ANGULAR IMPULSE MOTION-EFFECTS ON FRONT-LEG TECHNIQUE IN CRICKET BOWLING

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The purpose of this study was to determined whether front-leg technique is predominantly dependent on local joint torques or the result of non-local cumulative effects of dynamics generated elsewhere in the kinetic link chain. Elite young fast bowlers (n=13) were recruited for a motion analysis of their bowling actions in a biomechanics laboratory. Knee joint angular impulse motion-effects were calculated from kinematics and kinetics data of the front leg. Fast bowling actions were classified according to front-leg technique and their changes in front knee extension-flexion angle related to corresponding joint angular impulse motion-effects. The majority of bowlers (61.5%) bowled with a flexed front knee. Knee flexion-extension angle was not significantly correlated with ball speed. Only 3.4% of knee extension-flexion periods were subject to an active angular impulse motion-effect. These results imply that fast ball release speeds can be achieved with different front-leg techniques and that the knee extension-flexion angle in fast bowlers is dependent on motions ocurring away from knee joint, remotely located in the kinetic link chain.

KEYWORDS: cricket, fast bowling, front-leg mechanics, joint angular impulse

INTRODUCTION: In cricket, fast bowlers release the ball at high speed towards a batter, who must strike the ball to score runs or defend the wicket. A critical part of the fast-bowling action involves the mechanics of the front leg, which acts analogously as a dynamic lever connecting the ground to the pelvis. The coaching literature generally recommends that bowlers of all types (fast, medium, and spin) adopt a braced front leg during the entirety of the bowling action, from front foot contact to ball release, where braced generally refers to a rigid front leg with a fully extended knee (Bartlett et al., 1996), a technique that is thought to confer an optimal transfer of momentum from the run-up to the bowling action. In addition, some biomechanics research literature tends to support the technique of bracing the front leg, linking faster bowlers with a more extended front knee at front foot contact and the instant of ball release (Worthington et al., 2013).

The problem for researchers becomes more complex, because many types of front leg techniques exist. Portus et al. (2004) classified front knee motion into four different types: flexor, extender, flexor-extender, and constant brace. However, they found no significant relationship between front leg technique and ball speed, although it was commented that the extender and flexor-extender techniques tended to higher ball speeds, and the flexor group tended to generate lower peak horizontal and vertical ground reaction forces. A comparatively moderate relationship was found by Worthington et al. (2013), who studied a sample of 20 elite fast bowlers, reporting that the front knee angle at ball release explained 13.4% of the variance in ball speed.

Fast bowlers in elite squads throughout the world are encouraged to bowl with an extended front knee, not only as part of an attempt to produce higher ball speed, but also to gain extra release height. The question has therefore become one of determining an effective means of teaching bowlers to achieve an extended front knee technique. A direct intervention approach would entail instructing the bowler to extend the front knee during front foot contact via the contraction of the knee extensors, working on the premise that an independent increase in the knee extension angle will improve the functioning of the entire kinetic link chain. However, induced acceleration analysis of multi-segmental systems show that joint angle is subject to non-local cumulative effects produced remotely in the kinetic link chain (Hirashima et al., 2008). Ferdinands et al. (2014) found indirect evidence of remote cumulative effects on the rear leg drive in fast bowlers by analysing the torque-motion effects on their respective hip and knee joints: these hip and knee joint angular velocities were generally controlled rather than

actively generated by their respective joint torques. Hence, there is a pressing need to analyse the same for motion of the front knee joint in bowling.
The knee joint angular impulse is calculated from the area the under the knee joint torque-time graph (Stefanyshyn, 2006), from which the angular impulse motion-effect on the knee joint angle can be inferred by observing the change in knee extension-flexion angle, a method of quantifying the partial interaction kinetics and angular kinematics of the knee joint. The aim of this study was to analyse the front leg kinematics and the angular impulse motion-effects on the knee extension-flexion angles of a sample of young elite fast bowlers during the arm-acceleration phase. By categorising the angular impulse motion-effect on the knee joint angular kinematics as controlled, active, or negligible, we can determine the extent to which knee extension-flexion angle is influenced by non-local cumulative effects. We hypothesised that changes in knee extension-flexion angle are dependent on the effect of body segment motions ocurring at locations in the kinetics link chain remotely located from the knee joint.

METHODS: Thirteen young fast bowlers (17.0 ± 1.5 years) were recruited from the NSW development cricket squad. A Cortex Motion Analysis System (Version 1.0, Motion Analysis Corporation Ltd., USA) was used to capture the three-dimensional (3D) motion (200Hz) and force plate (1000 Hz) data from 6 bowling trials. Each bowler was instructed to bowl at maximum effort and pitch the ball within a 'good length' area within two white lines, 13 m and 19 m from the stumps at the bowler's end. Trials were considered successful when bowlers made separate rear and front foot contacts on two of the three Kistler force plates (Model 9287BA, Kistler, Switzerland) placed lengthwise in the lab. Using virtual markers, the centre of joint rotation was calculated for pelvis, front thigh, front shank, and front foot (Ferdinands et al. 2004). The fastest ball was chosen for analysis from front foot contact to ball release.
The kinematic data were smoothed at a cut-off frequency of 15 Hz using a fourth-order Butterworth filter before being used as input to a 3-D 4-segment inverse solution model of the human body using Visual3D software (Version 5, C-Motion, Germantown, MD). An x,y,z Cardan sequence of rotation was used to express the following inter-segmental joint angles and joint angular impulses. Joint angular impulses were generated by calculating the areas under the joint torque curves that corresponded to discrete periods of knee extension and flexion in the joint angular kinematics data (Stefanyshyn et al., 2008).
Based on knee flexion-extension angles, front knee action was categorised into three classes: bracer, extender and flexor – which in turn gave rise to nine front knee techniques (constant bracer, flexor-bracer, extender-bracer, continuous extender, flexor-extender, bracer-extender, continuous flexor, bracer-flexor, and extender-flexor – an extension of the classification system used by Beach et al. (2016). Furthermore, front knee technique was augmented with front-leg lever-type, which was defined on the knee flexion-extension angle at ball release, based on values measured in baseball pitching (Manzi et al., 2022): straight-leg (SL) lever, front knee angle ≥ 150º; bent-leg (BL) lever, front-knee angle < 150º.
To add a kinetics qualification of knee action types, we calculated the joint angular impulse-effect on knee joint angle, which is modification of the concept of joint torque-effect that was applied to rear leg motion in fast bowlers by Ferdinands, Sinclair, Stuelcken, and Green (2014). The percentile ranks (P) of the absolute values of normalised knee joint angular impulse from the sample were used to quantify the strength of the angular impulse-effect: $P \leq 25$, negligible; $25 < P \leq 50$, moderate; $P > 50$, strong. When normalised joint angular impulse acted in the same direction as the change in joint knee flexion-extension angle then corresponding effect was active; otherwise, it was controlled. Pearson correlation coefficients were determined for kinematics and kinetics variables.

RESULTS: Table 1 shows the results of the study, classifying front-leg technique, front-leg lever type from knee joint angular kinematics, and rating the strength of the joint angular motion-effect from the percentile rank of joint angular impulse scores. The bowlers grouped under each of the front-lever types were six bracer-flexors, four flexor-extenders, two flexors, and one extender-bracer. Most bowlers (61.5%) bowled with a bent-leg lever. Most angular impulse motion-effects on knee flexion-extension were moderate-strong controlled (55.2% of all knee extension-flexion periods). 35.5% of the angular impulse motion-effects on knee extension-flexion angle were negligible. 6.9% of knee extension-angle periods were subject to stabiliser impulse motion-effects. Only 3.4% of such knee extension-flexion periods were subject to an active angular impulse motion effect. Increase in knee extension angle in the extender class and the extender-bracers (bracer class) was correlated with a more extended knee at ball release ($r = 0.870$, $p < 0.001$). Neither the change in knee flexion angle in the last period of change prior to ball release nor the front knee angle at ball release were significantly correlated with ball speed ($p > 0.50$).

Table 1: Classification of front leg technique and angular impulse motion-effect based on percentile ranks of normalised knee joint angular impulse data.

Sub	Knee Extension-Flexion Periods (% Phase)	Change in Knee Angle *Extension + Flexion -*	Front leg Lever Type *Bent-Leg (BL) Straight-Leg (SL)*	Knee Action Technique	Percentile Rank (P) of joint angular impulse	Angular Impulse Motion-Effect
1	0 – 100%	-45.8º	126.4º (BL)	Flexor	57.5	Strong Controlled
2	0 – 7%	<10.0º		N/A	7.5	Negligible
	8 – 58%	-17.7º	175.8º (SL)	Flexor	45.0	Moderate Controlled
	59– 100%	+19.7º		Extender	32.5	Moderate Active
3	0 – 19%	<10.0º		(Bracer)	5	Negligible
	20 – 56%	- 12.5º	178.8º (SL)	Flexor	62.5	Strong Controlled
	57 – 100%	+18.7º		Extender	52.5	Strong Controlled
4	0 – 30%	+10.9º		(Extender)	10	Negligible
	31 – 66%	-15.5º	175.0º (SL)	Flexor	67.5	Strong Controlled
	67 – 100%	+17.3º		Extender	37.5	Moderate Controlled
5	0 – 100%	-54.6º	110.9º (BL)	Flexor	80	Strong Controlled
6	0 – 29%	<10.0º	147.6º (BL)	Bracer	35.0	Moderate Stabiliser
	30 – 100%	- 27.2º		Flexor	22.5	Negligible
7	0 – 22%	<10.0º	138.4º (BL)	Bracer	42.5	Moderate Stabiliser
	23 – 100%	- 27.2º		Flexor	72.5	Strong Controlled
8	0 – 20%	<10.0º	121.8º (BL)	Bracer	2.5	Negligible
	21 – 100%	- 44.9º		Flexor	95	Strong Controlled
9	0 – 19%	<10.0º	127.8º (BL)	Bracer	25	Negligible
	20 – 100%	- 37.4º		Flexor	100	Strong Controlled
10	0 – 27%	+12.4º	172.6º (BL)	Extender	47.5	Moderate Controlled
	28 – 100%	<10.0º		Bracer	27.5	Negligible
11	0 – 25%	<10.0º	125.7º (BL)	Bracer	12.5	Negligible
	26 – 100%	-39.2º		Flexor	87.5	Strong Controlled
12	0 – 23%	+10.2º		(Extender)	50	Strong Controlled
	24 – 59%	-16.2º	190.0º (SL)	Flexor	15	Negligible
	60– 100%	+20.9º		Extender	65	Strong Controlled
13	0 – 27%	+12.3º		(Extender)	70	Strong Controlled
	27 – 80%	-19.8º	154.7º (SL)	Flexor	40	Moderate Controlled
	80 – 100%	<10.0º		Bracer	15	Negligible

DISCUSSION: The biomechanics and coaching literature generally recommend that fast bowlers learn to execute a straight front-leg lever at the time of ball release. For this reason, the extender class of front-leg techniques is recommended. Therefore, the major aim of this study was to analyse the knee joint angular impulse motion-effects in relation to their respective front-leg techniques to determine whether changes in knee flexion angle are caused by local joint torques or non-local cumulative effects.

The preliminary kinematic analysis showed that most bowlers (61.5%) were of the flexor class with a bent-leg lever type: 6 bracer flexors and 2 flexors. This result was similar to that of Portus et al. (2004) who found that 59.5% of bowlers favoured the flexor technique. Hence, in both these studies, the recommended intervention would be for the flexors to modify their techniques, increasing the amount of knee extension during the arm acceleration phase. However, in this study, neither the change in knee extension-flexion angle nor the knee extension-flexion at ball release were significantly correlated with ball release speed: a result that is consistent with previous research, as only a weak-moderate relationship between knee extension-flexion angle and ball release speed has been found in previous studies (Portus et al., 2004; Worthington et al., 2013). Relatively low sample rates may explain this relatively moderate relationship, but the flexor group tends to be the predominant front knee technique in these samples and is also favoured by many of the world's best fast bowlers, such as Lillee (Aus), Marshall (WI), Hadlee (NZ), Tyson (Eng), and Akram (Pak).

Consistent with the hypothesis of this study, only one period of knee extension-flexion angle was subject to an active angular impulse-motion effect. The remaining periods were subject to controlled (55.2%), negligible (35.5%), and stabiliser (6.9%) angular impulse-motion effects. In addition, 41.4% of all angular impulse-motion effects were strong controlled (Table 1). This result has important implications for the coaching intervention prescribed to alter knee angle. Even if it is assumed that the braced front leg is optimal, the intuitive approach of issuing a direct instruction to the bowler to extend the front knee upon front foot contact is not advisable, since the front knee extension-flexion torque does not actively influence the change in knee extension-flexion angle. In other words, the change in knee extension-flexion angle in functional bowling actions is casually influenced by segmental motions remotely located from the knee joint, either through segment interactions or non-local induced cumulative effects, a result that is theoretically consistent with segment interaction analysis (Putnam, 1991) and induced-acceleration analysis (Hirashima et al. 2008).

Future research should address the limitations in this study, such as the relatively small sample bowlers who were trained under a single coaching pathway. In addition, it should also be ascertained whether there are mechanical principles that explain the predominance of the flexor class of front leg techniques in bowling samples, and their effective use by many of the world's leading fast bowlers..

CONCLUSION: This study analysed the joint angular impulse motion-effect on knee extension-flexion angle of the front leg in a sample of young elite fast bowlers. The preliminary data suggest that bowlers primarily modulate knee extension-flexion angle through the non-local cumulative effects of dynamics throughout the kinetic link chain. Hence, if the recommended practice of increasing knee extension during front foot contact is to be implemented, coaches may need to achieve much of this change non-locally, by modifying segment motions located remotely from the knee joint.

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