THE EFFECT OF A COMMON COACHING CUE ON BODY KINEMATICS IN THE TENNIS SERVE

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The objective of this study was to quantify the kinematic changes promoted by instructing players to implement a common coaching constraint, an arabesque finish position, in the tennis serve. A 10 camera 500 Hz 3D VICON MX motion analysis system recorded the service action of 8 elite junior players as they performed 3 normal serves and 3 serves with an arabesque finish. The arabesque finish promoted greater frontal plane trunk range of motion and angular velocity (shoulder over shoulder rotation) as well as increased leg drive; variables established as important in the development of serve speed. Instructing players to finish in an arabesque position can therefore be considered an effective way to elicit the desired kinematic change, and is consequently an effective instructional cue.

KEY WORDS: coaching, kinematics, arabesque.

INTRODUCTION: The serve, one of the most critical strokes in the game of tennis, has received much attention, particularly regarding its biomechanics (Elliott, Marshall, & Noffal, 1995; Reid, Elliott, & Alderson, 2008). Given the importance of the serve to success, it is not surprising that coaches and players dedicate a large portion of their practice time to developing and refining service technique. While the parameters or biomechanics that constitute a high performance serve have been well studied (Elliott, Marsh, & Blanksby, 1986; Elliott, Reid, & Crespo, 2003), there is a lack of research examining common coaching instructions or interventions used to elicit changes in these biomechanics. Analogies or indirect instructions are often used by coaches to promote changes in biomechanics without the use of explicit instructions, yet the validity of such instructions has rarely been explored. Recently, research has examined the effect of focus of attention on skill execution, with results suggesting an external focus leads to improved skill execution (Wulf, Höß, & Prinz, 1998; Wulf & Su, 2007). Specifically, as this instructional technique relates to the tennis serve, coaches often instruct players to focus on finishing in an arabesque landing position. This type of finish is thought to implicitly promote changes in the preceding kinematics, most particularly by encouraging more pronounced trunk rotation and leg drive. However, the efficacy of this arabesque instruction has not been experimentally examined, leaving coaches and players to presume that it yields the desired effect. The aim of this study was therefore to establish if finishing in an arabesque position elicited changes in the hypothesised preceding body kinematics, specifically whether the instruction resulted in increased trunk rotation and leg drive during the serve.

METHODS: Eight internationally ranked junior male tennis players (age 17.3 ± 1.2 years, height 177.8 ± 9.7 cm, weight 69.7 ± 15.6 kg) performed maximal effort serves implementing a common coaching cue. Players were required to perform their regular warm up prior to commencing the serve protocol. Players were instructed to perform a series of maximal effort first serves, directed at a 1 m long x 1.2 m wide target area bordering the T of the deuce service box, until a total of 3 successful serves were completed. A serve was considered successful if it landed within the target area.
Following this, players were asked to perform three maximal effort serves implementing the arabesque instruction. Specifically, players were instructed to finish their serve by

exaggerating the arabesque landing position (that is, with greater front/landing leg hip flexion and greater back leg hip extension). Three successful regular serves and the three arabesque serves were selected for analysis in each condition.

Eighty retro-reflective 14mm markers according to The University of Western Australia's (UWA) full-body marker set (Lloyd, Alderson, & Elliott, 2000; Reid, Whiteside, Gilbin, & Elliott, 2013) were used to calculate joint kinematics. In addition three markers were affixed to the racket and three ultra-light hemispherical markers were attached to the ball. A 10 camera, 500 Hz VICON MX optical motion analysis system (Oxford Metrics Inc, UK) captured all marker trajectories. Gaps in marker trajectories were filled using the cubic spline interpolation function within VICON Nexus. The body trajectories from one frame prior to impact were deleted and a customised polynomial extrapolation was applied to predict marker trajectories 10 frames post impact (Knudson & Bahamonde, 2001; Reid, Campbell, & Elliott, 2012). A Woltring filter with an optimal mean squared error of 3mm as determined by a residual analysis was applied to the raw data, which were then modelled using UWA's customized model to calculate body and racket/ball kinematics (Lloyd et al., 2000; Whiteside, Chin, & Middleton, 2013).

The serve was considered to begin when the vertical acceleration of the ball crossed zero, indicating the ball had been released from the tossing hand. Temporal phases of the serve were defined by time points of interest including: the peak vertical displacement of the racket ('trophy position'), ball zenith during ball toss (BZ), racket low point immediately prior to forward swing (RLP) and impact. The preparation phase of the serve was defined as the time between ball release and the trophy position, while the forward swing was defined as the time between RLP and impact.

Thirteen kinematic variables were analysed with respect to the proposed kinematic changes elicited by the arabesque finishing position; chiefly increased hip flexion and forward trunk flexion in the landing position, as well as, greater leg drive (as expressed by increased knee extension and increased vertical hip velocity) and increased trunk rotations in the forward swing. The angular displacements of trunk rotation (separation angle) and knee flexion were also considered in the preparation phase.

Kinematic differences between conditions were analysed using paired *t-tests*. Significance was adjusted *a priori* and set at $p < 0.01$ to account for the multiple applications of this test. Effect sizes are reported as Cohen's *d*, where 0.2 is defined as a small effect, 0.5 as a medium effect and 0.8 as a large effect (Cohen, 1988).

RESULTS: The mean (± standard deviation) group data for all participants is presented in Table 1. Mean serve accuracy in the arabesque condition was 54 % with just over half of serves landing within the service box, 29 % of these landing within the target area.

The arabesque finishing position was characterised by significantly greater left hip flexion and forward trunk flexion. Attention on this cue also affected the preceding angular displacement of the trunk, whereby greater frontal plane trunk range of motion was observed in the forward swing which ultimately resulted in significantly greater trunk tilt at impact. In addition, frontal plane trunk angular velocity (lateral trunk flexion) was also significantly greater in the arabesque serves. Interestingly, the arabesque finish position did not promote greater separation between the trunk and pelvis with separation angle significantly lower in the arabesque serves.

The arabesque position promoted further changes in the preceding lower body kinematics with maximum knee joint extension velocity (rear leg) and the peak vertical velocities of both the left and right hip significantly increased. Effects sizes for all significant changes in the preceding kinematics exceeded Cohen's (1988) convention for a large effect size, highlighting the magnitude of change elicited by the arabesque cue.

Table 1.
Mean, standard deviation, significance and effect size for selected kinematic variables.

	Normal Serve	Arabesque Serve	*P*	Effect size	% differe
Preparation					
Maximum separation angle (deg)	-34.34 ± 7.62	-28.26 ± 10.94	<0.001*	0.66	-17.71
Maximum right knee flexion angle (deg)	100.94 ± 20.98	96.2 ± 4.81	0.264	0.23	-4.70
Maximum left knee flexion angle (deg)	79.53 ± 8.22	81.09 ± 8.05	0.037	0.42	1.96
Forward Swing					
Maximum right knee extension velocity (deg/s)	-633.49 ± 71.09	-688.43 ± 69.72	<0.001*	0.66	8.67
Maximum left knee extension velocity (deg/s)	-556.87 ± 70.82	-535.82 ± 76.57	0.145	0.3	-3.78
Maximum right hip vertical velocity (m/s)	2.25 ± 0.11	2.36 ± 0.16	<0.001*	0.66	4.89
Maximum left hip vertical velocity (m/s)	1.77 ± 0.13	1.87 ± 0.17	<0.001*	0.74	5.65
Maximum frontal plane trunk angular velocity (deg/s)	-255.92 ± 58.52	-272.4 ± 58.94	0.001*	0.6	6.44
Frontal Plane Trunk rotation ROM (deg)	41.65 ± 7.32	44.86 ± 7.38	0.001*	0.62	7.71
Impact					
Trunk tilt (lateral flexion) (deg)	-25.1 ± 7.41	-28.77 ± 6.64	0.001*	0.62	14.62
Finish Position					
Maximum left hip flexion angle (deg)	68.54 ± 7.99	100.67 ± 10.01	<0.001*	0.94	46.90
Right hip flexion angle (deg)	13.28 ±8.79	8.52 ± 5.02	0.014	0.48	-35.84
Trunk flexion (deg)	-47.62 ± 11.48	-65.15 ± 11.87	<0.001*	0.89	36.81

DISCUSSION: While limited research exists examining the efficacy of common coaching interventions in tennis, some contemporary evidence suggests certain interventions may not achieve their intended outcomes. For example, isolating the swing and ball toss components of the serve, a common strategy employed by coaches to help establish toss consistency, variously resulted in the contrary effect (Reid, Whiteside, & Elliott, 2010). Given these results, it is important that common coaching interventions or instructions are empirically substantiated as part of their implementation with players. Without this evidence base, interventions may inadvertently lead to undesirable kinematic changes.

The current study therefore aimed to critique the efficacy of a common coaching constraint: the arabesque finish position, on its intended target mechanics in the tennis serve. Players successfully altered their finish positions in response to the arabesque instruction, landing with significantly more hip and trunk flexion compared to their normal serves. This alone demonstrates the powerful effect of instructions with an end point focus in changing the kinematics of an action. While a large body of research exists examining the effects of focus of attention on performance outcomes (E.g. Wulf & Su, 2007) few have examined the effects on movements kinematics or biomechanics.

Providing players with an endpoint instruction successfully induced the desired changes in the preceding kinematics that allowed players to finish in the arabesque position. Finishing in this position is thought to promote both increased trunk rotation angular displacement and velocity and increased leg drive through increased knee extension velocity. As observed in this study, the arabesque position promoted increased rear knee extension velocity and increases in hip vertical velocity without any underpinning directive to do so. Additionally, the end point (arabesque position) also promoted increases in frontal plane rotation trunk angular displacement and angular velocity. These changes in the preceding kinematics are particularly important given previous research has shown that both leg drive (Reid et al., 2008) and trunk rotation (Bahamonde, 2000) are important contributors to serve velocity.

Practically, the results of the current study suggest that providing instructions based on end point positions has the potential to evoke significant changes in the kinematics of a sports action. In this case, players realised changes in both trunk rotation and leg drive kinematics, without prior explicit instruction to that effect. It must be noted that the current study explored to the acute effects of a common coaching instruction, thus results may not be permanent and further research is needed to examine longer term skill transfer effects of this intervention. In addition, the current results lack generalizability given the relatively small sample and future work should consider examining the kinematic effects of other instructions or interventions regularly used in coaching.

CONCLUSION: Ultimately it would appear coaches looking to increase a player's frontal plane trunk angular velocity, or leg drive would succeed in doing so by instructing the player to finish in the arabesque finishing position. This would elicit the desired changes without the need for a large amount of technical instruction. From the perspective of the player, results demonstrate that a simple end point instruction conveys the necessary information required for players to make substantive changes in their service action.

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