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The Athletic Profile of Fast Bowling in Cricket: A Review

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Running Head: **Athletic Attributes of Fast Bowling**

Abstract

Fast bowlers have a vital position in a cricket team and there is an increasing body of scientific literature that has reviewed this role over the last decade. Previous research has tended to focus on biomechanical analysis and injury prevention in performers. However, this paper aims to critically review the emerging contribution of physiological based literature linked to fast bowling in cricket and also highlight the current evidence related to simulated and competitive in-match performance. Furthermore, the review considers limitations with past research and possible avenues for future scientific investigation. It is clear with the advent of new applied mobile monitoring technology there is scope for more ecologically valid and longitudinal investigations capturing data in-match, providing quantification of physiological workloads and analysis of the physical demands across differing formats of the game.

Key words: Team sport; Performance monitoring; Ecological validity; Cricket

1.0 Introduction

Fast bowlers are attracting increasing interest with regards to research in cricket as successful performance is linked to teams with these higher 'rated' individuals (44, 55, 56). Whilst fast bowlers are a vital element in the cricket team they typically have the shortest careers in comparison to their peers (16), and as such previous research in this population has had a biomechanical focus linked to injury avoidance and prevention (3, 9, 14). The lack of physiological performance related evidence has led to a hypothetical view of the fast bowler, with a "typical" fast bowler completing approximately 60 episodes of upper and lower body intense actions in a 10 over spell, covering approximately 1.9 km in 5.3 discontinuous minutes (34, 52). A move to address this lack of information has seen recent data presented in cross-sectional player anthropometric and physiological profile investigations (23, 46, 54), movement analysis papers (12, 40) and initial investigations of the physiology of bowling (5, 11, 31).

Within a "fast" bowling group, sub-divisions related to speed of delivery are commonly applied; fast, fast-medium, medium-fast. Glazier et al. (2000) reported, elite level fast bowlers deliver the ball between 36 – 40.5 $m.s^{-1}$ (129 – 145.8 $km.h^{-1}$) or in rare "express" bowlers >40.5 $m.s^{-1}$ (>145.8 $km.h^{-1}$). Though the aforementioned descriptors are often used, the lack of standardisation in this area makes cross-research data comparisons difficult.

Therefore, the incomplete evidence base for the fast bowler is leading to conditioning programmes and in-match advice being based on anecdotal or hypothetical data (11, 44). This paper aims to critically review the literature on fast bowling with specific reference to the wider athletic attributes of the sporting role.

2.0 Physical attributes associated with fast bowling

Effective fast bowlers need to maintain speed and accuracy of delivery during performance which has been linked to a number of factors including anthropometrics, body composition, bowling action, run up speed (44, 55).

2.1 Anthropometrics

Stature

Within the elite fast bowling population, at a fundamental level, fast bowlers' possess a tall stature ranging between 1.83 – 1.92 m (11, 20, 42, 46, 54) which is higher when compared to data on batsmen (1.76 – 1.85 m) (6, 22, 23) and a comparable general male population (mean 1.77 – 178 cm) (1, 33). A tall stature for fast bowlers could be perceived as a positive variable in terms of delivery release angle, bounce of ball from the pitch and maybe force production (20, 36, 46, 54). It has been argued that a natural selection process has occurred (36) and data supports the evidence of the wider benefit of increased stature, as 80% of leading elite test match bowlers, categorised by number of wickets taken, are over 1.83 m (7, 16). Such applied information seems valuable to exercise scientists and coaches alike though with varieties of performers bowling technique has led to questions regarding the importance of this variable and its effect on performance (e.g. increase speed of delivery and/or variety of bounce) (54, 56).

Bowling arm length

Glazier et al. (2000) suggested bowling arm length could be a key anthropometrical trait in relation to achieving high delivery speeds though subsequent contradictory research did not support this finding (46, 54, 56). In theory, the findings of Glazier et al. (2000) should hold some credibility as the linear velocity of a point on a lever undergoing angular rotation is proportional to the angular velocity and the radius of rotation. Since the bowling arm may be considered a quasi-rigid lever during the bowling action, for a given angular velocity, a longer arm would produce a faster velocity of the wrist. Although the theory sounds logical, a longer arm will mean greater moment of inertia of that segment meaning greater resistance to rotation. Moreover, unlike the work of Pyne et al. (2006) and Stuelcken et al. (2007), Glazier et al. (2000) did not use first-class performers and the sample was relatively small (n=9) so providing doubt as to their outcomes. Therefore, it appears that other variables may play a more important role in the generation of speed by the bowler (54).

Upper Body Muscularity

Within fast bowling, participants with higher ball release speeds have been shown to possess a greater anterior-posterior chest depth, a lean upper body and large arm girths (44, 46, 53, 54). The bowling action involves humerus circumduction, utilising the pectorals major and latissimus dorsi and the deltoid muscles. The biceps brachii are active during the bowling action stabilising the elbow and glenohumeral joint, along with the rotator cuff muscles (54). Force production from the upper body is one aspect of bowling technique and could account for between 36 – 45% of variance in bowling speed (44, 46, 54). Increased muscularity of the upper body in performers stems from conditioning programmes and adaptation to the game demands. Training literature (29, 45) notes a commonly held view of a proportional relationship between muscle force production and cross-sectional area of a muscle, confirming that bowling conditioning coaches should educate and raise awareness in players of the importance of the role of lean muscle tissue in relevant musculature to help generate higher and more consistent bowling speeds.

2.2 The bowling action and technique

The run up

Delivery speed can be affected by variations in the bowlers run-up speed, distance travelled and bowling action adopted (56). Run up length has been associated (r = 0.70) with mean speed of the delivery and run up speed could have an effect of up to 16% on release speed (11, 15, 20). Data is clouded by studies using both first-class and non-first-class fast bowlers which identifies run up lengths ranging between 15.2 - 17.7 m and mean run up velocity ranging between 17 – 21.6 $km.h^{-1}$, with higher values recorded (~22 $km.h^{-1}$) in the last 5 m pre-delivery (5, 11, 15, 53). Performers who bowled at higher speeds seem to have a faster final 5 m of the run up (r = 0.72) and evidence presented from "nationally-contracted" performers suggests faster bowlers have a faster run up (51, 56). However, the relationship between bowling speed, run up length and bowling action are yet to be resolved as somewhat conflictingly, run up speed must be balanced against the technical action, rhythm and momentum which influence the bowlers approach to the wicket (11, 51, 55). Variations of bowling techniques has previously been reported (18, 44) with run up speed altering with the type of technique adopted. Bowlers with a front-on and mixed bowling action allow for higher approach speeds, which may be possible due to the position that the bowler can, or needs to adopt at the start of the delivery action (i.e. back foot impact) (5, 15, 20). The uncertain intertwinement of technique and physical evidence may leave the technical and conditioning coach requiring more clarity on this issue in order to provide complementary advice to improve performance.

Front knee angle

It is documented that there could be a relationship between a straighter more extended front knee (e.g. >150^{o}) during ball release and higher delivery speeds (27, 46, 51, 56). Portus et al. (2004) notes that during front foot contact a more extended front knee may allow for better transfer of kinetic energy. However, this favourable trait could also be associated with increased injury incidence as more impact force (e.g. 5 to 9 times body mass) is absorbed by soft tissues and the lower back (43, 44). Effective lower body strength, specifically eccentric strength, could assist in maintaining an extended front knee and also assist in withstanding the impact forces that occur when the front foot lands during bowling (14, 35). In comparison to batters, bowlers on average possess higher levels of leg power achieving greater values in vertical jump tests (23) and lower body power is considered a partial predictor of bowling speed within first-class bowlers (46). It is unclear if higher levels of lower body power noted are achieved through game play or planned conditioning, as if it is mainly the former there is scope to develop this physical trait further. Optimum lower body strength qualities are yet to be confirmed, though may be a determining factor in achieving faster bowling speeds (56).

Summary

The interrelated physical and technical attributes of the bowling action has led to multivariable models being developed in an attempt to predict performance, though collectively these models are inconclusive due to participant selection and varying methodologies used (20, 27, 46, 49, 56). Clarity between key predictive variables needs establishing to identify the most effective technical sequencing (18, 42, 51) and physical (46) attributes to include within a predictive multivariable model.

2.3 Physiological fitness profile of fast bowlers

In comparison to other team sports such as rugby (13, 19) and football (28, 48) there is limited information on fitness profiles from first-class bowlers and cricket players generally. Previously international cricket players have recorded similar aerobic and anaerobic fitness levels as professional international rugby union players (2, 34) though a current full physiological profile of elite fast bowlers has yet to be established. When physiological data is noted, most investigators present this information as a secondary technicality and subsequently protocols used are not always explicit therefore limiting comparability of data. Examples of data on fast bowlers include; Predicted $\dot{V}O_{2\,max}$ max between 50.6 – 62.7 ml.kg^{-1}.min^{-1} (11, 23, 50) which is similar to professional players in Rugby Union (13) and Football (47) though the latter reported a higher upper range (75 ml.kg^{-1}.min^{-1}); Vertical jump values ranged 0.32 - 0.43 m (11, 46) which are lower than values reported in Football (0.48 to 0.60 m) (47) and Rugby Union and League (0.45 m to 0.56 m) (13, 19) respectively; Bench press throws (75.1 ± 11.7 cm) and deltoid throws (50.5 ± 9.4 cm) using a 9 kg loaded bar within a Smith machine (46) have also been reported though have limited comparability to other studies. International teams are now subscribing to more formalised fitness screening procedures (8, 17) yet these data are yet to appear in the public domain. Unlike in other sports (13, 19, 47) the intermittent depth in reporting of the methodology limits inter and intra sport comparisons, hindering the establishment of bowling-specific normative values which would be valuable for conditioning professionals and technical coaches alike.

Recent applied Global Positioning Systems (GPS) data identifies fast bowlers cover ~22 km in a single day of a multi-day (MD) match, ~13 km in a One day (OD) match and ~5.5 km in a Twenty-Twenty (T20) match (38). Moreover, in comparison to other members of the cricket team, fast bowlers have a greater number of high-intensity (> 14.4 km.h^{-1}) activities and less time to recover between these events in all formats of the game (38, 40, 41). Current conditioning practices do not always match the physical intensity required (37) and without comprehensive long term fitness profiles of fast bowlers, exercise scientists still have limited evidence to build bespoke programmes for players, limiting long term development.

2.4 Physiological responses when bowling

Investigations into physiological responses during fast bowling have revolved around participants bowling a pre-determined number of over’s and then the maintenance of the bowling action, physiological fatigue and/or accuracy of the deliveries are monitored. Reviewing peer reviewed literature from the past 25 years, with an inclusion criteria of studies having ≥ 5 participants, a minimum of one physiological measure (e.g. heart rate, temperature) being collected, research examining physiological responses to fast bowling is limited to 8 studies (Table 1). Considering the latter criteria, only one study (38) use simulated (i.e. not in-match) bowling events/environments to collect data. Bowling activity duration specified within the research has lacked consistency, with 12 overs (5), 6 overs (53) and 2 x 6 over spells (11) being arbitrarily applied and probably linked to anecdotal evidence from competitive matches. Confirmation of bowling spells from competitive match data is needed to corroborate the length of bowling events selected in future simulated research, which may improve the ecological validity of the data collected and therefore its application for exercise scientists working within the field.

The most reported physiological measure, heart rate, appears to respond to the intermittent increments, decrements and rest periods associated with the bowling activity. Burnett et al. (1995) identified a heart rate range between 163 ± 11 beats·min^{-1} to a peak of 176 ± 12 beats·min^{-1}, equating to 80.3% and 84.7% of theoretical maximum heart rate (i.e. 220 – age), which was similar to data noted in first-class performers (11). These peak heart rates are sustained for relatively short periods and relate to the high intensity physical work when bowling is occurring (34). Different heart rate data have previously been reported (10, 21, 53) however, the participants, environmental conditions and lack of information with regards to bowlers run up (i.e. speed and length) and delivery speeds may partly explain the variation in data reported (Table 1).

In the limited studies where blood lactate was measured, a mean of 4.8 mmol.L^{-1} (5) and a peak mean blood lactate of 5.0 ± 1.5 mmol.L^{-1} reported (11). Duffield and colleagues (2009) detail bowlers with longer run ups and/or faster run up speeds had higher lactate levels (r = 0.60) though blood lactate is not accumulating significantly during the bowling spell(s). Moreover, Duffield et al (2009) also reported that blood glucose decreases (6.3 – 5.5

mmol.L^{-1}) pre-test to the end of a second bowling spell intimating that specific nutritional support is required if high performance is to be maintained. Recently, Minett and colleagues (2012a; 2012b) have investigated cooling strategies on physiological responses (Table 1) of fast bowlers, suggesting a benefit from the process by reducing "thermal demands" on the body. There seems to be agreement that medium-fast bowling activity of up to 12 overs does not lead to a decline in bowling speeds or accuracy in temperate environmental conditions (5, 11, 31). This collection of results provides some evidence for exercise scientists to consider interventions pre, during or post bowling if high performance is to be maintained.

In summary, there appears to be bowling related increases in heart rate, suggesting substantial repeated intermittent cardio-vascular stress over the length of the bowling spell (11). Though an increase in blood lactate is noted, no significant accumulation occurs suggesting the role of the anaerobic metabolic system is moderate, with both the ATP-PC and glycolysis pathways contributing to the bowling event(s) (5, 11, 53). The absolute time engaged within high intensity bowling coupled with the between-over recovery and intermittent nature of the activity may explain the latter outcome, however the causes and specific markers of fatigue remain unclear. Noakes and Durrandt (2000) debated the theoretical concept of physiological fatigue mechanisms within cricket and suggest the "classic models" of cardiovascular-anaerobic energy depletion model and energy supply-depletion do not explain the fatigue that may occur in cricket. Fast bowlers do enter repetitive high intensity acceleration-deceleration (i.e. eccentric muscle action) episodes which could lead to specific muscular fatigue due to altered muscle action, recruitment and firing, which may link to the loss of elastic energy element within muscle (11, 32). Moreover, increased levels of markers associated with muscle damage (i.e. creatine kinase) and inflammation (i.e. C-reactive protein) have been reported post-bowling but this biochemical evidence is still in its infancy (30). Without further research into this area, mechanisms of fatigue within the fast bowler will remain speculative.

In-match physiological data

As physiological monitoring technology advances, devices become more reliable, valid and unobtrusive to wear, data that is captured during competitive matches could be considered to improve ecological validity of data (25, 39). To date there appear to be only two studies which have completed physiological in-match monitoring of first-class performers; Petersen et al. (2010) monitored heart rate response in-match of fast bowlers, though the data was restricted to T20 cricket and was part of a wider study focussing on movement patterns (Table 1). Secondly, a conference paper also assessed heart rate response, focussing on OD cricket, though data was limited to only two first-class participants (24). Even though this limited novel data were collected in different formats of the shorter game, mean heart rates were similar, though peak heart rates reported were ~10 beats$\cdot$min^{-1} higher in T20 cricket (Table 1). Considering the sparse data set, interestingly within the context of fast bowling, this in-match data notes similar peak heart rates but lower mean heart rates which are presented within the simulated bowling research (5, 11). The differences noted in heart rate data between the in-match and simulated events may have wider implications on the ecological validity of data collected in the latter environment. Moreover, the varying match formats now played within cricket and match timings associated with each also require clarification within monitoring research. It could be argued, that basing conditioning programmes for fast bowlers on evidence collected from simulated data may not be appropriate with physical training programmes in cricket not matching the game demands (37). Once a credible base of literature is developed which can corroborate the validity of simulated bowling events or a move occurs to use new technology within assessment of physiological responses in-match, exercise scientists may be able to draw more evidence based conclusions about physical demands on players and associated performance.

2.5 Limitations of physiological monitoring and recommendations for future research

Simulated bowling research attempts to recreate a real match format, where access to performers within competitive first-class matches and unobtrusive monitoring technology has not seemingly been available. These simulated events use equivalent match timings (i.e. overs per hour) and require players to perform as per match conditions in an attempt to increase the ecological validity of the research setting, though some aspects of these methods used could be questioned. For example, after the participant has bowled one over from a set of overs, to replicate a real competitive match, between-over fielding activities were completed (11). These between-over activities do not always note sufficient detail with regards to the actual activities and physical intensity participants worked at, as researchers crudely estimate this as there is little or no data reported from competitive matches for this period. Paradoxically, the physiological recovery available between-overs may be a crucial variable in relation to performance in the next over(s). Observations from matches suggest, between each over, fast bowlers are normally positioned in the field where it is least likely there will be significant fielding activity (i.e. physical work) in order to facilitate recovery for their next over. The value of this between-over, or *off the ball*, period is only now being considered in relation to recovery (31) and could be an important research area to follow with regards to bowling performance.

The simulated bowling research has mainly focussed on short term performance and can only be applied to the shorter forms (e.g. OD/T20) of the game. An exception to this is Minett et al. (2012), who assessed data on bowling performance on two consecutive days. Gore et al. (1993) collected simulated data over 3 seasons though in the main little attempt due to logistical reasons, has been made to assess physiological responses in bowlers across MD bowling events/match. Even though MD cricket is still a key game format, considering crickets historical engagement with exercise science research (4) it is unsurprising the area of physical responses and bowling performance over MD remains unknown.

Research collated within the area of fast bowling has used a variety of subjects linked to the speed of delivery these individuals can produce. As noted, elite level bowlers classed as “fast” have been reported to deliver the ball >40.5 $m.s^{-1}$ (>145.8 $km.h^{-1}$) (20), though identifying and then accessing performers who fulfil, or partially fulfil, this latter bowling trait is difficult. When reviewing the available research, the quality of data is partially limited by the access to appropriately skilled participants who fulfil the bowling speed criteria which in turn, may restrict the results wider application and usefulness. At present, first-class/professional cricketers have been used in only three studies where bowling speeds were reported (34.2 – 35.3 $m.s^{-1}$; 123 – 127 $km.h^{-1}$) (11, 30, 46). The utilisation of a lesser standard and/or skilled cricketers as participants has been common which produces lower bowling delivery speeds (i.e. 104.8 – 115.6 $km.h^{-1}$) and therefore non first-class physiological performance data is reported (5, 10, 20, 44). Moreover, participant numbers within these studies are low (n<10) except for Portus et al. (2000) (n=14), Elliot et al. (1986) (n=15) and Pyne et al. (2006). These issues highlight the difficulty of accessing elite performers which may not be unique to just cricket but may well limit the application of some research for conditioning specialists working at the performance level.

In summary, the limited subject numbers, diverse skill level and broad disparity in bowling speeds noted across research may affect the quality of knowledge gained and therefore the application of the research to the higher levels of performance. If fast bowling is to be fully investigated and further advances are to be made in performance, accessing appropriate participants who operate at the highest level should be a key research aim.

3.0 Practical Applications

Research has a great potential to influence the rapidly changing sport of cricket (26) and fast bowling requires the confirmation of evidence related to performance at the highest level. Further work identifying key physiological variables in order for more effective predictive multivariable models are required, which will allow conditioning coaches to further facilitate performance. Additionally, the advent of new unobtrusive monitoring technology (25) should allow for more in-match monitoring of performance, so ecologically valid data can be captured allowing a more complete insight in to the physical requirements of fast bowling across different game formats and over consecutive days play. Therefore, investigation in this area should be a priority in order to help exercise scientists and conditioning coaches quantify the physical demands of fast bowling which will aid in the development of more specific training programmes which may lead to improved performance and extended playing careers.

Table 1. Research reporting physiological responses of fast bowling for past 25 years (from years 1987 – 2012)

Study	Subject number	Mean ages (years)	Height and Mass	Methodology notes	Playing Standard [c]	Bowling type [d]	Mean run up speed ($km.h^{-1}$)	Mean Heart rates ($beats.min^{-1}$)	Bowling Velocity ($metres.sec^{-1}$)	Other measures
Gore et al. (1993)[a]	12	19.5 ± 0.1 19.7 ± 0.6	187.4 ± 2.2 cm 81.3 ± 3.8 kg	Outdoor cricket nets, 3 seasons of data	First grade (AUS)	-	-	Cool 121± 1 Warm 122 ± 1	-	Sweat rate, Core temp
Burnett et al. (1995)	9	18.1 ±1.0	1.85 ± 0.09 m 76.2 ± 10.0 kg	Outdoor cricket nets, 1 x 12 overs (28.1°C)	State development squad (AUS)	Fast	19.8	Over 1: 163 ± 11 Over 12: 172 ± 8	Range: 31.6 – 32.9	Bla, run up, Technique
Stretch and Lambert (2000)[b]	J=11 S=10	J:11.6 - 13.3 S: 17.7 - 21.5	J:158.3 ± 5.8 cm J:45.6 ± 5.2 kg S:184.9 ± 5.3 cm S:78.0 ± 10.6 kg	Outdoor cricket nets, 1 x 6 overs, subjects grouped by age (22.3°C)	Provincial Elite & potentially elite (SA)	Fast	-	J: 159 ± 12 S: 153 ± 10	-	Flexibility, Bowling accuracy
Devlin et al. (2001)	7	21 ± 1.0	- 89 ± 13 kg	Outdoor cricket pitch, 1 x 6 overs, (16°C)	Sub elite (AUS)	Med/ Fast	-	154 ± 15	Mean: 29.1	Accuracy, Hydration status
Duffield et al. (2009)	6	23 ± 3	185.6 ± 6.8 cm 86.9 ± 11.3 kg	Outdoor nets, 2 x 6 overs separated by 45mins, CAAIS FB[e] skill test (21-23°C)	First class (AUS)	Med/ Fast	19.9 ± 1.7 Final 5 m: 22.8 ± 1.9 [1]	Spell 1: 162 ± 9 Spell 2: 162 ± 12	Spell 1: 34.9 Spell 2: 34.8	Accuracy, Core body temp, Bla, pH, glucose
Petersen	10	22.1± 2.8	1.81 ± 0.08 m	Competitive (n=7)	Centre of	Fast	-	133 ± 12	-	GPS movement

et al. (2010)			84.3 ± 8.7 kg	international T20 matches, in-match	Excellence (AUS)			Peak 181 ± 10		analysis study
Minett et al. (2012a)	10	23 ± 8	189.8 ± 8.8 cm	Outdoor cricket square, 6 over, CAAIS FB skills test (31.9°C)	Senior club or Junior state level (AUS)	Med/ Fast	19.3 ± 3.81 Final 5m: 21.6 ± 2.3	Range: 160 - 170	Mean: 32.1 Peak: 32.8	Core and skin body temp, Urine gravity , Creatine kinase, Testosterone, Cortisol
Minett et al. (2012b)	8	23.3 ± 4.9	187.8 ± 5.9 cm	Outdoor cricket net, day 1: 10 over, Day 2: 4 over, CAAIS FB skills test (30.4°C)	State squad members (AUS)	Med/ Fast	20.3 ± 3.6 Final 5m: 20.9 ± 1.8	~150	Mean: 32.8 Peak: 34.7	Yo-Yo test, Core and skin body temp, Urine gravity , Creatine kinase, C-reactive protein

Tabular report: Data reported verbatim from journal (a) Cool = 22°C, Warm = 30°C, (b) J = Junior, S = Senior, Only age ranges provided, (c) AUS=Australia, SA=South Africa, (d) Med = medium.
(e) CAAIS FB = Cricket Australia Australian Institute of Sport Fast Bowling (skills test)

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