WHAT IS THE EFFECT OF ELBOW HYPEREXTENSION ON BALL SPEED IN CRICKET FAST BOWLING?

Paul Felton[1] and Mark King[1]

School of Sport, Exercise and Health Sciences, Loughborough University, Loughborough, UK[1]

This paper investigates how elbow hyperextension characteristics affect ball speed in fast bowling. A two segment planar simulation model, customised to an elite fast bowler, was used to produce simulations which closely matched three performances. The model was evaluated by simulating one further performance. It was shown that the fast bowler's ball speed was increased by 4% due to elbow hyperextension using a one segment planar simulation model to determine ball speed with a straight arm. Finally, it was concluded that the limiting characteristics of elbow hyperextension in order to maximise ball speed were found to be the magnitude of peak elbow hyperextension and the amount the elbow "recoils" back towards straight after reaching peak elbow hyperextension.

KEY WORDS: computer simulation, arm, ball velocity, recoil.

INTRODUCTION: The delivery of the bowling arm, the last part of a kinetic chain of events within the fast bowling action, is fundamental in achieving optimum ball speed. Previous research has suggested that the action of the bowling arm is the most important aspect regarding performance; with contributions of 40-50% of the final ball release speed reported (Davis & Blanksby, 1976a; Elliott et al, 1986). Experimental research into the role of the elbow joint of the bowling arm has shown that the load on the elbow can cause elbow hypermobility (Ferdinands & Kersting, 2004: Portus et al., 2003; King & Yeadon, 2012). Elbow hypermobility occurs when the range of motion passes the anatomically defined natural limit. The amount of hyperextension exhibited in fast bowling is subject-specific but it is not uncommon to see angles in excess of 20° (King & Yeadon, 2012). Unfortunately, the cause and effect relationship of elbow hyperextension on ball speed cannot be understood experimentally. The purpose of this study was to develop a forward dynamics simulation model to investigate the effect elbow hyperextension has on ball speed in fast bowling.

METHODS: A planar two segment model consisting of an upper arm and lower arm + hand segment was developed to simulate the bowling arm in fast bowling (Figure 1). A ball was included as a point mass at the end of the lower arm segment. A constant torque generator was included at the shoulder and a torsional spring damper was used to model elbow hyperextension. The shoulder joint centre was translated in the horizontal direction only using performance data. Ball release was deemed to have occurred once the arm had passed the vertical and the horizontal distance travelled between the predicted landing site and the origin, defined as the initial shoulder coordinates, matched the performance distance. Input to the simulation model comprised the orientation and angular velocity of the upper arm as well as the angle and angular velocity of the elbow. The output comprised the motion of the arm and ball speed at release. In order to investigate the effect of elbow hyperextension on ball speed, a one segment model consisting of an upper arm + lower arm + hand segment was also developed.

The simulation model was customised to an elite fast bowler by determining subject-specific segmental inertia parameters (Yeadon, 1990). The torsional spring parameters and constant shoulder torque magnitude were determined by matching three fast bowling trials using a common set of parameters by minimising a score function. The score function was the average of an RMS score given to each of the three matched bowling performances consisting of the differences between performance and simulation in four quantities; ball speed, total time of simulation, peak elbow hyperextension, and elbow angle at release. Each difference was weighted equally and one degree was equivalent to 1% difference in

other measures (Yeadon & King, 2002). The robustness of the optimised set of parameters was further examined by using them to accurately simulate a fourth performance.

Initially, the amount of ball speed gained by the bowler due to elbow hyperextension was investigated by comparing the quickest bowling simulation with the predicted straight arm ball speed from the one segment model. The simulation model was then optimised to maximise ball speed by allowing the torsional spring coefficients to vary. A penalty was imposed to prevent peak elbow hyperextension exceeding an upper bound of 25°. Subsequently, in order to investigate the effect of different hyperextensions and recoils on ball speed compared to a straight arm, the torsional spring stiffness was perturbed whilst maintaining the damping parameter at the previously discovered optimised value.
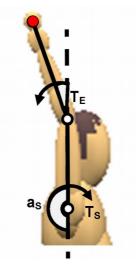

Figure 1: The two segment simulation model of the bowling arm. A torque generator, T_s opens the shoulder joint angle, a_s and a torsional spring, T_E closes the elbow joint angle.

RESULTS & DISCUSSION: The torsional spring parameters and constant shoulder torque determined by concurrently matching three bowling trials were seen to provide a good overall agreement, 3.8%, with individual trial scores of 4.5%, 4.4% and 2.5%. Evaluation of the determined torsional spring parameters and constant shoulder torque in a further bowling trial also provided a good level of agreement 4.4% (Table 1).

Table 1
RMS scores for the three matching and evaluation simulations with parameter differences

Variable	Match 1	Match 2	Match 3	Evaluation
Peak elbow angle (°)	0.1	0.0	0.2	0.5
Elbow angle at ball release (°)	0.4	1.1	1.4	2.5
Ball velocity (%)	5.0	1.1	2.2	4.2
Total time (%)	7.6	8.6	4.3	7.4
RMS (%)	4.5	4.4	2.5	4.4

Therefore, a two segment model with a constant shoulder torque and a linear damped torsional spring at the elbow is able to approximate the kinematics of the bowling arm. Furthermore, the level of agreement between actual performances and matching simulations is sufficiently close to allow the simulation model to be used to investigate how elbow hyperextension affects ball speed.
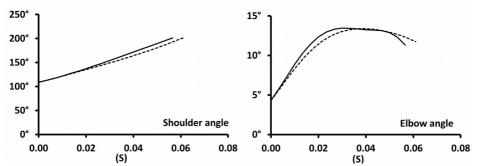
Figure 2: Comparison of key kinematic variables during the bowling period for Match 1; solid line – actual performance, dashed line – simulation

The elite fast bowler was found to have a ball speed of 85.8 MPH (38.1 m/s) in his quickest bowling trial. The amount of ball speed gained by the bowler compared to a straight arm due to elbow hyperextension was investigated using the one segment model, which predicted a straight arm ball speed of 82.5 MPH (36.7 m/s). Therefore, the fast bowler's elbow hyperextension generated an extra 4% of ball speed in comparison with bowling with a straight arm.

Optimisation of the torsional spring parameters at the elbow demonstrated that it was possible to bowl at 86.6 MPH (38.5 m/s), an increase in ball speed of 5% compared to bowling with a straight arm. The optimised elbow hyperextension reached the 25° upper limit, and recoiled 5° before ball release. In addition, the optimal torsional spring damping value was zero. However, since damping removes energy from a system this is unsurprising.

Whilst perturbing the spring stiffness to investigate the relationship between elbow hyperextension and ball speed, it became clear that the elbow time history could be classified as one of the three categories; "Recoiling" –the elbow hyperextends and is recoiling at ball release, "At peak" – when the elbow hyperextends and is at its peak at ball release or "Extending" – the elbow is still hyperextending at ball release. However, due to the rotational load on the arm during fast bowling the stiffness required for the arm to still be extending at ball release is unrealistic. Therefore, these cases have been ignored. When the elbow reaches peak hyperextension the ball release speed is seen to always be faster than a straight arm (Figure 3).
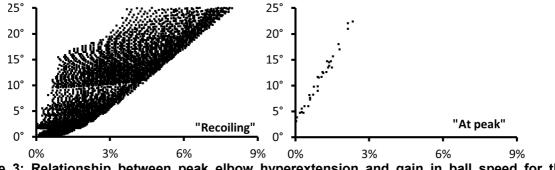

Figure 3: Relationship between peak elbow hyperextension and gain in ball speed for the Recoiling and at peak hyperextension scenarios

The gain in ball speed is a consequence of two mechanisms. Firstly, in order to satisfy the ball release criteria, i.e. release the ball towards the same point, the shoulder release angle has to increase as elbow hyperextension increases at release. This increases the work done by the shoulder and increases ball speed. Secondly, as the elbow recoils, the angular velocity of the wrist about the elbow acts in the same direction as the shoulder torque, and increases the relative torque of the wrist about the shoulder resulting in a gain in ball speed. However, as the elbow recoils, the increase in work done by the shoulder due to the first mechanism is reduced. Therefore, an optimal recoil percentage must exist for each peak hyperextension in order to maximise ball speed (Figure 4).
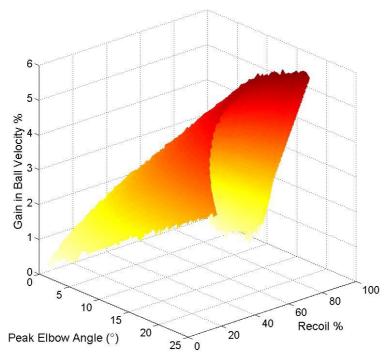
Figure 4: The gain in ball speed percentage curve as a function of peak elbow hyperextension and recoil percentage

CONCLUSION: Previously, elbow hyperextension was thought to have a positive effect on ball speed in cricket fast bowling. However, there was no scientific research behind such beliefs. This study has identified that elbow hyperextension increases ball speed compared had a straight arm trial. Furthermore, it also identifies that the gain in ball speed associated with elbow hyperextension is not solely linked to peak elbow hyperextension but also the amount of recoil. This knowledge can help inform talent identification protocols and coaching practice by providing a clear understanding of the effect of elbow hyperextension on ball speed.

REFERENCES:
Davis, K., & Blanksby, B. (1976a). The segmental components of fast bowling in cricket. Australian Journal for Health, *Physical Education and Recreation,71*, 6-8.
Elliott, B.C., Foster, D., & Gray, S. (1986). Biomechanics and physical factors affecting fast bowling. *Australian Journal of Science and Medicine in Sport; 18,* 16-21.
Ferdinands, R., & Kersting, U. (2004). Elbow angle extension and implications for the legality of the bowling action in cricket. In A. McIntosh (Ed.), *Proceedings of the Fifth Australasian Biomechanics Conference*, pp. 26-27. Sydney, NSW: University of New South Wales Press.
King, M.A,. & Yeadon, M.R. (2012). Quantifying elbow extension and elbow hyperextension in cricket bowling: a case study of Jenny Gunn. *Journal of Sports Sciences, 30 (9), 937-947.*
Portus, M.R., Mason, B.R., Raith, D.A., & Rosemund, C.D. (2003). Fast bowling arm actions and the illegal delivery law in men's high performance cricket matches. In R. Stretch, T. Noakes, & C. Vaughan (Eds.), *Science and medicine in cricket: A collection of papers from the second World Congress of Science and Medicine in Cricket,* 41-54. Port Elizabeth: comPress
Yeadon, M.R. (1990). The simulation of aerial movement – II: A mathematical inertia model of the human body. *Journal of Biomechanics, 23,* 67-74.
Yeadon, M.R., King, M.A., 2002. Evaluation of a torque driven simulation model of tumbling. Journal of Applied Biomechanics 18, 195-206.