BOWLING ARM MECHANICS IN CRICKET

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The purpose of this study was to identify the biomechanics of the bowling arm in fast bowlers in cricket. A sample of 34 fast bowlers was divided into four speed groups. A 3D motion analysis system was used to track and analyse the motion trajectory of forty-eight reflective markers placed on each subject to determine the kinematics of segment joint centres. Ground reaction forces were measured with a force platform. These data were used as input to a 3D 15-segment inverse solution model of the human body, which used a Newton-Lagrange multiplier iterative method to generate the dynamic equations of motion. The calculations show that the bowling arm segments undergo a sequence of active and controlled motion during the power phase, which tends to vary bowling speed.

KEY WORDS: cricket, biomechanics, bowling, power, sequencing.

INTRODUCTION: The ability of a bowler to propel a ball at high speeds gives the batter less time in which to respond. International cricket teams are developing training programmes to increase the quality and speed of their fast bowlers. Early research in the biomechanics of bowling was focussed on two areas: the identification of factors that increase a bowler's susceptibility to injury, particularly of the lower lumbar region (Elliott & Foster, 1989), and the correlation of kinematic variables and sequences with elite fast bowlers (Davis & Blanksby, 1976). However, the findings on segmental sequencing merely described the sequential order of key positions. There was no account of the forces and torques that enabled a bowler to achieve these positions.

The first 3D full body inverse solution model was developed by Ferdinands et al. (2001) to investigate the dynamics of an elite spin bowler. It was shown that many important movements, such as rear leg thrust and front arm pull down, are performed passively during much of the bowling action, which is contrary to the traditional teaching. This study was extended to study the bowling arm and trunk torques of a group of elite fast bowlers (Ferdinands et al., 2002). They concluded that the lower trunk acted as a reactive base of support because the torques were inhibitory to the direction of rotation and flexion. However, the segment powers needed to be calculated to show this more definitively.

We used the model of (Ferdinands et al., 2002) to calculate the segment powers for the bowling upper arm and hand for a large sample of fast bowlers. The results indicate that there is a preferred sequence of active and controlled motion of these bowling arm segments during the power phase.

METHODS: Thirty-four fast bowlers were selected from the top competitions in New Zealand, and divided into four groups based on speed: slow (27.8 ms 1 to 30.6 ms-1), medium (>30.6 ms 1 to 31.9 ms-1), med-fast (>31.9 ms 1 to 33.3 ms-1), and fast (> 33.3 ms-1). Eight Motion Analysis CorporationTM Falcon High Resolution cameras, set at a frame rate of 240 Hz, were placed around the subject so that the field of view was sufficient to capture the performance area of the trials. Forty-eight reflective markers were strategically placed on the subject. An EVa 3D motion analysis system (Motion Analysis Corp.) was used to track and analyse the movement trajectory of these markers. Using EVA's Virtual Marker facility, the centre of joint rotation was calculated for all the major body segments: head and neck (as one segment), thorax, lower trunk, thighs, shanks, feet, upper arms, forearms, and hands.

Each subject performed two trials. In the first trial, the subject had to bowl six balls on an artificial surface at a target (the stumps) 20 m away, while making front foot contact with a Bertec force plate during the delivery stride. In the second trial, the subject had to perform as before, but now with back foot contact on the force plate during delivery. The force plate

readings of the back foot were then averaged, and combined with the force plate readings from the first trial. Then the six balls in the first trial were chosen for analysis.
The kinematic data were used as input to a 3-D fifteen segment inverse solution model of the human body developed with the Mechanical Systems Pack, a set of Mathematica (Version 3.0) packages designed to assist in the analysis and design of spatial rigid body mechanisms (Dynamic Modelling, 1995). The software generated the equations of motion using a Newtonian-Lagrange Multiplier method.

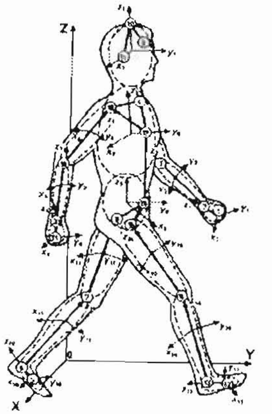

Figure 1: A 15-segment 3D rigid body model of the human body was created in the Mechanical Systems Pack. [Picture adapted from Zatsiorsky, V.M., 1988. Kinematics of Human Motion. Human Kinetics, Champaign, Illinois].

Ensembles averages of the segment powers and torques were calculated over the power phase, which was defined from front foot contact (FFC) to ball release (REL), when much of the power is generated during the bowling action. Both of these variables were normalised over their respective start and end times, and expressed as percentage of the cycle from 0% to 100%. The variance ratio (VR) was used to express the mean variability over this period (Kadaba, et al., 1985).

RESULTS AND DISCUSSION: At FFC the bowling arm is extended almost horizontally behind the back, and then circumducted about the glenohumeral joint to release the ball when the arm is approximately vertical. The major motions of the bowling arm were analysed: horizontal adduction and vertical adduction of the upper arm relative to the orientation of the upper trunk, the translation of the glenohumeral joint, and flexion of the hand.
Initially there was a steady positive horizontal adduction power, which was followed by a phase of increasing negative power (Figure 1). The mean value of the ensemble average curve during the positive period was higher for the two faster groups compared to the two slower ones (fast, 442 W; med-fast, 442 W; medium, 190 W; slow, 324 W). The two faster groups, in particular the fast group, had a delayed sequence transition point (STP) at which the horizontal adduction power became negative compared to the two slower groups (fast, 64%PC; med-fast, 56%PC; medium, 41%PC; slow, 53%PC). Also, the two faster groups produced a higher rate of negative adduction power than the two lower groups (fast, -3130 W/%PC; med-fast, -2403 W/%PC; medium, -1322 W/%PC; slow -1544 W/%PC). Also, despite the fast and medium-fast groups having the higher positive powers, and a later STP, they still generated the highest mean negative power overall (fast, -1096 W; med-fast, -1055 W; medium, -1006 W phase; slow, -832 W). Horizontal adduction of the bowling arm is a combination of active and controlled motions. The fast and med-fast groups were better able to control the horizontal adduction motion of the upper arm.

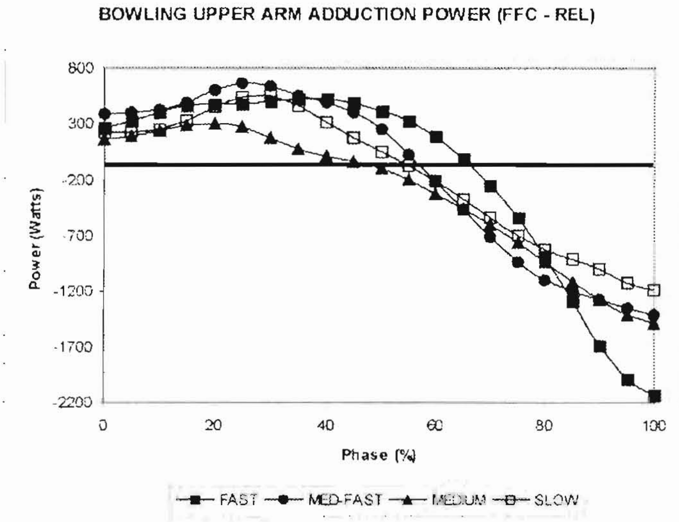

Figure 2: Ensemble averages of bowling upper arm horizontal adduction torque All groups had positive torque for approximately half the phase cycle (PC) after which the torque became increasingly negative until REL. VR: 0.24 (fast), 0.30 (med-fast), 0.55 (med), 0.22 (slow). Positive is defined for adduction. Zero line (—).

The vertical adduction power was small and negative initially, but became positive approximately during the power phase (fast, 66%PC; med-fast, 51%PC, medium, 65%PC, slow, 49%PC) indicating a strong active vertical adduction up to REL. However, it was difficult to find any relation with bowling group. For instance, after becoming positive, the medium-fast and slow groups had the highest average powers, and the fast and medium groups the slowest mean powers (fast, 249 W; med-fast, 491 W; medium, 367 W; slow, 478 W).

The force and power of the glenohumeral joint in the direction of horizontal motion showed that the distal end of the bowling arm was initially thrust forwards, but then reached a STP when this motion was strongly retarded (fast, 61%PC; med-fast, 54%PC; medium, 47%PC; slow, 51%PC). Interestingly, these STPs occurred at similar times to the horizontal adduction power, i.e. both the horizontal adduction power and linear power decreased approximately at the same time. As the bowling upper arm was above the horizontal during this time, the negative force on the distal end of the arm would tend to increase the angular velocity of the bowling arm. Therefore, there could be an interaction between these motions to maintain the angular acceleration of the bowling arm. Also, the fast group had the most delayed STPs for negative linear and horizontal adduction powers, and also the highest negative increase in these powers.

The only significant motion of the bowling hand is flexion. Rotation of the hand cannot occur independently of forearm rotation, and the range of adduction and abduction at the wrist is limited and not capable of imparting much power. The hand flexion power only became important during the latter half of the phase, when it changed rapidly from negative to positive (Figure 3). In general, hand flexion underwent a short period of controlled extension followed by a period of rapid active flexion until ball release. The occurrence of hand extension was most delayed for the fast group fast (50-75% PC; med-fast, 40-65% PC; medium, 30-75% PC; slow, 15-60% PC), which also had the highest rate of hand extension.

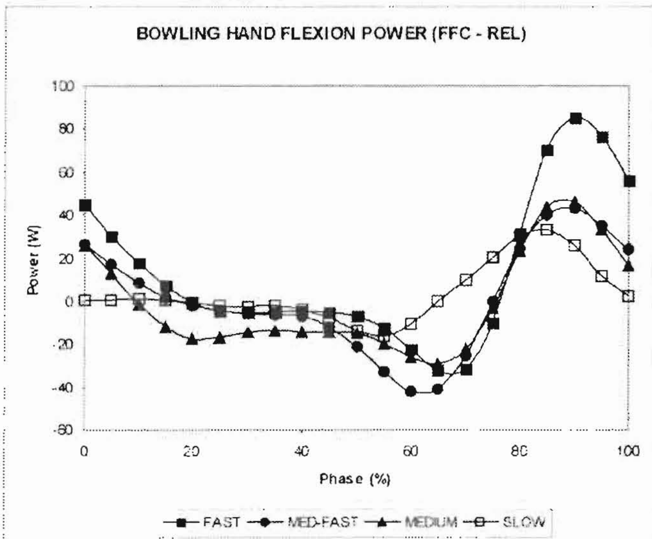

Figure 3: Ensemble averages of bowling hand flexion power. VR: 0.55 (fast), 0.81 (med-fast), 0.59 (medium), 0.92 (slow).

The mean active hand flexion power was highest for the fast group, followed by the med-fast and medium group, and then lastly the slow group (fast, 63.9 W; med-fast, 27.8 W; medium, 32.6 W; slow, 19.2 W). The corresponding mean flexion torques also increased with the speed of bowling group (fast, 2.48 Nm; med-fast, 1.39 Nm; medium, 1.30 Nm; slow, 0.87 Nm).

Bowling arm rotation in cricket has complex dynamic characteristics, which have not been considered in the coaching of fast bowlers. The two major motions of the bowling upper arm use different actuation strategies and yet combine to produce a high angular velocity of the bowling arm. Further, these motions must combine with the bowling hand to produce a rapid controlled extension phase prior to an active flexion phase as REL is approached. Also, there were differences in the timing of these phases among bowling speed groups, in particular the fast group. Much more than brute strength, these results show that fast bowling requires an intricate sense of timing.

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