THE EFFECT OF SELECTED KINEMATICS ON BALL SPEED AND GROUND REACTION FORCES IN FAST BOWLING

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Lumbar stress fractures and lumbar injury account for the greatest amount of lost playing time in international cricket. Previous research has associated lower back injury with large peak ground reaction forces occurring during the front foot contact phase of the fast bowling action. Selected kinematics of the bowling action of 16 elite male fast bowlers were measured using an 18 camera Vicon Motion Analysis System. Ground reaction forces during front foot contact and ball release speed were recorded; correlations with kinematic factors were identified using Pearson's correlation coefficient. Ball release speeds were correlated with run-up speed, plant angle and the motion of the front knee during the period of front foot contact. Knee flexion during the first 15 frames of the front foot contact phase was correlated with increased peak vertical force and decreased peak horizontal loading rate. The use of a heel strike technique at the instant of front foot contact was correlated with decreased peak vertical force and loading rates. All correlations observed were moderate in strength, representing the multifactorial nature of the generation of ball speed and ground reaction forces. This study motivates future investigation of the effects of these selected kinematic factors on forces occurring above the knee, and the effect of kinematic factors on the performance of an individual bowler.

KEY WORDS: fast bowling technique, cricket, ball release speed, ground reaction forces.

INTRODUCTION: Fast bowlers have the highest injury prevalence in professional cricket (Newman, 2003; Orchard, *et al*., 2006), the most common cause being lumbar stress fractures and lumbar injury (Newman, 2003). These injuries occur predominantly on the opposite side to the bowling arm (contralateral side) (Gregory, *et al.*, 2004; Ranson, *et al.*, 2005). The high incidence of lower back injuries in fast bowlers is thought to be the result of a combination of factors, including: incorrect technique; poor preparation; overuse; age; and clinical features (Bell, 1992). Research, however, has focussed on bowling technique due to reported relationships between aspects of technique and the appearance of radiological abnormalities (Elliott, *et al.*, 1992, 1993; Burnett, *et al.*, 1996).

Previous researchers (Bartlett, *et al.*, 1996; Ranson, *et al.*, 2008) suggested large peak ground reaction forces during the front foot contact (FFC) phase, together with lateral flexion, hyperextension and rotation of the lower back, could be the major cause of lower back injuries. The purpose of this investigation was to further the understanding of the effect of selected kinematic variables on ball speed as well as the magnitude and rate of build up of ground reaction forces during the period of FFC.

METHODS: Data Collection: Sixteen elite male fast bowlers (mean ± standard deviation: age 22.3 ± 2.6 years; height 1.88 ± 0.08 m; body mass 81.5 ± 6.1 kg) performed 6 maximum pace deliveries in an indoor practice facility, using their full length run-up. Kinematic data were collected using an 18 camera Vicon Motion Analysis System (OMG Plc, Oxford, UK) operating at 300 Hz. Forty-three 14 mm spherical retroflective markers were attached to each subject, positioned over bony landmarks, in accordance with an 18 segment full-body model developed for the analysis of fast bowlers. An additional marker, in the form of a 1.5 cm x 15 cm patch of 3M Scotch-Lite reflective tape was attached to the ball, enabling ball speed and the instant of ball release to be identified. A Kistler force plate (900 x 600 mm), with a thin layer of artificial grass fixed to its surface, was used to measure ground reaction forces during the FFC phase (1008 Hz).

Data Analysis: Trials were manually labelled and the best three selected for each bowler (maximum velocity with minimal marker loss). The instants of back foot contact (BFC), FFC and ball release (BR) were identified in the kinematic data and used to synchronise the force data. Kinematic data were filtered using a fourth-order low pass Butterworth filter (double pass) with a cutoff frequency of 30 Hz.
Kinematic parameters were determined for each bowler, describing: run-up velocity (at BFC); plant angle (Figure 1) and motion of the front knee during FFC; the manner of footplant at the instant of FFC (heel strike or otherwise); and the ball release speed. Subject-specific segmental properties were determined using Yeadon's (1990) geometric model.

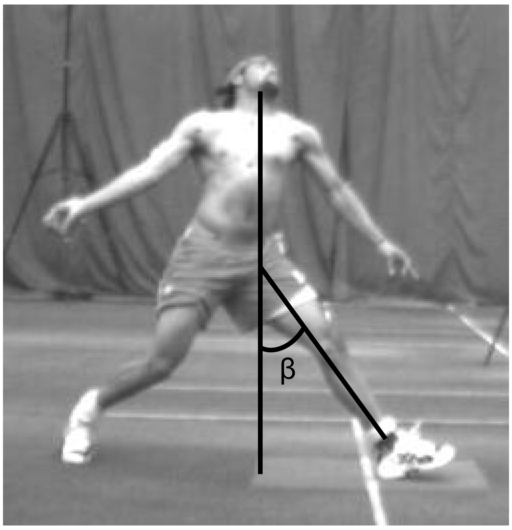

Figure 1: Illustration of the plant angle (β) at the instant of front foot contact.

Descriptive parameters calculated for the ground reaction forces (Figure 2) consisted of: horizontal (braking) and vertical peak forces; peak vertical loading rate (PVLR) and peak initial loading rate (PILR) (as defined by Hurrion, *et al.,* 2000); peak horizontal loading rate (PHLR); and horizontal and vertical impulse up to BR. Correlations between parameters were assessed using Pearson's correlation coefficient.

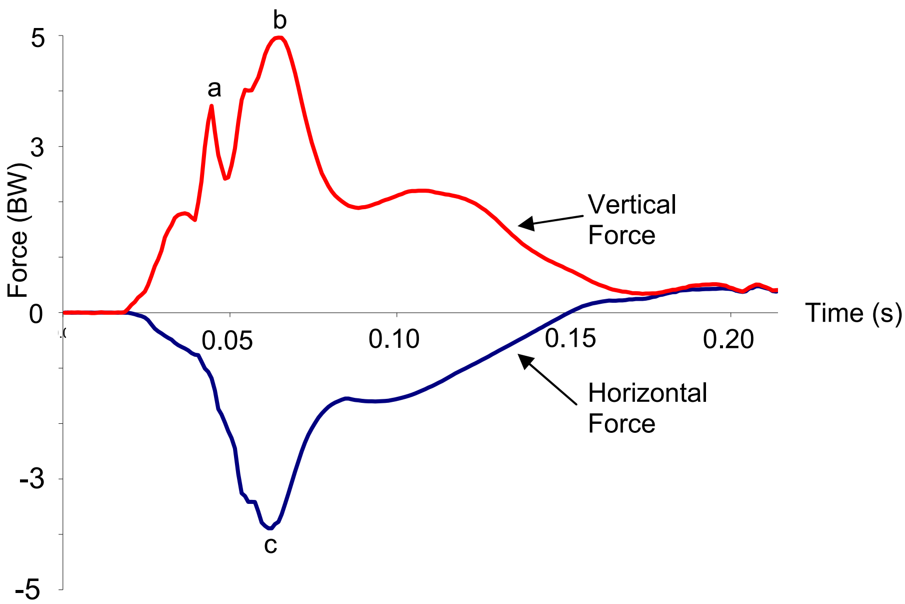

Figure 2: A typical force trace during the front foot contact phase.
[a – initial peak vertical force; b – peak vertical force; c – peak horizontal force]

RESULTS:

Table 1 Details of significant correlations (P<0.02)

Variable	Correlated to	R	P-Value
Ball Speed	Run-up Speed	0.449	0.001
	Plant Angle	0.450	0.001
	Knee Flexion up to BR	-0.434	0.002
	Knee Flexion in Initial 15 Frames of FFC Phase	-0.497	0.000
	Horizontal Impulse to BR	0.561	0.000
	Vertical Impulse to BR	0.339	0.018
Peak Vertical Force	Knee Flexion in Initial 15 Frames of FFC Phase	0.364	0.011
	Heel Strike? (1 = Yes; 0 = No)	-0.486	0.000
Peak Horizontal Force	Run-up Speed	0.378	0.008
PVLR	Heel Strike? (1 = Yes; 0 = No)	-0.618	0.000
PILR	Heel Strike? (1 = Yes; 0 = No)	-0.481	0.001
PHLR	Knee Flexion in Initial 15 Frames of FFC Phase	-0.525	0.000
	Heel Strike? (1 = Yes; 0 = No)	-0.623	0.000

DISCUSSION: Previous research into ground reaction forces during the FFC phase of the fast bowling action have reported mean peak vertical and braking forces of 3.8 – 9.0 BW and 1.8 – 3.54 Body Weights (BW), respectively (Hurrion, *et al.*, 2000). The mean peak forces of 6.66 (± 1.48) BW vertically and 4.57 (± 0.90) BW horizontally in this group of bowlers, although higher than the mean values reported in previous studies, are similar to those of individuals reported in the literature. These relatively high peak forces may be attributed to the elite nature of the subjects (mean ball speed 35.10 (± 1.77) $m.s^{-1}$ and mean approach speed 5.83 (± 0.60) $m.s^{-1}$).

The goal of a fast bowler is to release the ball as quickly as possible, whilst retaining accuracy, ideally using a technique which does not predispose them to injury. Within this group of fast bowlers, correlations were observed between ball release speed and: run-up speed; plant angle; and the motion of the front knee during the FFC phase.

Ball speed was positively correlated with run-up speed; bowlers with a faster approach speed have more kinetic energy which can be potentially transmitted to the ball. However, run-up speed was also related to the peak horizontal force produced during FFC. A positive correlation was also observed between ball speed and plant angle. By adopting a wide stance (characterised by a large plant angle), bowlers are well positioned to generate large forces with their front leg, enabling run-up speed to be converted into rotational energy about the plant foot.

Bowlers exhibiting greater knee flexion between the instant of FFC and BR tended to release the ball at lower speeds. This appears to support previous relationships reported between release height (as a percentage of standing height) and ball speeds (Bartlett, *et al.*, 1996). However, no direct relationship between the knee angle at BR and ball release speeds was observed.

Knee flexion during the first 15 frames of the FFC phase was correlated with increased peak vertical force and decreased PHLR, as well as ball speed. This appears to contradict previous suggestions that knee flexion during the FFC phase dissipates ground reaction forces (Foster, *et al.,* 1989; Portus, *et al.,* 2004). However, the correlations observed in this investigation should remain in context – they represent relationships betweeen variables in a group of bowlers, rather than the effect of changing the kinematics of a particular bowler. Further investigation into the inter-relationships between these variables is warranted and should investigate the effect of the front knee kinematics on the forces above the knee, as well as at the foot-ground interface.

These relationships observed between kinematic factors and ball release speed are perhaps explained by the correlations observed between the horizontal and vertical impulses (between the instant of FFC and BR) and ball speed. Smaller peak loading rates (PVLR, PILR and PHLR) and peak vertical force were associated with the use of a heel strike technique at the instant of FFC. The moderate correlations observed in this investigation are indicative of the multifactorial nature of the generation of ball speed and ground reaction forces.

CONCLUSION: This study shows that ball release speeds are related to run-up speed, plant angle and the motion of the front knee during the period of FFC. The use of a heel strike technique at the instant of FFC was found to decrease peak vertical force and loading rates. Further investigation is required to establish the effect of changing particular kinematic variables on the performance of an individual subject, rather than relationships within a population. Future work should investigate peak forces and loading rates above the knee as well as at the foot-ground interface.

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