

## **Anticipating the placement of a tennis serve from stroke kinematics**

### **Introduction**

In high intensity sports such as tennis, anticipation is fundamental to successful performance (Reid *et al.*, 2010). Professional tennis players must anticipate and exploit key visual information from stroke kinematics in a quick and efficient manner, such to provide themselves sufficient time to plan and execute a successful return shot (Reid *et al.*, 2011). This ability to anticipate future events quickly is particularly important when returning serve, since humans are inherently limited in terms of reaction time and movement time to plan and initiate effective responses (Glencross & Cibich, 1977). Due to this, numerous researchers have attempted to determine the mechanisms underpinning anticipation skill, and have in general found more skilled players to employ more effective visual search behaviours (Goulet *et al.*, 1989; Singer *et al.*, 1998) and to possess greater knowledge of situational probabilities (Shim *et al.*, 2005; Ward & Williams, 2003). However, despite its clear importance as a source of visual cuing information, few studies have looked to quantify kinematic differences of the service motion when serving to different locations. Research by Reid *et al.* (2011) has suggested that when serving out wide (on the deuce side), right handed players impact the ball further to their right, as well as standing with their front foot further from the centre mark. Comparatively, research using computer modelling systems has shown players to have faster forearm pronation when servicing down the left side of the service box, but faster elbow extension when serving down the right side. Consequently, this study aims to determine whether there are any differences in stroke kinematics when serving to different locations, and whether the returner can use these as a source of visual cuing information.

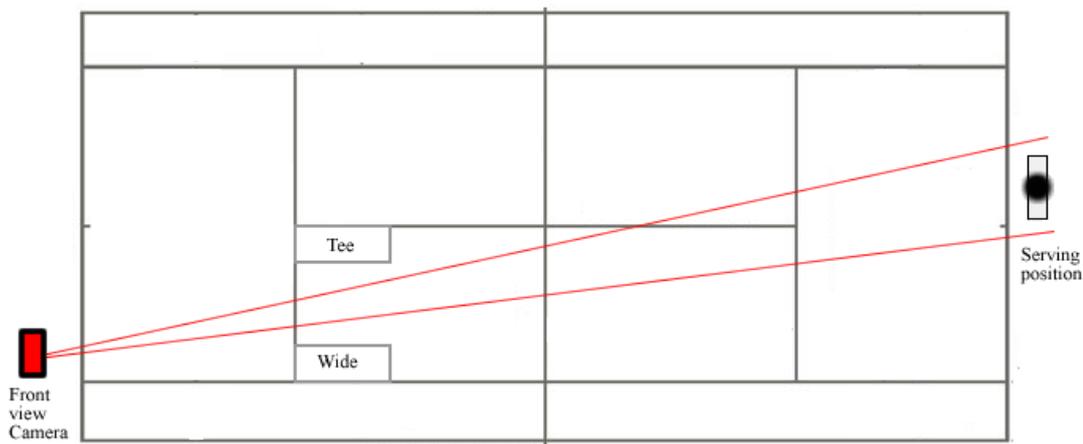
### **Methods**

#### ***Subjects.***

The analysis was performed on a single 21 year-old male. The participant was right handed, injury-free and played off a 3.2 British rating.

#### ***Testing procedures.***

All testing was undertaken on a full size outdoor Astroturf tennis court in still, warm and dry conditions. Prior to undertaking any data collection, the participant undertook a full whole body warm-up. The participant then performed maximum velocity first serves aimed towards target areas which were 2m long by 1m wide and reflected the landing areas of the prominent 'Wide' and 'T' serves on the deuce side of the court (Figure 1).



**Figure 1.** Target areas of the two serving locations

To maintain ecological validity all target areas bordered the service line and the participant used their own racket and new balls throughout the protocol. The participant served alternatively to the tee and wide positions, and was allowed a two minute rest between each block of 8 serves. Only serves that landed within the assigned locations were included, until a total of 8 successful serves were recorded for both service locations.

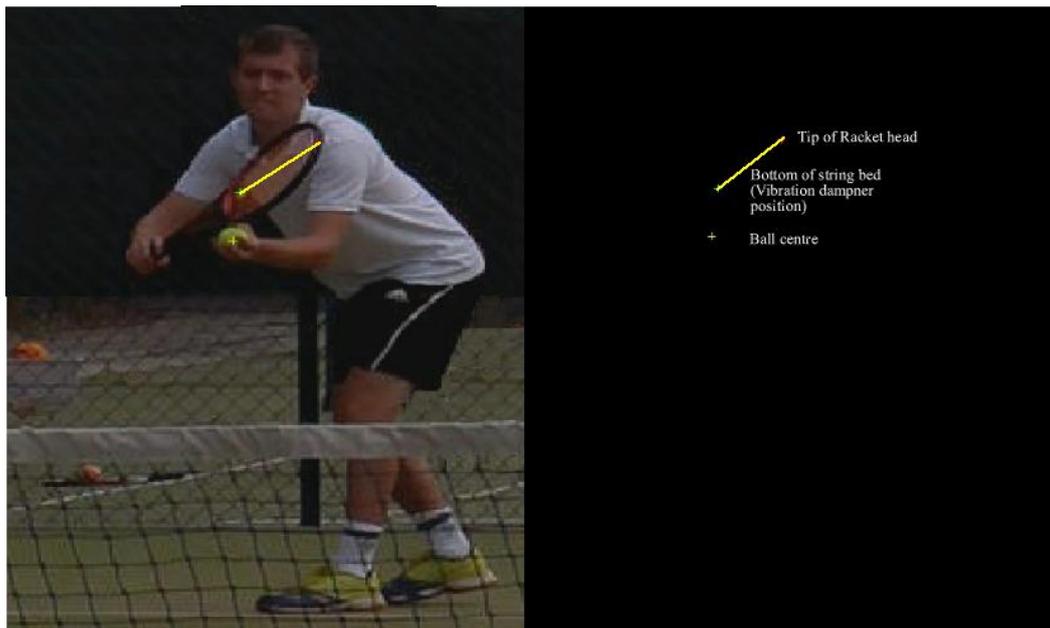
#### ***Data collection and analysis.***

The service recordings were filmed using a Casio EX-FH100 camcorder with a frame rate of 120 frames per second. The camera was set-up on a fixed tripod 1.5 metres off the ground and positioned one metre behind the baseline on the opposing side of the court directed face-on to the path of action, to simulate the view of the returning player. Upon collecting the data, the service recordings were analysed on Quintic Biomechanics V21 video analysis software (Quintic Consultancy Ltd, Coventry, UK). Two-dimensional scaling prior to digitisation was carried out using two-dimensional calibration. Initial three point manual digitisation was undertaken on all 16 trials from the point of ball toss release, in order to determine vertical and horizontal ball displacement at racket contact, and time until racket contact (Figure 2). Furthermore, ball toss release height and lateral front foot position from the centre point were also measured from the final video frame prior to ball toss release. Proceeding this, 20-point manual digitisation was undertaken to determine qualitatively and quantitatively any discrepancies in stroke kinematics (Figure 3).

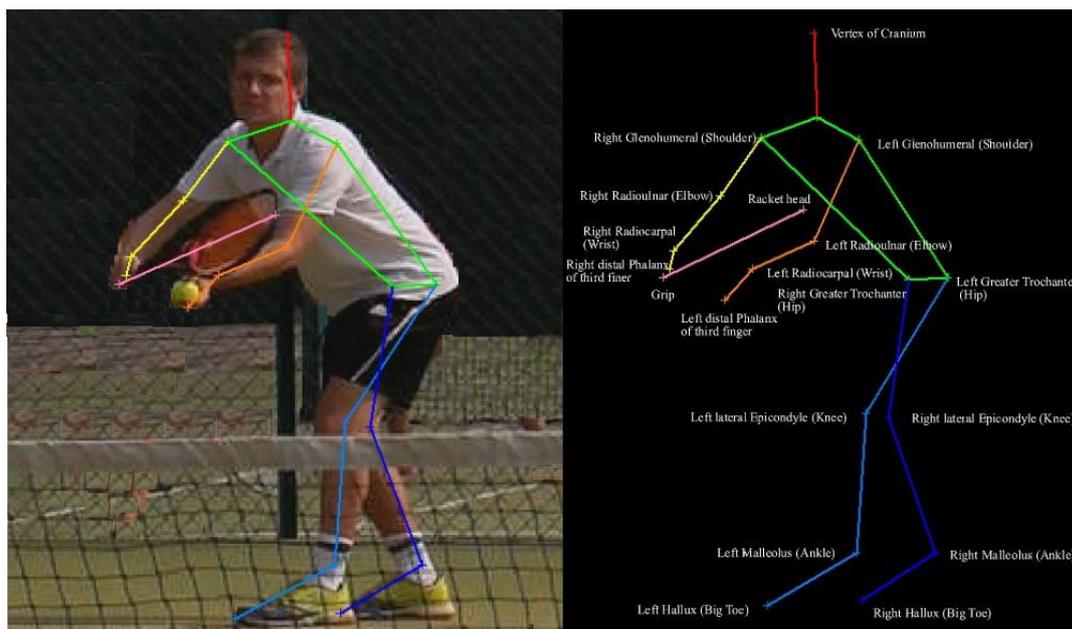
#### ***Data handling.***

Calculated variables from the 3-point digitisation included vertical and horizontal ball displacement from ball toss release to racket contact, ball toss release height, peak ball toss height, toss time and lateral front foot positioning from the centre service line. Subsequent to

qualitative analysis, calculated variables for the 20-point digitisation included vertical displacement of the right knee from ball toss release until maximum knee flexion, the absolute angle of the right knee at maximum flexion, and the time taken from ball toss release until maximum right knee flexion. For all variables, Butterworth filters were employed (a feature of Quintic biomechanics V21) to determine the optimum filtering values for each point on both axis, and to remove error associated with the manual digitisation process. Six unpaired Wilcoxon non-parametric tests were used to determine whether any differences in ball toss kinematics existed when serving to the two target areas.



**Figure 2.** 3-point digitisation markers



**Figure 3.** 20-point digitisation markers

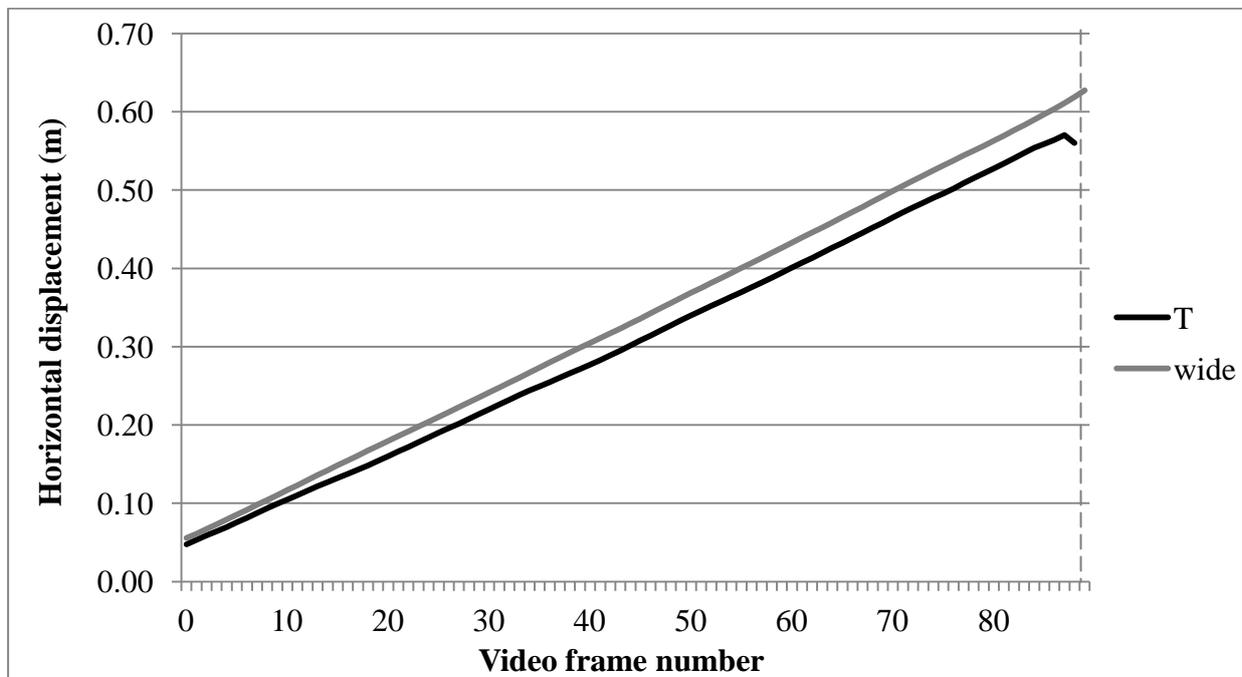
## Results

### *Ball toss kinematics.*

Data are reported as grouped mean ( $\pm$ SD) data of the eight trials for both service locations. The vertical and horizontal displacement of the ball toss at racket contact was not significantly different for the T and wide serves (Table 1), despite horizontal displacement (to the left) being greater when serving wide (Figure 4). Similarly, mean ball toss release height, peak ball height, toss time and lateral front position were all greater for the wide serve, although again none of these differences were significant (Table 1).

**Table 1.** Racket and ball kinematics of the T and wide serves

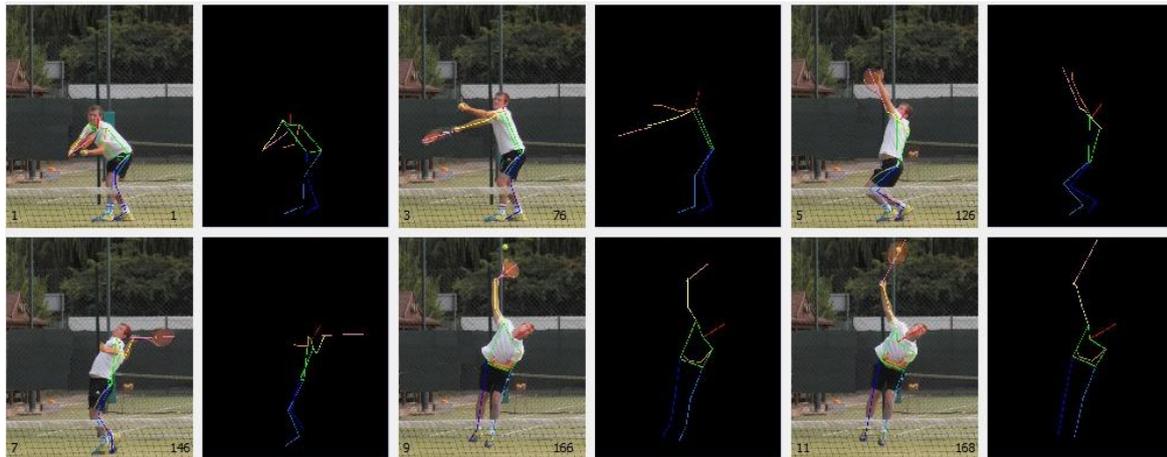
	T	Wide	<i>p</i>
	Mean $\pm$ SD	Mean $\pm$ SD	
Vertical displacement at contact (m)	2.83 $\pm$ 0.23	2.87 $\pm$ 0.16	0.67
Horizontal displacement at contact (m)	0.56 $\pm$ 0.07	0.63 $\pm$ 0.06	0.09
Ball toss release height (m)	1.65 $\pm$ 0.01	1.68 $\pm$ 0.02	0.14
Peak ball height (m)	3.19 $\pm$ 0.18	3.23 $\pm$ 0.15	0.58
Toss time (s)	0.82 $\pm$ 0.03	0.83 $\pm$ 0.03	0.29
Lateral front foot position (m)	0.80 $\pm$ 0.03	0.81 $\pm$ 0.03	0.17



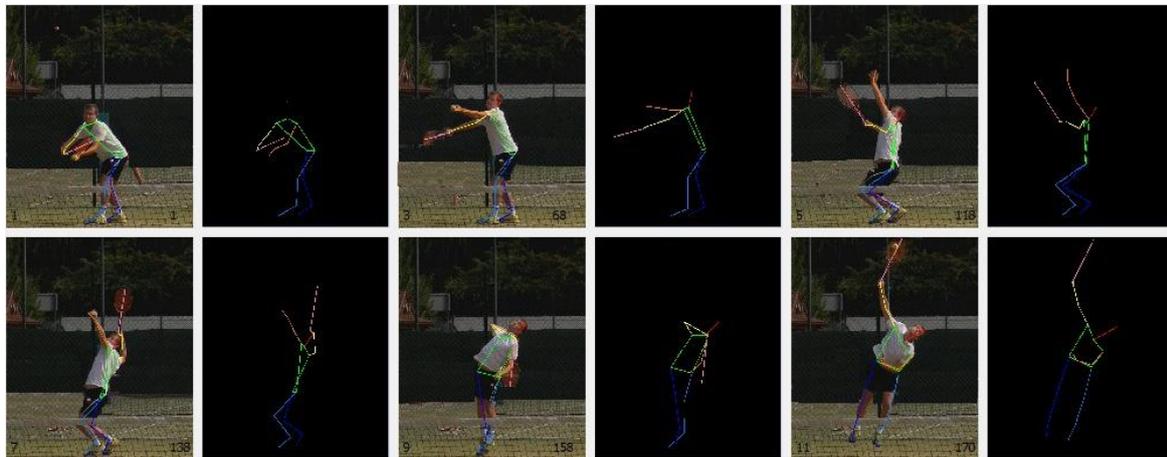
**Figure 4.** Mean horizontal ball displacement for the T and wide serves until racket contact

**Swing kinematics.**

Initial qualitative observations taken in real time showed no obvious kinematic differences when serving to the T and wide locations. When slowed down however, it did become apparent that a deeper right knee bend and consequently a longer loading phase occurred when serving out wide (Figures 5&6). When analysed quantitatively these observations were supported, with peak vertical knee displacement (0.06m), peak absolute knee angle (0.08 rads) and loading time (0.1s) all being greater when serving out wide (Table 2).



**Figure 5.** Still image photo capture sequence of the T serve



**Figure 6.** Still image photo capture sequence of the wide serve

**Table 2.** Right knee kinematics of the T and wide serves

	T	Wide
Peak vertical displacement of knee (m)	-0.08	-0.14
Peak absolute angle of knee to vertical (rads)	0.66	0.74
Loading time (s)	0.32	0.42

## **Discussion**

### ***Ball toss kinematics.***

The influence of serving to the ‘wide’ and ‘T’ locations was not found to significantly alter ball toss kinematics, despite some difference in lateral ball displacement at contact. This would suggest that for the returning player anticipation of the direction of the serve is almost impossible prior to ball contact. While the prominence of attending to service kinematics, in particular the ball toss is frequent in coaching of the service return, the extent to which it has been researched within the literature is perhaps surprisingly limited. Indeed, only Reid *et al.* (2011) who examined the set up, toss and racket kinematics of 6 professional male players using 3D motion analysis have previously looked to systematically quantify the affect of the service direction on the ball toss. Vertical displacement at impact, peak height, and toss time were indifferent whether serving out wide or down the T. However, lateral front foot position, as well as lateral displacement of the ball toss at its peak and at impact were found to be significantly different. Specifically, players stood closer to the centre mark when serving down the T and threw the ball up further to the left when serving out wide. While it has been shown that differences in lateral front foot position may not be a common cue, the shift in the toss left, from the T to wide serve is at least partially supported. This is particularly interesting since it provides evidence in contrast to what players and coaches might reasonably expect (Reid *et al.*, 2010). That is, the positioning of a ball toss further to the right (for a right hander) is a time-honoured coaching cue for the development of the slice FS (Rineberg, 2004) – that which is typically associated with a wide serve to the deuce court. Therefore, as presented in coaching manuals (Yandell, 1999) and outlined by professionals it would appear that the skill of the player in maintaining lateral positioning of the ball toss when serving to different locations is key to preventing the returner any anticipatory information (Masters *et al.*, 2007).

### ***Swing kinematics.***

Differences in stroke kinematics when serving to the wide and T locations were shown to be minimal. More specifically, when observed using qualitative analysis in real time, no clear kinematic differences could be shown, which suggests visual anticipatory information is limited. However, when observed in slow motion and quantitatively frame by frame, analysis did indicate some change in right knee flexion, although due to the lack of available data it is hard to reliably draw any meaningful conclusions from this. Instead, the findings oppose a growing body of literature (Abernethy, 1990; Ward *et al.*, 2002) which suggests that more

skilled players are better able to perceive anticipatory cues from both proximal and distal segments of their opponents swing kinematics. Therefore, in association with the work of Reid *et al.*, (2011) it would appear that variance in swing kinematics when serving to different locations are minimal, inconsistent and virtually impossible to confidently anticipate.

### **Future research**

While the participant analysed in the present study showed little variation in service kinematics when serving to different locations, future research may look to distinguish the proportion of players (of a variety of playing levels) able to do this and the effect of this expertise. Likewise, it may also be beneficial to compare differences in serve kinematics when serving to different locations using topspin and slice. Finally, future work may also look to account for potential order effects by randomising the serve sequence, while it may too be beneficial to simultaneously examine the capacity of returners to attend to specific kinematic cues.

### **Conclusion**

The results of this investigation suggest that players are able to maintain serve kinematics when serving in different directions, therefore limiting the visual information available to returning players to anticipate the location of the serve.



## References

- Abernethy, B. (1990). Anticipation in squash: Differences in advance cue utilization between expert and novice players. *Journal of Sports Sciences*, 8, 17-34.
- Glencross, D.J., & Cibich, B.J. (1977). A decision analysis of game skills. *Australian Journal of Sports Medicine*, 9, 72-75.
- Goulet, C., Bard, C., & Fleury, M. (1989). Expertise differences in preparing to return a tennis serve: A visual information processing approach. *Journal of Sport and Exercise Psychology*, 11, 382–398.
- Ida, H., Fukuhara, K., Kusubori, S., & Ishii, M. (2011). A study of kinematic cues and anticipatory performance in tennis using computational manipulation and computer graphics. *Behavior research methods*, 43, 781-90.
- Masters, R. S. W., van der Kamp, J., & Jackson, R. C. (2007). Imperceptibly off-centre goalkeepers influence penalty-kick direction in soccer. *Psychological Science*, 18, 222–223.
- Reid, M., McMurtrie, D., & Crespo, M. (2010). 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., Whitside, D., & Elliott, B. (2011). Serving to different locations: set-up, toss, and racket kinematics of the professional tennis serve. *Sports Biomechanics*, 10, 407-414.
- Rineberg, D. (2004). *Recipes for a tennis player’s soul*. Hollywood, FL: Frederick Fell.
- Shim, J., Carlton, L.G., Chow, J.W., & Chae, W. (2005). The use of anticipatory visual cues by highly skilled tennis players. *Journal of Motor Behaviour*, 37, 164-175.
- Singer, R. N., Williams, A. M., Janelle, C., Frehlich, S. G., Barber, D., & L. Boutchard (1998). Visual search during ‘live’ on-court situations in tennis. *Research Quarterly for Exercise and Sport*, 69,109–116.
- Ward, P., & Williams, A. M. (2003). Perceptual and cognitive skill development in soccer: The multidimensional nature of expert performance. *Journal of Sport and Exercise Psychology*, 25, 93–111.
- Ward, P., Williams, A.M., & Bennett, S.J. (2002). Visual search and biological motion perception in tennis. *Research Quarterly for Exercise and Sport*, 73, 107-112.
- Yandell, J. (1999). *Visual tennis*. Champaign, IL: Human Kinetics.