THE INFLUENCE OF KNEE JOINT FLEXION-EXTENSION ON WRIST JOINT SPEED IN CRICKET FAST BOWLERS

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The purpose of this study was to assess the sensitivity of wrist joint velocity to manipulations of knee joint flexion–extension kinematic waveforms through the use of a forward kinematic approach. The bowling kinematics of twelve male cricket pace bowlers were entered into a forward kinematic model using MATLAB software. Participants‘ knee joint flexion-extension kinematics were manipulated in two ways: 1) offset by ± 20° and 2) amplified by a factor of ± 2. Both manipulations led to increases in resultant wrist joint velocity at the time of ball release. An offset of 20° extension increased wrist joint velocity by 5.6% whereas an amplification factor of 2 increased wrist joint velocity by 29.9%. These results support the notion that a flexor-extender knee joint technique is ideal for cricket pace bowlers.

KEYWORDS: ball speed, pace bowler, forward kinematic model

INTRODUCTION: Ball release speed is one of the most important factors for the success of a cricket fast bowler. Higher ball release speeds have been shown to discriminate high-performance bowlers from amateur bowlers (Middleton, Mills, Elliott, & Alderson, 2016), as well as between developmental levels (Phillips, Portus, Davids, & Renshaw, 2012). There is a growing body of evidence within the literature that the front lower limb plays a significant part in contributing to ball release speed. A number of studies have shown that an extending knee leading up to ball release and a more extended knee at ball release are associated with higher ball release speeds (Salter, Sinclair, & Portus, 2007; Worthington, King, & Ranson, 2013). Although Middleton et al. (2016) found moderate-large effect sizes for maximum front knee flexion and front knee flexion at the time of ball release between high performance and amateur bowlers, these variables were only significantly correlated with ball release speed for the amateur group. The larger relative variability of the high performance group (coefficient of variation of 84% vs 45% for the amateur group for knee flexion at ball release) suggests that either the action of the knee for high performance bowlers is less important than for less skilled bowlers, or group-based correlation analysis may not be the most appropriate statistical technique to investigate associations between execution and outcome variables in the population.
Recent research had used modelling techniques, such as forward kinematic modelling, to investigate the relationships between upper limb kinematics and wrist joint velocity *in silico* (Middleton, Alderson, Elliott, & Mills, 2015). Therefore, the aim of this study was to assess the sensitivity of wrist joint velocity to manipulations of knee joint flexion–extension kinematic waveforms through the use of a forward kinematic approach. It was hypothesised that a decrease in knee joint flexion angle (more extended) and a higher amplification of knee joint waveforms would result in an increased wrist joint velocity.

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) who were playing at a 1st grade level in a state premier 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. Marker trajectory data were collected using a 12-camera MX-13 motion capture system (Vicon Motion Systems Ltd, Oxford, UK; 250 Hz). A full body marker set (Chin et al., 2009; Middleton et al., 2016) consisting of 64, 12-millimetre retro-reflective markers, was affixed to the trunk, pelvis and the lower and upper limbs. Participants were instructed to bowl five sets of six consecutive deliveries (n = 30) at 'match intensity' (n = 20), 'maximal effort' (n = 5) and a 'slower ball' variation (n = 5) while aiming at a target marked 0.3 m above and 0.3 m to the left of the top of the off stump (for a right-hand batsman). A small rest was provided between sets of deliveries to replicate match conditions.

Vicon Workstation software 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 direct kinematic models (Besier et al., 2004; Campbell et al., 2009a, 2009b; Chin, et al., 2010).

Trajectory data from the 20 'match intensity' deliveries per participant were exported to MATLAB programming software (MathWorks, Natick, Massachusetts, U.S.A). Each bowler was modelled 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 knee joint flexion-extension was assessed by systematically manipulating knee joint flexion-extension kinematic profiles in the forward kinematic model (Middleton et al., 2015). The first manipulation involved offsetting knee joint flexion-extension angular displacement waveform by ±20° in steps of 2°. The second manipulation involved constraining the amplification of knee joint flexion-extension angular displacement waveforms, in which the knee flexion-extension angles at front foot impact and ball release were constrained to the empirical values and rotated to zero (slope = 0). The remainder of the angular displacement waveform underwent amplification (multiplication) by a factor ranging from 0 to 2 in steps of 0.1. The waveform was then rotated back to empirical values for front foot impact and ball release values, resulting in both an increase in range of motion and angular velocity.

RESULTS: At the time of ball release, empirical resultant wrist velocity was 23.0 ± 0.9 m/s. Knee joint flexion-extension angular displacement offset had a negative linear relationship (R^2 = 0.991, SEE = < 0.001) with wrist speed (Figure 1). An offset of -20° increased wrist velocity by a mean of 5.6% (± 9.1%), whereas an offset of 20° decreased wrist velocity by a mean of 3.9% (± 6.8%). The mean decrease in wrist velocity was 0.9% for every 2° increase in knee joint flexion offset.

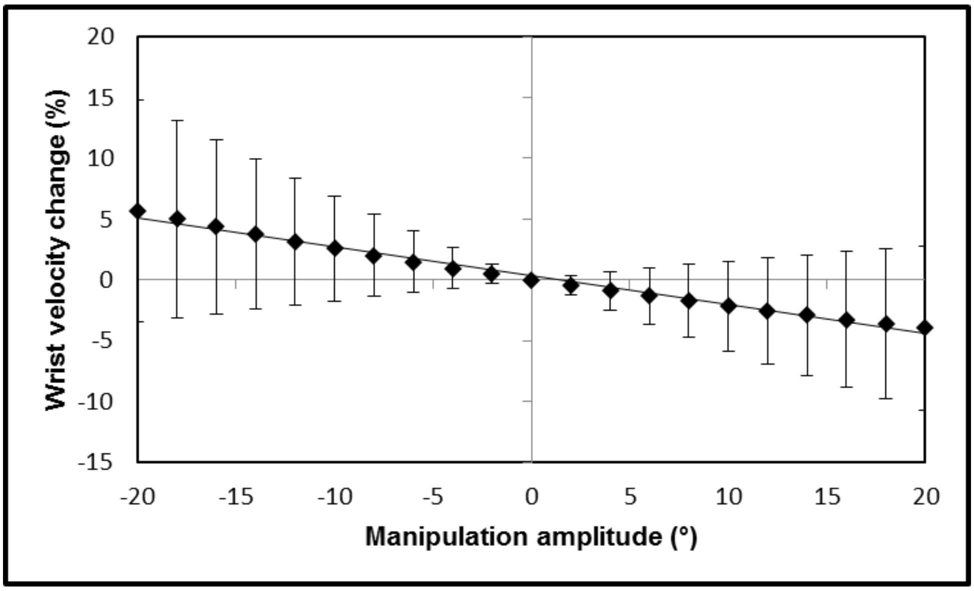

Figure 1: Mean change in wrist velocity (%) for manipulations of between 20° extension (-) and 20° flexion (+) of empirical knee angle waveforms in steps of 2°. Error bars represent ± SD.

Knee joint flexion-extension angular displacement amplification had a positive linear relationship (R^2 = 0.999, SEE = < 0.001) with wrist velocity (Figure 2). A manipulation factor of zero decreased wrist velocity by a mean of 28.5% (± 13.8%), whereas a manipulation factor of two increased wrist velocity by a mean of 29.9% (± 14.2%). The mean increase in wrist velocity was 2.9% for every 0.1 increase in amplification factor.

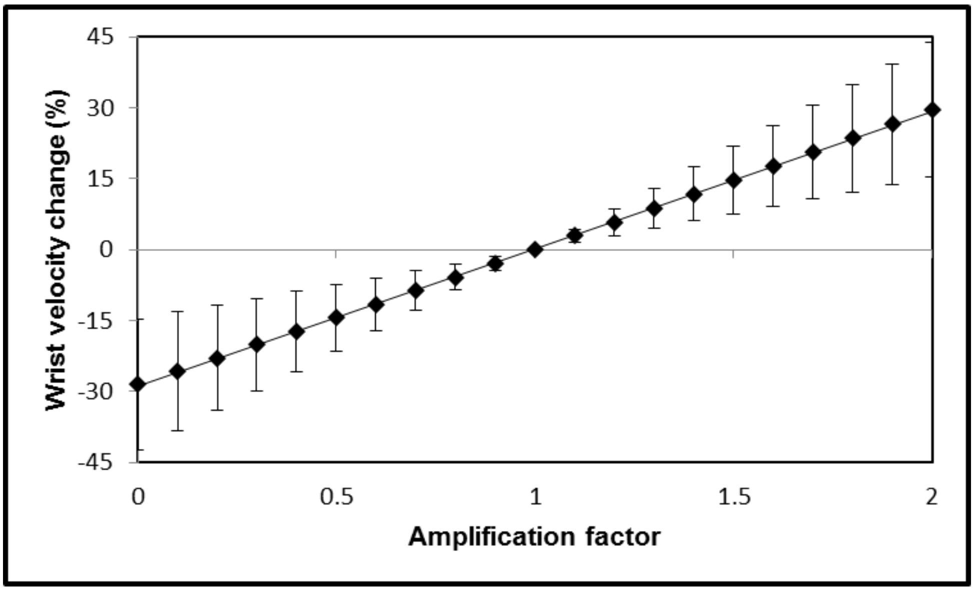

Figure 2: Mean change in wrist velocity (%) for an amplification factor of between 0 and 2 of empirical knee flexion-extension angle waveforms in steps of 0.1. Error bars represent ± SD.

DISCUSSION: This study sought to assess the sensitivity of wrist joint speed to systematic manipulations of knee joint flexion-extension kinematic profiles. Wrist joint centre velocity was shown to be sensitive to both knee joint kinematic offset and amplification. Knee flexion-extension offset had a significant relationship with wrist joint velocity. A 20° extension offset resulted in a 5.6% increase in wrist joint velocity and a 20° flexion offset resulted in a 3.9% decrease in wrist joint velocity. This supports the numerous studies that have suggested that having an extended knee from front foot impact to ball release is advantageous as the bowler can use the fixed lower limb as a lever (Davis & Blanksby, 1976; Elliott & Foster, 1984; Elliott, Foster & Gray, 1986), increasing the distance between the foot and the ball.

An amplification factor of 2 applied to knee joint flexion-extension resulted in a wrist joint velocity increase of 28.5%. It seems that as the group were extending the knee joint up to ball release, the larger range of motion and angular velocity created an increase in wrist joint velocity. Given that the gain in wrist joint velocity was up to 28.5% for an amplification of empirical knee flexion-extension, the angular extension velocity prior to ball release seems to be more important than the discrete angle at ball release. This adds support to the proposal that the 'flexor-extender' knee action (Portus, Mason, Elliott, Pfitzner & Done, 2004) is the ideal front knee action, where the initial flexion may aid in reducing impact forces and the extension prior to ball release will increase wrist joint velocity (Bartlett, Stockill, Elliott, & Burnett, 1996) by introducing a stretch-shorten cycle of the quadriceps and increasing the height of release (Portus et al., 2004).

This study was subject to a number of limitations. Unfortunately, small changes to the position of the ball while in the bowling hand, and its associated velocity component, could not be modelled. Therefore, the velocity of the wrist at release reported in this study does not contain this component and may in part contribute to the lower velocities of the current sample than previously reported literature. However, it is important to note that the relationships detected would not be adversely affected by reasonable changes in ball velocity. In addition, only resultant wrist velocity was measured without consideration for the direction of travel of the ball. Further work in the area will include measures of tri-planar wrist joint velocity and trajectory. The changes in joint kinetics were not quantified with respect to empirical and manipulated joint kinematics. Using inverse dynamics, the necessary kinetics required to elicit those kinematic changes could be approximated.

CONCLUSION: The cricket bowling technique uses many joint rotations to impart linear velocity on the ball. A cricket bowling specific forward kinematic model was developed to describe the relationships between knee joint kinematics on wrist joint velocity. A joint angular offset of the knee revealed to have a strong linear relationship with wrist joint velocity. The importance of the range of motion and angular velocity of segments were identified by the large gains in wrist joint velocity with empirical waveform amplification. Increased rates of knee extension resulted in large wrist joint velocity gains. The results support the notion that a flexor-extender knee joint technique is ideal for cricket pace bowlers.

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