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THE PLAYER DEVELOPMENT PATHWAY: A BIOMECHANICAL PERSPECTIVE

Bruce Elliott

School of Sport Science, Exercise and Health
The University of Western Australia

The purpose of this paper is to challenge biomechanists to think more about how they may assist coaches to enhance the player development pathway (11 – 15 – 18 year old). It is imperative we play an integral role in creating the appropriate 'learning environment', by providing a sound theoretical framework with respect to; task decomposition (practice using the appropriate lead-up drills), together with skill and practice variability. Biomechanists must also understand how variables change over the development pathway if they are to assist coaches structure the optimal learning environment. This paper will discuss the above with specific references to a number of sporting activities.

KEY WORDS: Lead-up drills, Task decomposition, Variability

INTRODUCTION: Biomechanists together with motor control specialists have a major role to perform in the player development pathway. It is a responsibility that has been neglected by many scientists, as there is a paucity of research knowledge on 'task decomposition', the appropriate use of variability in the 'learning' of a new skill and how variables integral to success change throughout the developmental pathway. The purpose of this paper is to motivate scientists to address, as far as possible, an integrated approach to these areas.
The motor learning literature tells us that variability is critical to the effective learning of a new skill. A young athlete must learn to differentiate the feel of the 'new skill' from a previously learned response if skill is to be developed. The nervous system of a young athlete is continually reconstructing this 'feel pathway' during the learning process (Barreiros et al., 2007; Bartlett et al., 2007; Handford et al., 1997). Theoretically this requires 'variability' to be a key component in the learning process. The concept of variability during skill learning is poorly understood by coaches, who typically believe that practice is all about reducing variability in performance. They have little appreciation for the fact that internal variability (e.g. joint angles, velocities and accelerations) is not only evident, but functionally critical to the success of the skill through mechanical compensation (Bootsma and van Weiringen, 1990). This is true even during skilled performances (e.g. tennis forehand – Knudson, 1990).
Coaches employ task decomposition, as a means of reducing variability in the skill being learned (Naylor & Briggs, 1963). The question that we, as biomechanists, must address is whether this task decomposition promotes the performance improvements that coaches' claim. To do this we must first differentiate decomposed skills, performed by elite and novice players, from the complete performance (Figure 1).

Open skills:	⇨	Cricket batting Volleyball set and spike
Closed skills:	⇨	Gymnastics skills (outcome-based) Tennis and volleyball serve Golf drive

Figure 1: Classification of skills discussed in task decomposition

The following paper will briefly review the biomechanical implications of task decomposition in these sports to better understand its role in skill development. Furthermore the concept of skill development, as a staged process, will be reviewed with specific consideration to the tennis serve.

METHODS: Typically biomechanical studies have used 3D motion analysis of the complete skill and then compared the kinematic or kinetic data with that from a 'decomposed skill' or what may be termed a lead-up drill.

RESULTS: Data will be presented on decomposed skills in; tennis (2 drills commonly used in service development), cricket batting (use of a batting tee and ball machine), volleyball (serve), gymnastics (vaulting and floor exercises) and the golf drive.

Serve in tennis (Reid, Whiteside and Elliott, 2010)

Significant adaptations of coordination and timing were observed under different practice task constraints

a. ***Isolated toss:*** The timing of the ball toss to its zenith, as a percentage of toss duration was significantly more for the full action compared with the ball toss in isolation. The ball was also 'pushed' higher in the decomposed practice (2.9 v 3.1 m).

b. ***Isolated swing:*** The racket swing velocity was higher in the complete serve (43 ms^{-1}), compared with the free swing condition (34 ms^{-1}).

Serve in volleyball (Davids et al., 2001)

a. They were particularly interested in the extent to which skilled servers use invariance in ball placement to set a type of 'spatial clock' for timing. In comparing two groups; one who learned the ball toss separately to the strike component, and a second who learned the motions together.

- Task decomposition in this self-paced extrinsic timing task did not yield clear benefits for novice learners.

Cricket batting

a. ***Batting tee*** (Baker, 1989)

Various differences were observed between an off-drive in cricket and the same shot played from a batting tee. Differences were noted in many body segment orientations for the two strokes. Table 1 shows significant differences between these strokes for key output variables. The off drive from a tee could not be classified as a true representation of the stroke played from an oncoming ball.

Table 1
Selected variables in an off-drive played from a tee and in an open situation

Variable	Tee	Open stroke
Trunk angle (backswing)(rad)	1.37	1.18*
Trunk angle (impact) (rad)	1.61	1.48*
Downswing time (s)	0.18	0.21
Linear velocity of bat at impact (end - ms^{-1})	16.3	15.2
Distance between ball and head at impact (m)	0.4	0.2*
Peak vertical GRF at impact (BW)	0.5	0.4

*Significantly different to other measure

b. ***Ball machine*** (Renshaw et al., 2007)

Significant adaptations of coordination and timing were observed under different practice task constraints.

- Different ratio of backswing-downswing when batting against a bowling machine (47% & 53%), compared with a bowler (54% & 46% respectively).
- Mean length of front foot stride was shorter against the bowling machine (0.55 m), compared with a bowler (0.59 m).
- Correlation between initiation of backswing and front foot movement was higher against a bowler (r=0.88), compared with a ball machine (r=0.65)

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Gymnastics

a. ***Vaulting*** *(*Elliott & Mitchell, 1991)
Specific lead-up drills commonly used in gymnastics did not appear to create a learning environment for completion of the Yurchenko vault (Table 2).

Table 2
Horizontal and vertical velocity (ms^{-1}) at take-off from the beat board and horse impact in the Yurchenko vault

Vault Characteristic	Drill 1 Round-off; 11/4 layout back somersault onto crash mats	Drill 2 Round-off; back handspring onto a hard mat followed by back somersault to landing.	Vault
Take-off			
Horizontal	3.2	3.9	4.3*
Vertical	3.3*	2.5	2.7
Impact			
Horizontal	4.8	4.9	5.3
Vertical	1.0	1.0	1.1

*Significantly different to other measures

b. ***Floor exercises*** (McLean, 2004)
McLean investigated selected lead-up drills used in preparation for a tumble row, with both elite and novice performers. She found selected aspects of the lead-up drills were representative of the tumble row, while other aspects were not (Table 3). In this paper only the very simple round-off drill will be compared with the same skill performed as part of a tumble row.

Table 3
Variables associated with the round-off as a decomposed skill in tumbling

Variable	Round-off in isolation		Round-off - tumble row	
	Novice	Elite	Novice	Elite
Trunk angle – take-off (°)	49	50	123*	124*
Horizontal velocity at take-off (ms^{-1})	1.4	1.8	2.2*	2.0
Vertical velocity at take-off (ms^{-1})	2.9	2.4	3.7*	3.6*

*Significantly different to other measures

Golf drive (Sweeney et al., 2011)
In a study looking at smoothing through impact it was found that a swing at a ball on a tee (≈45 ms^{-1}) was different to that with no ball (≈38 ms^{-1}) – the free swing was lower in velocity, in a similar manner to Reid et al. (2010). The need for some form of 'focus mechanism' such as a 'paper tee' produced a similar swing velocity to that with a ball.
Having developed an understanding of the role of task decomposition in teaching a skilled movement, it is then imperative to adopt a progressive approach across ages and maturity levels. In doing this we again must help the coach understand what mechanical features of skilled development (e.g. shoulder internal rotation in the tennis serve) should be taught at what age/maturity level. Table 4 provides a summary of variables across the learning pathway in the tennis serve with approximate percentages for various age classifications. While the learning sequence may be based in science, the percentage contributions at the various ages are approximated. Hopefully further research will enable these to be based more in science as we look forward to the future.

Table 4
The learning pathway in the tennis serve

Variable	% of mature action 11-years	15-years	Adult
Rhythm (coordination – balance)	60	100	100
Wrist flexion	60	80	100
Trunk rotations (backswing)			
Horizontal separation angle	50	80	100
Vertical separation angle	30	80	
Leg drive	20	60	100
Trunk rotation (forward swing)			
Twist axis	100	100	
Shoulder-over-shoulder	20	70	100
Somersault	60	80	
Internal rotation	10	60	100
Serve Velocity	60	80	100

CONCLUSION: Biomechanists will be of service to coaches when they are able to assist in creating an optimal learning environment. That environment must address key features of performance over the athlete development pathway.

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