TASK DECOMPOSITION AND THE HIGH PERFORMANCE JUNIOR TENNIS SERVE

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To develop consistency in the toss placement and racket trajectory, coaches often decompose the serve and practise it in separate parts. This study compared the kinematics of the ball toss as part of the discrete serve skill and when the skill was decomposed. A 22 camera VICON MX motion analysis system, operating at 250 Hz, captured racket and ball kinematics of 5 elite junior players hitting flat first serves (FS) directed to the 'T' of the deuce service box and a ball toss (BT) drill where players were instructed to perform the decomposed skill as in the FS. Paired t-tests were used to assess within-group differences. Vertical displacement of ball zenith increased significantly (~20cm) during BT. Consistency in select racket and ball kinematics characterised the FS, while this appeared to decrease in BT.

KEYWORDS: skill development, whole-part practice

INTRODUCTION: The first serve, the most important stroke in tennis is also the stroke that has attracted the most investigative interest from biomechanists. The kinematics of lower and upper limb joint motion as well as the movement of the racket have been examined (Fleisig et al., 2003; Chow et al., 2003), while other researchers have preferred to explore the relationships between select joint kinetics and joint injury or the skill's performance (Elliott et al., 2003; Reid et al., 2007). Given that successful serve performance is ultimately governed by impact between racket and ball, it's surprising that so little research has attempted to comprehensively evaluate this link.
Traditionally, tennis coaches have emphasised the need for mechanical consistency in stroke production and therefore the performance of the serve. This approach, however, contrasts with more contemporary principles of skill acquisition, where variable movement patterns are considered functional facets of performance (Davids et al., 2001). In an effort to simplify the learning of the serve or reduce its dimensionality, coaches often decompose the service action or, in coach parlance, break it down into its component parts. Similar findings have highlighted the link between perception and action in cricket batting, where the temporal and kinematic features of a forward defensive drive change when a batsman faces a ball machine instead of a bowler. Indeed, the ability to nurture information-movement coupling has been proposed to rely heavily on the specificity of training (Savelsbergh and van der Kamp, 2000) and therefore questions the efficacy of skill decomposition in skill development.
The aims of this study are therefore (a) to investigate the hand, ball and racket kinematics of the flat serve (FS) of elite junior players and (b) to examine the effect of a ball toss drill, where the toss is rehearsed independent of the swing (BT), on those kinematics.

METHOD*:* Five nationally-ranked male right-handed junior players aged 13.40 ± 0.54 yrs and 164.86 ± 8.46 cm tall participated in the study with their own racket. Following a standardised warm-up, participants were instructed to perform two tasks, the first being to hit 10 successful, maximal effort FSs at a 1 x 1 m target area bordering the T of the service box on the deuce court. Ten trials were selected to attain a statistical power of 90% with only 5 participants (Bates et al., 1992). The second task focused on the performance of the BT component of the FS skill. Players were instructed to toss the ball as they would in a FS but without racket-ball contact; thus rehearsing or simulating the ball toss of a FS. All participants indicated that they were familiar with the isolated performance of the BT, having routinely engaged in this type of drill during practice. Each participant completed the tasks

(FS and BT) in a randomised manner, with a two minute rest period permitted after each block of 10 serves.

A 22-camera, 250 Hz VICON MX motion analysis system (Oxford Metrics Inc., UK) was used to track the 3D marker trajectories.The marker set consisted of; 3 retro-reflective markers on the left hand, one marker on the head of the first metatarsal (LMT1) of the left foot, 5 markers on the racquet and 3 markers on the ball. All displacements were made relative to each player's foot position by re-positioning the origin of the global coordinate system to the position of the LMT1 marker (Figure 1). LMT1 position was determined during each participant's address and prior the players initiating the backswing of their serve. Within the global co-ordinate system, positive X was to the right; positive Y was forward and positive Z upward.

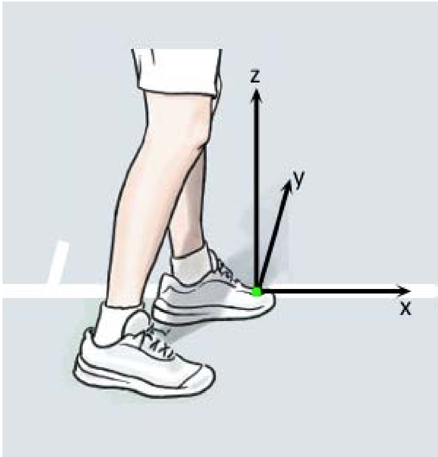

Figure 1. Position of global coordinate system.

Impact was determined as one frame (0.004 s) prior to racket-ball contact. In the BT condition, this was accomplished by determining the mean vertical displacement of the ball at impact during the FS. In each BT trial, the frame in which the ball best approximated the mean vertical displacement recorded in each subject's FS was considered to represent impact. Gaps in the marker trajectories were filled using the cubic spline interpolation function within VICON Nexus. To account for impact accelerations, a second order polynomial extrapolation was performed in line with previous recommendations (Knudson and Bahamonde, 2001). All data subsequent to one frame pre-impact were deleted before the extrapolation was performed using customised Matlab software (The Mathworks, Natick, Massachusetts, USA). A Woltring filter with an optimal mean squared error (defined as 25 mm) was applied to the raw data. Raw anatomical, racket and ball data were modelled using the University of Western Australia's customized full body, racket and ball models, respectively. A Z-X-Y order of rotation was used to express the rotational axis of the ball and calculate rotation rate. Thirteen paired t-tests were used to investigate if kinematic differences existed between FS and BT conditions. Due to the multiple comparisons being conducted, statistical significance was adjusted a priori to $p<0.01$.

RESULTS: All reported data are for the mean (± SD) for the five subjects over the 10 trials. In the FS condition, ball position at height of the toss (BZ) trended further forward and to the left, while its vertical displacement was significantly higher ($t=-5.794$, $p=0.004$) in the BT condition (BT: 311.2 ± 24.4 cm; FS: 288.2 ± 19.2 cm). The position of the ball at impact did not change significantly in any plane. Ball rotation also increased significantly in the BT condition (FS: 837 ± 343 vs BT: 927 ± 333 deg.s^{-1}; $t=-4.893$, $p=0.008$).

Table 1. Comparison of hand, racket and ball kinematics in the FS vs BT conditions.

	Flat Serve (FS)		Ball Toss (BT)		
	Mean	S.D.	Mean	S.D.	P
x ball pos @ zenith (cm)	-17.8	9.1	-8.0	13.1	.111
y ball pos @ zenith (cm)	39.6	11.1	35.3	13.1	.444
z ball pos @ zenith (cm)	288.2	19.2	311.2	24.4	.004*
x ball pos @ imp (cm)	-34.0	9.5	-22.8	12.6	.189
y ball pos @ imp (cm)	51.8	8.5	40.8	16.0	.246
z ball pos @ imp (cm)	250.9	9.3	250.8	9.31	.458
Ball rot during toss (deg.s^{-1})	837	343	927	333	.008*
Toss time (s)	0.802	0.079	0.886	0.122	.246
Release to zenith (s)	0.526	0.042	0.568	0.043	.015

Zenith as % of toss	66.0	1.71	61.8	1.43	0.001*

Toss time increased ~10% from 0.802s in the FS to 0.886s in the BT. BZ when expressed as a percentage of toss time occurred significantly earlier when the skill was decomposed (FS: 66.0 ± 1.71 v BT: 61.8 ± 1.43%, t=8.918, p=0.001). Only the vertical displacement (and resulting flight time characteristics) of the tossed ball changed significantly between the two conditions. Table 2 presents the variability of the 3D ball position at BZ in the FS compared with BT conditions. This was achieved by calculating the mean and standard deviations of the standard deviations describing the x, y and z displacement at BZ (Davids et al., 2001). The position of the ball at BZ trended toward being most variable in the lateral direction during the FS. When the ball toss was practised in isolation, the consistency of the lateral (FS: 5.49 ± 1.19 cm vs BT: 7.76 ± 2.40 cm; t=-2.969, p=0.041) and vertical (FS: 5.06 ± 1.82 cm vs BT: 9.00 ± 3.43 cm; t=-2.924, p=0.043) positions of ball zenith appeared to deteriorate.

Table 2. Comparison of the mean and standard deviations of 3D ball position at BZ in the FS and BT.

	Flat Serve (FS)		Ball Toss (BT)		
	Mean	SD	Mean	SD	p
x ball pos @ BZ (cm)	5.5	1.19	7.8	2.40	0.041
y ball pos @ BZ (cm)	10.1	7.70	8.2	2.47	0.648
z ball pos @ BZ (cm)	5.1	1.82	9.0	3.43	0.043

DISCUSSION: While the position of the ball at BZ was further forward and to the left, only its vertical position changed significantly when the toss was rehearsed independently. The ball was tossed ~24 cm higher when the skill was decomposed; logically accounting for the increased toss time observed in this condition (FS: 0.802 s; BT: 0.886 s). These results would appear contrary to coach suggestions that isolating a component of the skill makes it easier for the player to replicate that component. The changes in both the spatial and therefore temporal aspects of the toss suggest that the players tossed the ball in a manner notably different to that seen during their FS. These results are consistent with previous work that has illustrated the deleterious effect of decoupling the toss from the swing in the volleyball serve (Davids et al., 2001). While it could be argued that the effect of this type of task decomposition would be less pronounced among elite adult performers, the investigated sample have practised their serves extensively and were familiar with the task performed. As compared to professional players directing first serves to a similar court location, these players made racket-ball impact further to the left but not as far forward (Chow et al., 2003).

The ball's average peak rotation during the toss increased significantly during BT (FS: 837 deg.s^{-1}; BT: 927 deg.s^{-1}). This is instructive as it points to players applying more force to the ball, not just in the vertical direction to bring about the increase in BZ, but also eccentrically. In practice, the authors have observed coaches encourage players to rehearse the BT to reduce spin rates – the very characteristic that it would appear to be amplifying in this group of players. One of the primary motives behind decomposing a highly organised skill is to condense the informational load to augment learning (Naylor et al., 1963). For this reason, it was with interest that there was a trend for ball placement to become more variable in the forward and vertical directions during the BT drill. Inadvertent introduction of larger amounts of variability in the vertical position of BZ may impair rather than assist a movement pattern, which has been refined around a lower and relatively (or at least *more*) stable BZ.

The small sample size is considered a limitation of this study and future research is encouraged to further explore the effects of task decomposition or whole-part practice on tennis stroke biomechanics.

CONCLUSION: Consistency in select ball toss kinematics characterise the performance of the FS from a young age. This consistency decreases when the serve is decomposed, as is routinely done by coaches, while key characteristics of the serve, like BZ, change significantly when the ball toss is practised in isolation. These differences point to the role of information-movement coupling in the serve and question the efficacy of practices that involve the decoupling of ball and swing.

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