THE CONTRIBUTION OF ELBOW EXTENSION TO WRIST SPEED IN CRICKET FAST BOWLERS

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The purpose of this modelling study was to assess the sensitivity of wrist joint speed to systematic manipulations of empirical elbow joint flexion-extension kinematic profiles. The joint kinematic profiles of 12 cricket fast bowlers were entered into a Forward Kinematic Model and the elbow joint kinematic profiles were subsequently amplified to elicit wrist speed changes. An amplification factor of zero decreased wrist speed by a mean of 8.6% (± 6.9%), whereas an amplification factor of two increased speed by a mean of 8.8% (± 7.1%). An opposite relationship was found for two participants who extended the elbow joint prior to release and it is proposed that an internally rotated humerus will displace the wrist joint posteriorly when the elbow joint is extending.

KEY WORDS: kinematics, biomechanical modelling, link segment model, wrist speed

INTRODUCTION: Cricket's fair delivery law states that a cricket bowler cannot extend the elbow joint during the delivery swing. This law aims to prevent bowlers from gaining an unfair advantage by using elbow extension to increase the speed of the wrist at the point of ball release, i.e. to prevent them from 'throwing the ball'. However research has shown that the arm is generally not straight or rigid through this period (Lloyd et al., 2000; Portus et al., 2006). Due to the growing database of bowling data, the International Cricket Council allows bowlers to extend the elbow joint by up to 15° during the delivery swing.
Portus et al. (2003) found a significant increase in ball release speed for bowlers who extended by more than 15°, when compared with bowlers who extended less than 15°. In addition, Roca et al. (2006) found that ball release speed significantly greater for bowlers who flexed more than 8.2° and extended more than 5.9° during the delivery swing. Although these studies show a relationship between elbow extension and ball speed, it is still unclear whether this is a direct relationship. Roca and colleagues (2006) went as far as to question the direction of the relationship between these two parameters.Therefore the aim of this study was to assess the sensitivity of wrist joint speed to systematic manipulations of elbow joint flexion-extension kinematic profiles using a three-dimensional simulation modelling approach.

METHODS: Twelve right-handed male fast bowlers (age 21.1 ± 2.1 years, height 1.88 ± 0.06 m and mass 79.0 ± 5.7 kg) competing at a first grade level within the Western Australian Cricket Association (WACA) competition volunteered to participate in this study. Ethics approval was granted and written informed consent was obtained from each participant prior to the commencement of the study, in accordance with the requirements of The University of Western Australia Human Research Ethics Committee. Three-dimensional bowling kinematics were sampled at 250 Hz using a 12-camera VICON MX3 motion analysis system (Oxford Metrics, Oxford, UK). An abridged version of the UWA full body marker set (Chin et al., 2009) consisting of 64 12-millimetre retro-reflective markers, was affixed to the trunk, pelvis and the lower and upper limbs.
A cricket pitch was constructed with a rubber mat being laid down the length of the laboratory. Participants were instructed to bowl a standard 'match intensity' delivery and aim at a target mark 0.3 m above and 0.3 m to the left of the top of the off stump, as viewed from

the bowler's end. Each participant bowled five sets of six consecutive deliveries, with a short break between each set.

Vicon Workstation software (Oxford Metrics, Oxford, U.K.) was used to track, label and complete marker trajectories for each bowling trial. Data were filtered in Vicon Workstation using a Butterworth low pass filter with a cut-off frequency of 20 Hz. Filtered data were modelled using custom static and dynamic UWA models (Besier et al., 2004; Campbell et al., 2009a, 2009b; Chin, et al., 2010).

Trajectory data from twenty deliveries per participant were exported to MATLAB programming software (MathWorks, Natick, Massachusetts, U.S.A). Custom code was written to model each bowler as a 10-link kinematic chain with the front foot as the initial segment and the wrist joint centre as the terminal point. The sensitivity of resultant wrist joint speed to elbow joint flexion/extension was assessed by systematically manipulating elbow joint flexion-extension kinematic profiles in the Forward Kinematic Model. This involved constraining the amplification of elbow joint flexion-extension angular displacement profiles, in which the elbow flexion-extension angles at front foot impact and ball release were constrained to the empirical values, while the remainder of the angular displacement profile underwent amplification by a gain factor ranging from 0 to 2 in steps of 0.1.

RESULTS: At the time of ball release, empirical resultant wrist speed was 23.0 ± 0.9 $m \cdot s^{-1}$. Elbow joint flexion-extension angular displacement amplification had a positive linear relationship (R^2 = 1.000, SEE = < 0.001) with wrist speed (Figure 1). A manipulation factor of zero decreased wrist speed by a mean of 8.6% (± 6.9%), whereas a manipulation factor of two increased speed by a mean of 8.8% (± 7.1%). The mean increase in wrist speed was 0.9% for every 0.1 increase in amplification factor.

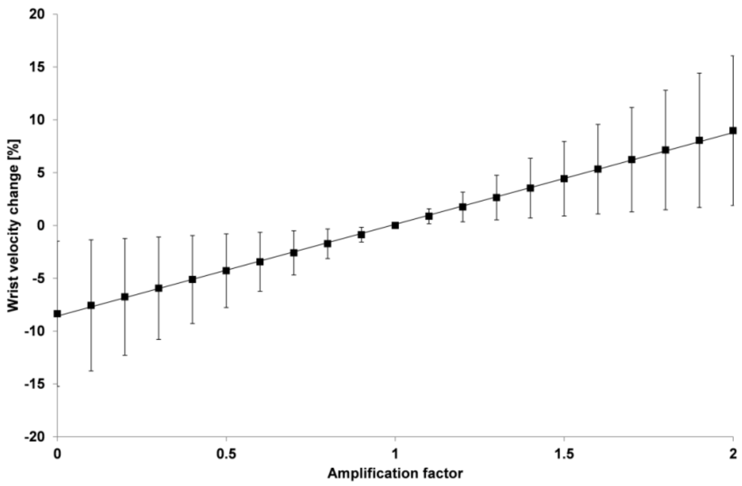

Figure 1: The effect of amplification manipulations to empirical elbow flexion-extension angular displacement waveforms on change in resultant wrist speed (%). Amplification factor manipulations range from 0 to 2 in steps of 0.1. Error bars represent ±1 standard deviation.

At the time of ball release, the participants were internally rotated at the shoulder joint, relative to the global coordinate system, by 19.3 ± 17.4° (range 1.2° - 57.6°). By plotting individual wrist velocity changes as a function of amplification (Figure 2), it was revealed that there was a negative linear relationship between these two variables for two of the 12 participants. Further investigation identified that these two participants extended the elbow joint to release while the other ten participants flexed to ball release (Figure 3).

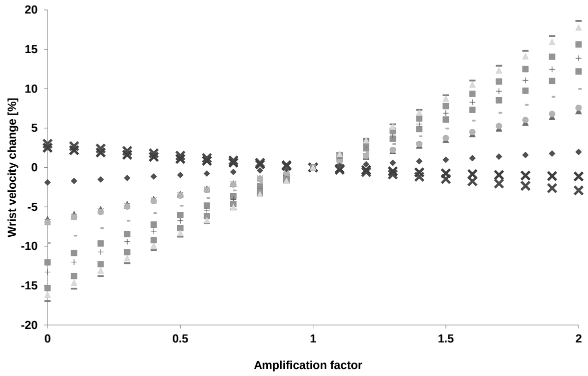

Figure 2: The effect of amplification manipulations to empirical elbow flexion-extension angular displacement waveforms on change in resultant wrist speed (%). Each pattern of data points represents one of the participants except for two participants who displayed a negative relationship between these two variables (cross patterns).

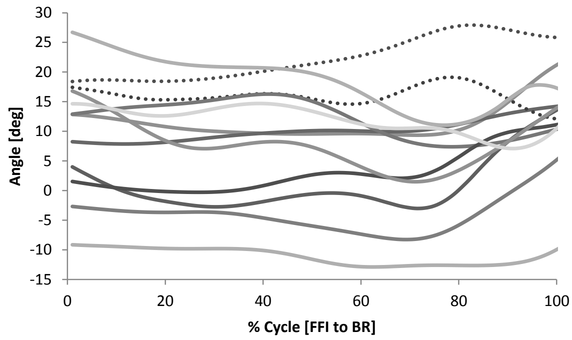

Figure 3: Elbow joint angular waveforms of the 12 participants from FFI to BR. Each line represents the mean waveform of each participant. The participants that flexed to release are shown by solid lines while the two participants that extended to release are shown by the dotted lines.

DISCUSSION: This study sought to assess the sensitivity of wrist joint speed to systematic manipulations of elbow joint flexion-extension kinematic profiles. Wrist joint centre speed was shown to be sensitive to elbow joint kinematic amplification. The 15° elbow extension limit for bowlers has been debated vigorously for many years. Most debate has concentrated on coming to a consensus as to an appropriate extension limit. Ferdinands and Kersting (2007) found that elbow joint angular displacement could not differentiate between participants who had been previously suspected of 'throwing'. The authors suggested that using the speed of elbow extension at ball release would be a conceptually more valid measure in identifying bowlers that use this speed component of throwing to their advantage. However, the results of the current study indicate that an amplification of elbow joint flexion range of motion and speed prior to ball release increased wrist speed. In fact, the results show that amplification of elbow extension velocity immediately prior to ball release had a detrimental effect on wrist speed. These results were similar to those reported by Elliott and colleagues (1995) who found that during the tennis power serve, players were internally rotated enough that elbow extension produced a lateral and slight posterior movement of the racket head leading up to ball contact.

The reduction in wrist speed caused by the aforementioned amplification of elbow joint extension can be explained mechanically. All bowlers who participated in this study were internally rotated at the shoulder joint at ball release. If the flexion/extension axis of the upper arm was perfectly aligned parallel to the x-axis of the global laboratory coordinate system in the transverse plane (parallel to the pitch), there would be no anterior-posterior velocity component (excluding misalignment of the forearm due to the presence of a 'carry' angle). Once the upper arm starts to internally rotate, the anterior-posterior velocity component will increase until the upper arm flexion/extension axis becomes perpendicular to the global x-axis and pitch in the transverse plane. At this point, anterior velocity will be maximised during elbow flexion and minimised during elbow extension. For example, Elliott and colleagues (1995) recorded a -14.2% change in racket head speed in the forward (x) direction of a 'power serve' with the participants extending to impact. In contrast, anterior velocity will be maximised during elbow extension when the upper arm is externally rotated so that the upper arm flexion/extension axis is again perpendicular to the global x-axis and pitch in the transverse plane.

CONCLUSION: In summary, the use of a Forward Kinematic Model to simulate elbow joint angle manipulations showed that increased elbow joint extension does not result in increased wrist joint speed. This study showed that bowlers who flex the elbow joint immediately prior to ball release gain an advantage in increased wrist joint speed. However, elbow flexion-extension may not be the only functional movement that should concern cricket administrators in relation to suspect bowling actions. The orientation of the upper arm coordinate system about its long axis may be an additional measure to ascertain whether a bowler is gaining an unfair advantage through the use of elbow flexion-extension. Future studies may consider investigating the action of the humerus in cricket bowling, particularly its orientation at and just prior to ball release.

REFERENCES:

Besier, T.F., Sturnieks, D.L., Alderson, J.A. & Lloyd, D.G. (2003). Repeatability of gait data using a functional hip joint centre and a mean helical knee axis. *Journal of Biomechanics*, 36, 1159–1168.

Campbell, A.C., Lloyd, D.G., Alderson, J.A. & Elliott, B.C. (2009a). MRI development and validation of two new predictive methods of glenohumeral joint centre location identification and comparison with established techniques. *Journal of Biomechanics*, 42, 1527–1532.

Campbell, A.C., Alderson, J.A., Lloyd, D.G. & Elliott, B.C. (2009b). Effects of different technical coordinate system definitions on the three dimensional representation of the glenohumeral joint centre. *Medical & Biological Engineering & Computing*, 47, 543-550.

Chin, A., Elliott, B., Alderson, J., Lloyd, D. & Foster, D. (2009). The off-break and "doosra": Kinematic variations of elite and sub-elite bowlers in creating ball spin in cricket bowling. *Sports Biomechanics*, 8, 187-198.

Chin, A., Lloyd, D., Alderson, J., Elliott, B. & Mills, P. (2010). A marker-based mean finite helical axis model to determine elbow rotation axes and kinematics in vivo. *Journal of Applied Biomechanics*, 26, 305-315.

Elliott, B., Marshall, R. & Noffal, G. (1995). Contributions of upper limb segment rotations during the power serve in tennis. *Journal of Applied Biomechanics*, 11, 433-442.

Ferdinands, R.E.D. & Kersting, U. (2007). An evaluation of biomechanical measures of bowling action legality in cricket. *Sports Biomechanics*, 6, 315-333.

Lloyd, D.G., Alderson J.A. & Elliott B.C. (2000). An upper limb kinematic model for the examination of cricket bowling: A case study of Muttiah Muralitharan. *Journal of Sports Sciences*, 18, 975-982.

Portus, M.R., Rosemond, C.D. & Rath, D.A. (2006). Fast bowling arm actions and the illegal delivery law in men's high performance cricket matches, Sports Biomechanics, 5, 215 — 230.

Portus, M., Mason, B., Rath, D. & Rosemond, 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* (pp. 41-54). Port Elizabeth, South Africa: Com Press.

Roca, M., Elliott, B., Alderson, J. & Foster, D. (2006). The relationship between shoulder alignment and elbow joint angle in cricket fast-medium bowlers. *Journal of Sports Sciences*, 24, 1-9.

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