MECHANICS OF THE FRONT ARM TECHNIQUE IN CRICKET FAST BOWLING

René E.D. Ferdinands

Faculty of Health Sciences, University of Sydney, Sydney, Australia

The purpose of this study was to analyse the kinetics of front arm motion in fast bowling. A sample of 34 fast bowlers was divided into four speed groups. A three-dimensional (3-D) 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 3-D 15-segment inverse solution model of the human body, which used a Newton-Lagrange multiplier iterative method to generate the kinetics equations of motion. The calculations show that the front upper arm torques are time-varying cyclic, challenging the coaching notion recommending fast bowlers to pull the front elbow down as fast as possible into the front hip.

KEY WORDS: kinetics, kinematics, cricket, bowling.

INTRODUCTION: Fast bowlers play a key role in determining a cricket team's success. By releasing the ball at high velocities of up to 45 m s^{-1}, batsmen have only a short time in which to perceive and react to the ball. In assessing the performance potential of bowlers, good coaches observe the general coordination pattern of movements during the action. The motion of the non-bowling (front) arm is considered an essential part of the coordinated sequence of bowling. During back foot contact, the normal recommendation is for the bowler to raise the front arm vertically, sighting the target from either outside the front arm if a side-on bowler or inside the front arm if a front-on bowler (Elliott & Foster, 1989). During front foot contact, the bowler is advised to tuck the front arm into the ribs in a rapid downwards motion as the arc of the bowling arm begins to assist in the forceful flexion of the trunk (Philpott, 1973; Elliott & Foster, 1989). This aspect of forcibly tucking or pulling-down the front arm arm is emphasised by most coaches. The idea is substantiated with some kinematic evidence. Davis & Blanksby (1976) found that faster bowlers tend to have higher a front arm velocity than slower bowlers.

The type of bowling technique also seems to affect the velocity of the front arm. Side-on bowlers tend to record higher velocities of the front elbow than front-on bowlers. Elliott & Foster (1984) found that the mean elbow velocity of the front arm was 3.2 m s^{-1} for side-on group, as opposed to 2.4 m s^{-1} for the front-on group. A group of front-on bowlers tested by Elliott et al. (1986) had a front elbow velocity of 2.8 m s^{-1}, slower than the respective velocity for side-on bowlers. However, kinematics does not imply causation. No study of kinetics has been done to assess whether the torques on the front arm act in a direction that corresponds with the pulling-down motion recommended by coaches. Hence, the aim of this study was to study the kinetics of the front arm in a sample of fast bowlers. Validation of the coaching hypothesis on front arm technique would require kinetics data showing that the joint torque about the front shoulder is either a constant or increasing ramp function.

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 m s^{-1} to 30.6 m s^{-1}), medium (>30.6 m s^{-1} to 31.9 m s^{-1}), med-fast (>31.9 m s^{-1} to 33.3 m s^{-1}), and fast (> 33.3 m s^{-1}). Eight Motion Analysis Corporation™ 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., Ltd.) 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 (Beretta, 1995). The software was used to generate the equations of motion using a Newtonian-Lagrange Multiplier method.

Front arm motion in adduction-abduction plane relative to the thorax corresponds to the general direction of pulling down the front arm in fast bowling (Ferdinands, 2004). Hence, ensembles averages of the joint torques in this adduction-abduction plane were calculated over the arm acceleration phase, which was defined from front foot contact (FFC) to ball release (REL), when much of the power is generated during the bowling action. The data 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: The joint torques of the front arm were calculated in plane of vertical adduction, indicating a time-varying history across the arm acceleration phase (Figure 1).

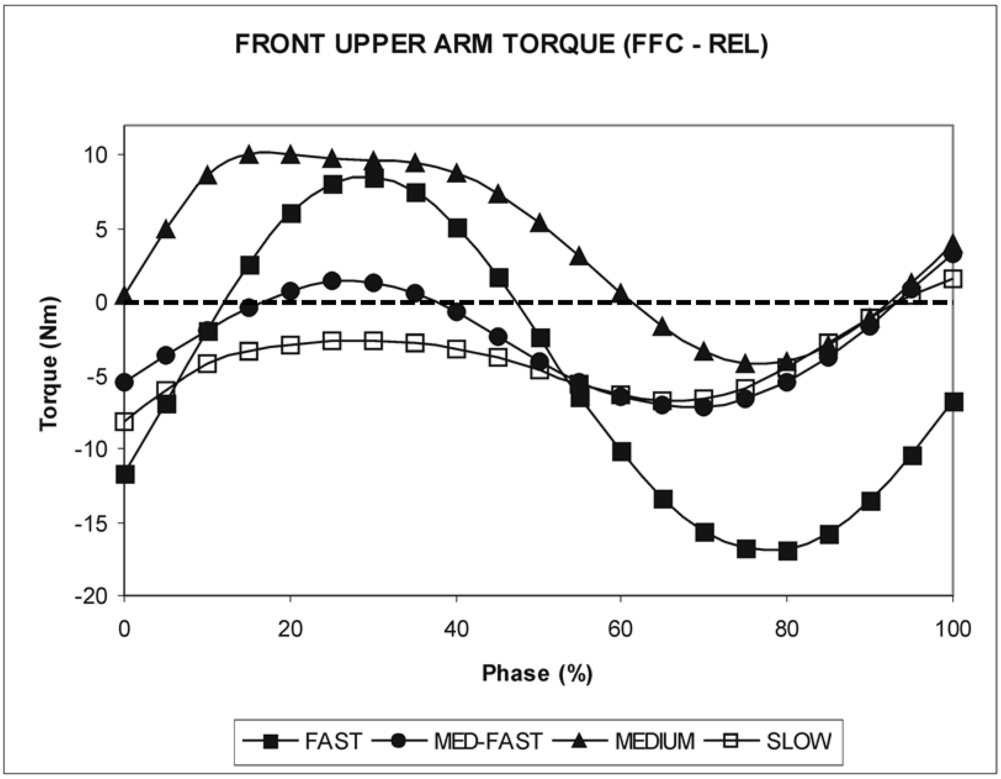

Figure 1: Ensemble averages of front arm upper arm torques the vertical abduction/adduction plane relative to the motion of the thorax. Positive is defined for abduction, the area of the graph above the dashed line. VR: 0.63 (fast), 1.00 (med-fast), 0.88 (medium), 1.00 (slow).

DISCUSSION: Coaches recommend a strong pulling-down motion of the front arm in fast bowling, a technique that is supposed to mechanically assist fast bowlers generation ball speed. The relevant shoulder musculature would have to generative a net concentric force in order to follow this instruction. If this notion is correct, then in the kinetics analysis of front arm motion, one would expect either a constant or increasing ramp function in joint torque about the front shoulder joint.

The kinetics data show that the front upper arm torque was time-varying periodic during the arm acceleration phase (Figure 1). In the two fastest bowling groups – i.e., the fast and fast-medium groups – there was an early upper arm adduction torque for the fast and fast-medium groups, lasting until 13 and 18%, respectively; after which the torque reversed, continuing to inhibit or control front upper arm motion until 50% and 38%, respectively. Beyond these points, the torques were once again adductive, although they tended to decrease as ball release was approaching, reversing and becoming slightly positive (abductive) towards the end of the phase. The slow group tended to apply front upper arm adduction torques, except for the small period of torque reversal at the end of the phase, similar to the fast and fast-medium groups. The medium group was an anomaly, registering abduction torques for the major portion of the phase, until 60% before becoming adductive. This group also had the small torque reversal towards the end of the phase.

In neither of these groups did the data correspond to the conventional coaching notion of an a single active pulling-down motion of the front arm. The front upper arm torques were not constant or simple increasing functions. If one were to consider the fast bowling group as the best model on the basis that higher ball release speed should correspond to more mechanical power output, then the torque pattern may be as important as the magnitude of torque, since it was in the fast group that the largest fluctuations of front arm torque were registered. But note that pattern itself was relatively consistent, the fast bowling group registering the lowest variability in the sample.

These findings do not contradict the kinematics data in previous studies showing that the front elbow motion increased with ball speed (Davis and Blanksy, 1976). Neither do they diminish the important of the front arm in bowling. It is expected that faster limb motion is associated with higher ball speed. But the question is one of causation. The coaching literature is replete with instruction on pulling the front elbow into the hip. This indeed does happen, and at an increasing rate for each faster bowling group. However even the simple analysis of kinetics in this study suggests that the pulling down motion is not solely caused by front shoulder torques, but dependent on motion-dependent torques generated elsewhere in the kinetic link chain. Coaches may need to reconsider the technique of using the front arm as integrated component of bowler's whole body coordination during the action.

CONCLUSION: In this study, the front arm mechanics in fast bowling were investigated, the objective being to increase the current level of understanding on this aspect of technique. A more scientific viewpoint on front arm motion in fast bowling could assist coaches in training fast bowlers to release the ball with faster speed. The data showed that the front upper arm in bowling is subject to a complex control strategy involving time-varying torques, the process far more complicated than the simple coaching notion of pulling the front elbow as fast as possible into the hips. To train bowlers to use the front arm correctly, coaches will need to consider the whole body coordination patterns that characterise each bowling action. Further research will be designed to investigate how the mechanics of the front arm complements the segmental interactions in the entire musculoskeletal system during bowling.

REFERENCES:

Beretta, R. (1995). *Mathematica Mechanical Systems User's 1 Guide*. Champaign: Wolfram Research, Inc.

Davis, K., & Blanksby, B. (1976). A cinematographic analysis of fast bowling in cricket. *Australian Journal of Health, Physical Education, and Recreation*, **71**, 9-15.

Elliot, B. C., & Foster, D. H. (1984). A biomechanical analysis of the front-on and side-on fast bowling techniques. *Journal of Human Movement Studies*, **10**, 83-94.

Elliot, B. C., & Foster, D. (1989). Fast bowling technique. In B.C. Elliott and, D. Foster (eds), *Send the stumps flying: the science of fast bowling*, pp. 26-36. Nedlands: University of Western Australia Press.

Ferdinands, R.E.D. (2004). *Three-dimensional biomechanical analysis of fast bowling in cricket*. Unpublished PhD Thesis, Hamilton: University of Waikato.

Elliot, B. C., Foster, D. H. & Gray, S. (1986).. Biomechanical and physical factors influencing fast bowling. *The Australian Journal of Science and Medicine in Sport*,18(1), 16 - 21.

Kadaba, M.P., Wootten, M.E., Gainey, J., & Cochran, G.V.B. (1985). Repeatability of phasic muscle activity: performance of surface and intramuscular wire electrodes in gait analysis. *Journal of Orthopaedic Research*, **3**, 350-359.

Philpott, P. (1973). *How to Play Cricket.* Sydney: Pollard Pty. Ltd.

Acknowledgement

We thank Bob Beretta, the developer of the Mechanical Systems Pack, for his expert advice on modelling in this dynamics software package