport Biomechanics Laboratory. A 22-camera, 250 Hz VICON MX motion analysis system (Oxford Metrics Inc., UK) tracked the three-dimensional (3D) trajectories of retro-reflective markers on the left hand, first metatarsal of the left foot, racket and the ball. The origin of the global coordinate system was translated to the position of the first metatarsal marker, which was determined prior to the initiation of each participant's backswing, to ensure that all displacements could be held relative to the front foot. Positive X was to the right and parallel with the baseline (displacement along this axis is referred to as lateral or left/right), positive Y was forward and parallel with the singles sideline (displacement along this axis is referred to as forward/backward) and positive Z upward (displacement along this axis is referred to as vertical). A second order polynomial extrapolation was performed on ball and racket data to account for impact accelerations (Knudson and Bahamonde, 2001) and impact was determined as one frame (0.004 s) prior to racket-ball contact. Discrete mean kinematics describing key characteristics of the player's set-up position, tossing action and swing were reported from the successful trials. Calculated variables included lateral foot position from the centre mark of the baseline, ball zenith (BZ) during toss, ball displacement at impact, toss time and absolute racket velocity at impact. For both the FS and SS, nine repeated measures ANOVAs, with accompanying Bonferroni post-hoc analyses, investigated whether any kinematic differences existed between the ball and racket kinematics of the serves hit to the three target areas (Table 1).

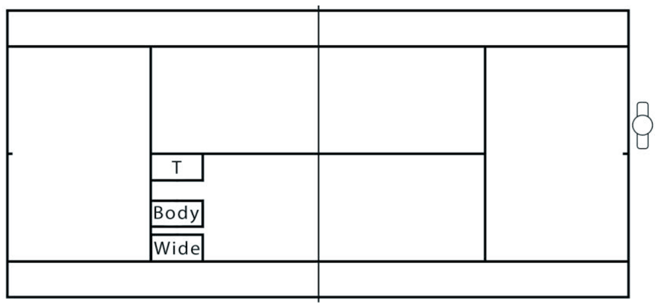

Figure 1: Target areas for the three serving locations.

RESULTS: Data are reported as grouped mean (±SD) data of the six participants. In the FS, the lateral baseline position of the players as well as the lateral displacement of the ball at zenith and at impact were significantly different (Table 1). The players stood closer to the centre mark when hitting T serves (0.94±0.10m) as compared to body (0.99±0.13m) and wide serves (1.03±0.16m). Lateral displacement of the toss followed the direction of the serve with the impact position being significantly further left in the wide than the T serve. The height and forward displacement of the ball toss were stable across the three FSs, as well as toss time and racket velocity. In contrast to the FS, no significant differences existed among the investigated characteristics of the SS. That is, the lateral front foot displacement, toss kinematics and racket velocity were achieved independent of SS location.

DISCUSSION: Prior to the current investigation, no research had attempted to describe the influence of serve direction on the ball toss. The work of Chow et al. (2003), ranks among the few published efforts to have reported comparable data for T serves. On FS, the four male professionals in Chow's study impacted the ball in similar lateral (0.16m right of the left toe) and vertical (2.74m) positions to those described in the current study (mean 0.12-0.19 to the right and a mean 2.75m high), but considerably further forward. The abovementioned lateral hitting positions are consistent with those reported in other case studies (Vorobiev et al.,

Table 1
Racket and ball kinematics in the FS and SS

	T	Body	Wide	
	Mean ± SD	Mean ± SD	Mean ± SD	*p*
First Serves				
Lateral front foot position (m)^	0.94 ± 0.10	0.99 ± 0.13	1.03 ± 1.62	0.02*
Lateral zenith (m)	0.02 ± 0.06	-0.01 ± 0.06	-0.04 ± 0.09	0.04*
Forward zenith (m)	0.47 ± 0.07	0.48 ± 0.12	0.45 ± 0.09	0.35
Zenith (m)	3.38 ± 0.23	3.37 ± 0.20	3.35 ± 0.17	0.56
Lateral ball disp. at impact (m) #	-0.12 ± 0.08	-0.15 ± 4.58	-0.19 ± 0.08	0.02*
Forward ball disp. at impact (m)	0.58 ± 0.13	0.62 ± 0.16	0.58 ± 0.14	0.29
Vertical ball disp. at impact (m)	2.75 ± 0.10	2.75 ± 9.72	2.75 ± 0.10	0.99
Toss time (sec)	1.01 ± 0.16	0.97 ± 0.10	0.96 ± 0.08	0.32
Racket velocity ($m.s^{-1}$)	49.8 ± 5.5	51.0 ± 3.0	49.8 ± 5.9	0.56
Second Serves				
Lateral front foot position (m)	0.95 ± 0.10	1.00 ± 0.10	1.01 ± 0.13	0.14
Lateral zenith (m)	-0.14 ± 0.10	-0.16 ± 0.09	-0.16 ± 0.10	0.50
Forward zenith (m)	0.38 ± 0.13	0.37 ± 0.13	0.36 ± 0.13	0.70
Zenith (m)	3.33 ± 0.20	3.39 ± 0.19	3.37 ± 0.20	0.23
Lateral ball disp. at impact (m)	-0.35 ± 0.11	-0.40 ± 0.07	-0.38 ± 0.10	0.18
Forward ball disp. at impact (m)	0.47 ± 0.18	0.42 ± 0.18	0.45 ± 0.18	0.66
Vertical ball disp. at impact (m)	2.73 ± 0.10	2.72 ± 0.10	2.74 ± 0.11	0.71
Toss time (sec)	0.95 ± 0.09	0.97 ± 0.09	0.93 ± 0.14	0.40
Racket velocity ($m.s^{-1}$)	47.3 ± 5.0	47.8 ± 5.1	47.5 ± 5.8	0.85

*significant main effects (p<0.05); ^ T:B (0.028), T:W (0.044); # T:W (0.028)

1993) and support the commonly used instructional tip that players should impact the FS in line with the 'heel' of their front foot. The continued lateral progression of the toss from its zenith also underlines the inappropriateness of the 'straight up' tossing instruction (Elliott and Kilderry, 1983). Most notably though, these lateral differences in the FS were deemed significant – suggesting that serve location may indeed affect toss kinematics. The stability of the vertical displacement of the toss across serve locations complements past research that has underlined its importance to the coordination of the serve (Reid et al., 2010b). On the second serve, the players contacted the ball some 0.20-0.25m further to the left, 0.15-0.20m closer to the baseline but at a similar impact height (~2.74m) to the FS. Forward and vertical hitting positions were consistent with previously collected SS data (Chow et al., 2003). Absolute racket velocities were comparable between FS and SS and were developed to similar magnitudes, independent of serve location. Further, toss times were alike within both serves (mean FS: 0.96-1.01s; mean SS: 0.93-0.97s) and saw the ball fall mean distances of 61.7cm and 63.6cm to impact in the FS and SS respectively. Post-match press conferences are replete with players relating their 'struggle' to get a read on an opponent's serve due to the lack of discernible cues from the toss (Palmer, 2010). From the perspective of the server, the ideal that players should use the same toss for every serve is common to many coaching texts (Yandell, 1999). Our findings suggest that professionally ranked male players hit SSs to different parts of the deuce court 'off the same toss', yet require significant but subtle variation in toss kinematics to do the same with their FSs. Players also appear to stand slightly further right when hitting FS to the T. The study therefore offers partial support to the contention of Courier. That is, certain characteristics of the action and ball toss were held stable across the three serve locations, most particularly on the SS. Subtle differences in foot or start position may provide players with an early insight into their opponent's tactical intent, even prior to their commencement of the toss. To this end, however, it seems more intuitive for returners to attend to the spatial characteristics of the toss. Although cues that are early-occurring and more central are available and used (Abernethy et al., 2001), many players suggest that subtle variations in ball toss are what is expected and sought for anticipatory purposes (Scott Draper, personal communication, January 11 2011). It would then appear that the observed difference in the lateral displacement of the tossed ball at zenith and at impact in the FS provides a case in point.

CONCLUSION: This study has offered partial support to the notion that players hit serves to different parts of the court using the 'same' ball toss. All serves were impacted to the left of the front foot, which has been suggested to facilitate the involvement of upper arm internal rotation – a key contributor to serve speed (Chow et al., 2003). While kinematics were similar across serves, namely in the SS, the lateral displacements of the front foot, ball zenith and ball impact were significantly different across the three FSs, potentially pointing to sources of cuing information to aid the performance of the FS return.

REFERENCES:

Abernethy, B., Gill, D., Parks, S., and Packer, S. (2001). Expertise and the perception of kinematic and situational probability information. *Perception*, *30*, 233-252.

Chow, J., Carlton, L., Lim, Y., Chae, W., Shim, J., Kuenster, A., et al. (2003). Comparing the pre- and post-impact ball and racquet kinematics of elite tennis players' first and second serves: a preliminary study. *Journal of Sports Sciences, 21*, 529-537.

Courier, J. (2005, September 12). Returning serve with Jim Courier. *BBC Sport: Tennis*. Retrieved from http://news.bbc.co.uk/sport2/hi/tennis/skills/4237736.stm

Crespo, M., and Miley, D. (1998). Advanced Coaches Manual. ITF Limited: London.

Elliott, B., and Kilderry, R. (1983). The art and science of tennis. Philadelphia, PA: Saunders College Publishing.

Knudson, D. and Bahamonde, R. (2001). Effect of endpoint conditions on position and velocity near impact in tennis. *Journal of Sports Sciences, 19*, 839-844.

Palmer, J. (2010). Federer through but still seeks the old magic. *Reuters*. Retreived from http://www.reuters.com/article/2010/06/23/us-tennis-wimbledon-wednesday-idUSTRE65M0FQ20100623

Reid, M., McMurtrie, D., and Crespo, M. (2010a). The relationship between match statistics and top 100 ranking in professional men's tennis. *International Journal of Performance Analysis in Sport*, *10*, 131-138.

Reid, M., Whiteside, D., and Elliott, B. (2010b). Effect of skill decomposition on racket and ball kinematics of the elite junior tennis serve. *Sports Biomechanics*, *9*, 296-303.

Shim, J., Carlton, J. G., Chow, J. W., and Shae, W. (2005). The use of anticipatory visual cues by highly skilled tennis players. *Journal of Motor Behaviour*, *37*, 164-175.

Vorobiev, A., Ariel, G. and Dent, D. (1993). Biomechanical similarities and differences of A. Agassi's first and second serves. In J. Hamill, T.R. Derrick and E.H. Elliott (Eds.), *Proceedings of the 11th Symposium of the International Society of Biomechanics in Sports*, pp. 323–327. Amherst, MA: University of Massachusetts.

Yandell, J. (1999) Visual tennis. Champaign, IL: Human Kinetics.