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Biomechanical factors contributing to effective bowling in cricket: A review study

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Abstract
Introduction: Cricket team consists of eleven players. Depending on his or her primary skill, a player may be classified as a specialized batsman or bowler. A well balanced team usually has 5 or 6 specialist batsman and 4 or 5 specialist bowlers. Each team is headed by a captain who is responsible for making tactical decisions such as determining batting order, the placement of the fielders and the rotation of bowlers. Literature is review to create the content from the past for the new study to be conducted with new subjects and newly obtained data.
Objective: The objective of this study is to critically evaluate the scientific study related to the biomechanics of bowling for better bowling performance in cricket.
Methods: This article critically reviews the biomechanical factors which contribute to the bowling skill in cricket from referred published research work unpublished thesis. The scholar identified very few studies which directly focus on the outcomes of a bowler in cricket.
Conclusion: biomechanical factors like horizontal velocity, long delivery stride length, anthropometric, kinematic, temporal and kinetic parameters, shoulder counter-rotation is related with better performance of ball release speed during fast bowling in cricket.

Keywords: Biomechanical factors, contributing, effective bowling, study

Introduction
Today, in the modern competitive cricket era, every cricket player is in a race to excel others, and cricket competitions have become fundamental mode of human expression as they are one of the very important functions by which National and International recognition and prestige is gained. From its very simple from cricket has emerged into highly organized activity of Indian society and it has become a complex social and cultural phenomenon. Cricket has permeated most of our social institutions including education, economics, art, politics, law, mass communication and international diplomacy.
In a sample of nine male fast-medium bowlers, Glazier *et al*. (2000) [8] reported a high correlation between ball release speed and the length of the bowling arm. Anthropometric dimensions and morphological characteristics play an important role in determining the success of a sportspersons (Rico-Sanz, 1998; Wilmore, & Costill, 1999; Keogh, 1999) [1, 2, 3]. The importance of passing, length arm has been stated by Irwin (1971) as athletes and players who have longer arm might do well to use the better grip because it provides better control over the skill. Chest girth and composition and body composition were significantly related to ball release speed at various times during the spell. Fast bowling is fundamental to all forms of cricket (Wormgoor, Harden, and Mckinon, 2010) [4]. Chest girth and composition and body composition were significantly related to ball release speed at various times during the spell. Body size had a strong positive influence on bowling performance in a heterogeneous population of different ages.
The fast bowling action can be classified as side-on, front-on, semi-front-on or mixed depending on the orientation of the shoulder± hip axes and back foot alignment during delivery. Bowlers who use the side-on and front-on techniques are not at as much risk of injury as those who use the mixed technique. The semi-front-on action is a new technique that is based on the same principles as the two `safe actions', where the alignment of the shoulders and hips are in the same direction. A combination of these factors has been linked to an increased incidence of radiological features in the thoracolumbar spine, including

spondylolysis, inter-vertebral disc degeneration and spondylolisthesis (Foster *et al.*, 1989; Elliott *et al.*, 1992; Burnett *et al.*, 1996) [5]. Spondylolisthesis was reported in50% of A-grade fast bowlers over a period of 5 years by Payne *et al.* (1987) [14] and has been found to represent 45% of bony abnormalities reported by retired, elite fast bowlers (Annear *et al.*, 1992) [1].

Main Part

Sankar, C.K. (2011) [17] conducted a study entitled as **"**The Relationship between Anthropometric and Kinematic Variables and Ball Release Speed in Men's Slow-Medium Bowling". Twelve male slow-medium bowlers (age=21.33 ± 1.87years), representing various cricket clubs, playing at the divisional level of Coimbatore city voluntarily took part in the study.

The relationship between selected anthropometric variables and ball release speed and kinematic variable and ball release speed was identified using Pearson's product moment correlation coefficients. The kinematic variable of delivery stride length (112.1 ± 10.4cms, r=0.611, $P<0.05$, $r^2=0.373$) was strongly related to ball release speed (87.33kph ± 4.53kph). This strong positive correlation suggests that bowlers with long delivery stride lengths are able to achieve greater ball release speed. Coefficient of determination ($r^2=0.373$) indicates 37.3% of the variance between delivery stride length and ball release speed and the remaining 63.6% of the variance is due to other factors of bowling.

High correlation was identified between the leg length (93.59 ± 4.37cms, r=0.578, $P<0.05$, $r^2=0.334$) and ball release speed and total height (175.9 ± 8.56cms, r=0.582, $P<0.05$, $r^2=0.338$) and ball release speed in this group of bowlers. A high correlation between leg length and height and ball release speed suggests that tall bowlers with long legs are able to release the ball with higher speeds. The variance between leg length and ball release speed and height and ball release speed was 33.4% and 33.8% respectively. From the above results it can be hypothesized that anthropometric characteristics of the bowler contribute significantly to the ball release speed. Upper limb length has been found to have high correlation with ball release speed. These influences of limb length combined with bowling technique explain why world-class fast bowlers are tall.

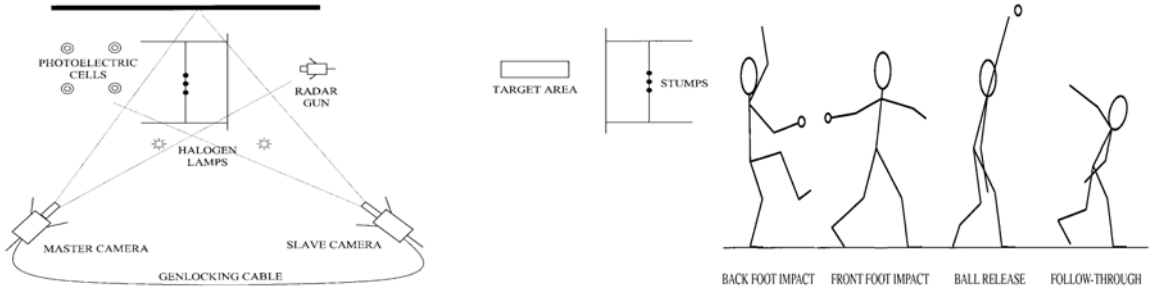
N.P. Stockill and R.M. Bartlett. (1992) [18] conducted a study "A Three Dimensional Cinematographically Analysis of The Techniques of International and English County Cricket Fast Bowlers ". Seventeen elite fast and fast medium bowlers (classified as such by Abernethy, 1981) [6] were filmed during the 1991 season at Test and Britannic Assurance County Matches and Preal Tanged Open Net Sessions. The ball release speeds (37.4±1.87m.s-[1]). The analysis of Run up speed was found to be positively correlated (r=O.55, p<O.05) with ball release speed, though due to the limited ($8m^3$) calibration volume utilised, producing unusually high approach speeds (6.81 *m.s-[J]),* these result must be treated with caution. Possibly due to these inaccuracies no relationship was found between run up speed and the angle of the back foot, hips or shoulders at back foot contact. Significant relationships were found between the angle of back foot and the hips at back foot (r=0.73, p<0.05) and front foot contacts (r=0.60, p<O.05), and also between the angle of the back foot and the shoulders at back foot contact (r=0.51, p<0.05). These findings are consistent with previous work which has suggested that the attainment of a side-on position, as measured by shoulder angle, is largely dependent upon the angle of the back foot at back contact. From a coaching perspective this finding suggests implications in terms of the importance placed on correct placement of the back foot, and the subsequent choice of the con·ect type of technique (Side-On or Front-On) that is coached for individual bowlers.

K D. Aginsky, L Lategan, R A Stretch (2004) [11] conducted **"**Shoulder injuries in provincial male fast bowlers — predisposing factors "To investigate the relationship between shoulder flexibility and isokinetic strength as possible factors that may predispose provincial fast bowlers to shoulder injuries. Twenty-one players, 12 of whom had no history of shoulder injuries and 9 of whom had experienced a shoulder injury to the bowling arm, were assessed for shoulder strength using a Cybex Norm isokinetic dynamometer. Absolute and relative peak torque measures were obtained at isokinetic speeds of 90°/s and 180°/s, with both concentric and eccentric contractions performed. Shoulder flexibility was tested using a Leighton Flexometer in both internal and external shoulder rotation. The bowlers were classified as front-on (N = 7), side-on (N = 7) and semi-front-on (N = 7). Of these, 12 had not sustained a shoulder injury to their bowling arm, while the other 9 had sustained a chronic shoulder injury to their bowling arm. The results revealed that 5 of the 7 bowlers with a front-on technique had chronic shoulder injuries. Bowlers with the side on and semi front-on bowling techniques reported 2 injuries each, with 1 of these injuries being a chronic shoulder injury. The absolute concentric and eccentric torque measure 90°.s-1 and 180°.s-1 for internal shoulder rotation was not different between the injured and uninjured groups. However, when the concentric internal rotation was weight-normalized, the injured subjects had a higher torque at 180°.s-1 (65.20 ±10.30 versus 45.91 ± 10.26; injured versus uninjured (;p = 0.009).The peak torque values of shoulder external rotation Showed no significant difference between the injured and uninjured groups and within groups between the velocities. The absolute torque ratios between the injured and uninjured subjects for external and internal shoulder rotation showed no significant.

Elissa Phillips, Marc Portus, Keith Davids, Nick Brown and Ian Renshaw (2010) [15] conducted a study entiled as "How do our 'Quicks' Generate Pace? A Cross Sectional Analysis of the Cricket Australia Pace Pathway". Technique and physical contributions to ball delivery speed in fast bowling have been popular research topics in sports science. Thirty, Australian nationally-contracted (NAT, n = 8, age 29.1 + 3.2 yrs), centre of excellence and emerging (EMG, n = 11, age 20.8 + 3.1 yrs) and junior pace squad (JNR, n = 11, age 17.4 + 0.6yrs), fast bowlers performed 30 trials of good, short and full length deliveries at match intensity. Bowling action and coordination were measured from three-dimensional full body movement data captured using a 22-camera VICON motion analysis system (Oxford Metrics Ltd., Oxford, UK)sampling at 250 Hz. The University of Western Australia cluster-based model was used to calculate three-dimensional joint kinematic measures (Lloyd *et al*., 2000) [7]. Full body global and relative joint angles were measured using the conventions outlined in Portus *et al*. (2004) [8]. Ground reaction force (GRF) for back foot contact (BFC) and front foot contacts (FFC) were collected at1000 Hz (Kistler, Amherst, USA). Anthropometric measures were taken (skin folds, girths, and breadths) following the protocols used by Pyne *et al*. (2006) [9]. A one way analysis of variance with post hoc Scheffé tests was used to determine any differences in anthropometrics between the groups. Pearson's product moment correlation coefficients (r) were calculated to establish the relationship between selected

anthropometric, kinematic, temporal and kinetic parameters and ball release speed both within individual fast bowlers and between skill groups (significance set at $p<0.05$). Correlations were classified in accordance with Hopkins *et al*. (2000) [10] as follows: r<0.01trivial, small 0.1 – 0.3, moderate 0-3 – 0.5, large 0.5 - 0.7, very large 0.7 – 0.9, nearly perfect > 0.9. The EMG group also had significantly greater % muscle mass and chest depth and bi acromial distance compared with the JNR group. The NAT group produced significantly higher ball speeds than the JNR group (125.6 km/h + 6.7 v 120.0 km/h + 3.9, $p = 0.03$). These data were similar to the EMG group (123.1 + 2.5).

Paul S. Glazier, Giorgos P. Paradisis and Stephen-Mark Cooper (2000) [11] conducted "Anthropometric and Kinematic influences on Release Speed In Men' S Fast-Medium Bowling". The main aim of this study was to identify significant relationships between selected anthropometric and kinematic variables and ball release speed. Nine collegiate fast-medium bowlers (mean ± *s*: age 21.0 ± 0.9 years, body mass 77.2 ± 8.1 kg, height 1.83 ± 0.1 m) were l med and reconstructed three-dimensionally. Ball release speeds were measured by a previously validated Speed cheek TM Personal Sports Radar (Tribar Industries, Canada). Relationships between selected anthropometric variables and ball release speed and between kinematic variables and ball release speed were investigated using Pearson' s product± moment correlation coeýcients (*r*).A significant relationship was found between the horizontal velocity during the pre-delivery stride ($r = 0.728$, $P<0.05$) and ball release speed (31.5 ± 1.9 m´ s-1). We believe that the high correlation was due to the bowlers using techniques that allowed them to contribute more of the horizontal velocity created during the run-up to ball release speed. We also found that the angular velocity (40.6 ± 3.4 rad ´ s- 1) of the right humerus had a low correlation ($r = 0.358$, $P > 0.05$) with ball release speed. Although the action of the wrist was not analyzed because of an inadequate frame rate, we found high correlations between ball release speed and shoulder± wrist length (661 ± 31 mm; $r = 0.626$, $P<0.05$) and ball release speed and total arm length (860 ± 36 mm; $r = 0.583$, $P<0.05$).



Parameswari, G. and Gopinath, V. (2012) [13] conducted a study "Body Dimension Among Indian University Women Cricket Bowlers." The purpose of this investigation was to analyze of Anthropometric variables among Indian university women cricket bowlers. Fifty women university cricket bowlers were selected from ten universities (Annamalai University, Thiruvaluvar University, Pune University, Veer Narmod South Gujurut University, Rajasthan University, Andhra University, Kakatiya University, Pondicherry University, Kerala University and Mumbai University) participated in south west inter university women cricket tournament organized by Jiwaji University, Gwalior during the year 2009-2010. The age of the subject ranged from 18 to 25 years as per the eligibility form. Their anthropometric (Length) measurements were taken from Arm span length (ASL), Total arm length (TAL), Arm length (AL), fore arm length (FAL), Hand length (HL), Total leg length (TLL), Thigh length (TL), Lower leg length (LLL), and Foot length (FL) using flexible steel tape to the nearest 0.2 mm. The data was analyzed by using the Pearson's Product Moment Correlation. Results: positive Correlation on the body dimensions found among Indian – university women cricket bowlers on arm span length, total arm length, fore arm length, hand length, leg length, lower leg length, and foot length (p≤ .05 & .01) but upper arm length have no correlation with hand length, total leg length, thigh length and foot length. Conclusion: Anthropometric (length) measurements have strong correlation among the Indian university women cricket bowlers.

Nigel P. Stockill and Roger M. Bartlete (1996) [20] conducted "Possible Errors in Measurement of Shoulder Alignment Using 3-D Cinematography" The aims of this study were: 1). To determine the possible magnitude of errors involved in measuring shoulder alignment and hence hip-to-shoulder separation angles owing to movements of the shoulder girdle. 2It was evident that the most flexible subjects, as determined from the flexibility test performed prior to filming (Table 2), showed larger shoulder axis angle rotations than the less flexible subjects. This trend did not prove to be statistically significant *(P*<0.05*)* in all conditions when tested using Pearson Product Moment Correlations. Significant correlations between shoulder alignment angles and maximal horizontal extension of the left humerus in conditions L2R3 (r=-0.72) and L3R2 (r=0.79) were found.

Portus MR, Sinclair PJ, Burke ST, Moore DJ, Farhart PJ. (2000) conducted "Cricket Fast Bowling Performance and Technique and The Influence of Selected Physical Factors During An 8-Over Spell." The aims of this study were to determine the influence of an 8-over spell on cricket fast bowling technique and performance (speed and accuracy), and to establish the relationship of selected physical capacities with technique and performance during an 8-over spell. Fourteen first-grade fast bowlers with a mean age of 23 years participated in the study. Physical capacities assessed were abdominal strength, trunk stability, selected girth and skinfold measure. During the delivery stride, bowlers were filmed from an overhead and lateral perspective (50 Hz) to obtain two-dimensional data for transverse plane shoulder alignment and sagital plane knee joint angle respectively. Ball speed was measured by a radar gun and accuracy by the impact point of each delivery on a zoned scoring target at the batter's stumps. Shoulder counter-rotation did not change significantly between overs 2 and 8 for all bowlers, but was significantly related to a more front-on shoulder orientation at back foot impact. When the front-on fast bowlers (n = 5) were isolated for analysis, shoulder counter-rotation increased significantly

between overs 2 and 8. Ball speed remained constant while accuracy showed some non-significant variation during the spell. Shoulder counter-rotation was significantly related to accuracy scores during the second half of the 8-over spell. Chest girth and composition and body composition were significantly related to ball release speed at various times during the spell.

Ikram Hussain, Mohd. Arshad Bari & Mohd. Imran conducted a study "Biomechanical Analysis of Flex Elbow on Bowling Speed in Cricket" Six (06) cricket players from Narashans Cricket Academy (NCA), Aligarh were randomly selected for the purpose of the study. They performed bowling during training session. The mean age of the cricket players were age (18.98 years), height – (167.87 cm.), weight (53.29 kg.). For the acquisition of kinematical data, the subject's throwing motion were recorded using Canon Legaria SF-10, 8.1 Mp video camera in a field setting operating at a nominal frame rate of 60 Hz and with a shutter speed of 1/2000 s *and at 60fps* . The camera was set-up on a rigid tripod and secured to the floor in the location at a distance of 12 meter from the point of throw. The camera was positioned perpendicular to the sagittal plane and parallel to the medio lateral axis (camera optical axes perpendicular on the sigittal plane) as their throwing arm giving approximately a 90o between their respective optical axes. The camera was also elevated to 95 cm and tilted down in order to get the image of the subject as large as possible while that all points of interested within one frame. The resultant arm length (rA) decreases as the flexion angle (0) is increased whereas the effective wrist internal rotation axis distance (d) increases (Table 1). With an increase in elbow flexion angle to 35°, the resultant arm length decreases minimally (0.043 m) while distance d increases to 0.167 m. As θ is changed from 5° to 35° the increase in wrist speed due to internal rotation at either 1950 0/s or 46000/s becomes increasingly greater than the loss in wrist speed due to a decrease in forearm length. For example, with an elbow flexion of 35°, the loss in wrist speed due to the decrease in rf is 1.20 m/s while the gain from the use of internal rotation could be between 4.71 m/s and 11.34 m/s.

Jacobus Noël Liebenberg (2010) [12] conducted a study "Kinetics at front foot contact of cricket bowling during a 10-over spell" The purpose of this study was to determine what effect bowling a 10 over spell (60 balls) would have on approach velocity, vertical ground reaction forces and shock attenuation during the front foot contact of a delivery stride in cricket. Ten Amateur cricket players (age 27±4 years, height 1.78±0.3 m, mass 80.6±8.5kg) participated in the study. Testing was conducted at University of Nevada, Las Vegasin the Biomechanics laboratory. Participants performed a 10-over bowling spell from a12 meter run-up. These dependent variables were measured and calculated during the bowling protocol: 1) approach velocity 2) vertical ground reaction force (vGRF) and 3) shock attenuation (SA). A significant change across the 10-over bowling spell were found for approach velocity (p<0.001), vertical ground reaction force (p<0.024) and shock attenuation (p<0.032). Planned comparison tests identified a significant difference (p<0.05) for APV between the beginning (4.34 ± 1.22 m/s) and middle (5.18 ± 1.42 m/s) as well as a significant difference between middle (5.18 ± 1.42) and end (4.13 ± 1.27 m/s). The vGRF results illustrated a significant difference (p<0.05) between the middle (4.09 ± 0.81BW) and the end (3.76 ± 0.58 BW). No significant difference (p<0.05) was found in vGRF between the beginning (4.03 ± 0.69) and the middle (4.09 ± 0.81BW). An overall significant difference was found in SA across all 10 overs. A significant difference was found between the middle (79.48 ± 10.43%) and the end (78.23 ± 10.72%) as well as between beginning and end.

Conclusions

From the analysis of the scientific research paper conducted on fast bowling in cricket the following conclusion may be drawn

1. Bowlers with long delivery stride lengths are able to achieve greater ball release speed.
2. Upper limb length has been found to have high correlation with ball release speed. These influences of limb length combined with bowling technique explain why world-class fast bowlers are tall.
3. There are statistically significant large correlations between SCR and lumbar rotation ROM from BFC to FFC, and from FFC to ball release.
4. There is a moderate correlation between SCR and lateral flexion ROM from BFC to FFC.
5. There is a relationship between selected anthropometric, kinematic, temporal and kinetic parameters and ball release speed.
6. There is a correlation between the horizontal velocities created during the run-up to ball release speed.
7. Anthropometric (length) measurements have strong correlation among the Indian university women cricket bowlers.
8. Significant correlations between shoulder alignment angles and maximal horizontal extension of the left hummers in conditions L2R3 (r=-0.72) and L3R2 (r=0.79) were found.
9. Shoulder counter-rotation was significantly related to accuracy scores during the second half of the 8-over spell.
10. Chest girth and composition and body composition was significantly related to ball release speed at various times during the spell.

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