“Expert cricket coaches’ conceptions of the fast-bowling technique and how they coach it”

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Candidate Declaration

I hereby declare that:

1. I have been enrolled for another award of the University, or other academic or professional organisation, whilst undertaking my research degree. I was an enrolled student for the following award:

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Contents

Abstract:

The purpose of this study was to investigate expert coaches' conceptions (internal models) of the fast-bowling technique, how they coached it and how they acquired the knowledge for both.

Twenty expert cricket coaches from around the world, took part in semi-structured interviews, with all interviews being transcribed verbatim. Thematic analysis (Braun & Clarke 2006) was carried out and thematic networks (Attride-Stirling, 2001) were produced for the coaches' models of a 'good' fast-bowling technique, a 'poor' fast-bowling technique; coaches' approaches to coaching; and coaches' sources of knowledge.

The coaches' model of a 'good' fast-bowling technique matched the empirical literature findings, as did the model of a 'poor' technique, with both models using the six-phase technique (Bartlett et al 1996). It is believed that the model of a 'poor' technique is the first of its kind to be produced. Fetisova et al (2020) suggested that coaches (expert and non-expert) tend to be able to identify the individual components of a technique, but the ability to distinguish the 'big picture' of the technique, how individual elements fit together and the biomechanical principles that cause this, are the factors that differentiate the expert coaches from the non-expert coaches. The coaches' explicit discussion of biomechanical principles was varied across the cohort.

The coaches' approach to coaching was broken down into six sub-themes: '*Coaching philosophy & beliefs', 'Physical and mental preparation and development', 'Coaching environments and interventions', 'Coach-player relationships and communications',* and *'Other factors'.* Coaches believed strongly in individualising coaching analysis and interventions and stated a preference for holistic development. However, there was little discussion of variation to pedagogical approaches, with coaches having a strong preference for using drill-based coaching interventions.

The coaches' sources of knowledge were also pulled into six sub-themes: '*Experience, Coach education/CPD', 'Other formal professional knowledge and education', 'Conversations with other experts', 'Self-directed study',* and *'Personal theory and experimentation'*. Coaches built their knowledge and expertise in a non-linear fashion. Coaches preferred referring to former and current high-level performers as models of technique and worked closely with

physiotherapy and strength & conditioning staff. UK coaches in particular valued resources made available through their NGB (ECB). Coaches with a more sophisticated epistemology had strong personal theories and looked to test them.

The implications of the coaches' expert knowledge for the field of biomechanics, was to increase representative design (Araújo, Davids & Passos (2007) of experimentation to include umpires, a protected area, a batter to bowl at and game-like scenarios, as game context created suitable variations within technique.

The implications for coach education were that coaches need assistance in the long term. A formal *apprenticeship* may help elite players transfer to elite coaching environments. This related to key stake holders who employed coaches, with an urge to not employ coaches based on their playing credentials, but to value coaching knowledge and experience more strongly.

Chapter 1 - Introduction

Introduction:

The key questions to be asked in this study are:

1. *"Is there an ideal fast bowling technique, and if so, what does it involve?"*
2. *"How do expert coaches coach the fast-bowling technique?"*
3. *"How do expert coaches know (a) what the fast-bowling technique is and (b) how do they know how to coach it?"*

This chapter will set out what the field of literature to date has to say about these question areas. Firstly, fast-bowling is defined, and what is known about fast-bowling is discussed in relation to technique, biomechanics, and skill acquisition (Question areas 1 and 2). This chapter then looks at how coaches coach (plan deliver and review) effectively, and how these coaching practices are developed, and where coaching expertise may develop from (Question areas 2 and 3).

1.1 "What is cricket and what role does fast-bowling play?"

Cricket is a global sport played across many countries and watched by over a billion people (Johnstone et al 2014). Cricket is classified as a striking and fielding game (Gill, 2020), with the winner determined by the highest total number of runs scored. The bowler's role is to both get batsman out (so that they can no longer continue to score) and to reduce scoring opportunities. There are many different formats of cricket ranging between T10 games (ten 6-ball overs per side) lasting around an hour, through 20 and 50 over variants, all the way through to Test matches that can last 5 days (30 hours of cricket).

While there are different types of game formats, there are also different bowling types. Fast-bowling can be defined as a bowler delivering the ball above 140 kph (approx. 40 m/s) in the men's game and 120 kph (approx. 30m/s) for females. Fast-bowlers are allowed to run before delivery but release behind a line, much in the same way as javelin as opposed to the pitching mount in baseball. This then means that there are several phases of body motion required to optimally project a cricket ball (5.5 oz/155.9 gm) 22 yards (20 meters) towards the batter and the wickets.

The differing formats of the game place different constraints on the fast-bowler. Bowlers may bowl as little as 1 over in a game (especially in the shorter T10 and T20 formats) to 30 overs in a day, repeated over several days within a 5-day game format (Test Cricket). As well as the differing physiological and psychological demands of these workloads, there are also vastly different tactical demands placed upon the bowler. In turn, these differing tactical demands create demands for bowlers to use different types of deliveries from different areas of the bowling crease (see later), which will in turn create different forces and lines of force on the fast-bowler's technique.

Therefore, speed of release and accuracy of projection, and the ability to orientate the ball for differing bowling delivery types, become key task requirements for the fast-bowler and in turn the coaches' role becomes one to best facilitate this in their bowlers.

1.2 Fast bowling - what do we know?

The 'fast bowler' is seen as having a key role to the success of a cricket team and tends to bring great interest to the spectating public (Johnstone et al 2014; Bartlett et al 1996; Morton et al 2014; Glazier and Wheat 2014). Whilst fast bowers are often seen as match winners in cricket and bring excitement to the spectator, they are also the most likely set of players to be injured (Johnstone et al 2014; Bartlett et al 1996; Morton et al 2014; Glazier and Wheat 2014), with injuries to the lower back the most prevalent (Johnstone et al 2014; Stretch 2003). With prevalence rates being reported between 6% and as high as 67%, injury prevention as well as performance should be areas of focus for the cricket community (Johnstone et al 2014; p.45).

Senington, Lee and Williams (2018) in their systematic literature review suggested that the bowlers with the greatest shoulder counter-rotation were most likely to suffer from lower back pain and injury but noted that all studies had taken place during laboratory conditions and wondered if field-based testing could be used to elucidate further details. Alway et al (2020) conducted their own study of 50 elite male fast bowlers and looked at their techniques in relation to lower back stress injuries (LBSI). Of the 50 bowlers, 39 sustained a prospective LBSI. There were significant differences between injured and non-injured bowlers in their rear knee angle, rear hip angle, thoracolumbar side flexion angle, and thoracolumbar rotation angle at back foot contact (BFC). They also found the front hip

angle, pelvic tilt orientation, and lumbopelvic angle at front foot contact (FFC) and the thoracolumbar side flexion angle at ball release and the maximal front hip angle and ipsilateral pelvic drop orientation were all related to LBSI. Finally, a binary logistic model, consisting of rear hip angle at back foot contact and lumbopelvic angle at front foot contact, correctly predicted 88% of fast bowlers according to injury history and significantly increased the odds of sustaining an LBSI (p.581). This suggests then, that there are clear parameters as to what is a safe and unsafe bowling technique, and that coaches need to be aware of these in their coaching practices.

A coach's role is to bring about improvement in the bowler while seeking to reduce the risk of injury; this is done via selected coaching interventions directed at areas that need improving (Ransom et al 2009). To know which areas, need improving, the coach needs to have some principles or models of what is optimal that they can work from and ideally these should come from empirical evidence base.

Bartlett et al. (1996), in their literature review, suggested that *"an 'optimal' fast bowling technique could be defined as one that allows the bowler to bowl fast with a relatively low injury risk"* (p.403). However, they stated that there were no firm conclusions drawn as to what the 'optimal technique' was, and this has remained an issue in cricket fast-bowling biomechanical research. There was a suggestion that the fast-bowling technique, may at least in part, be highly individualistic, and, therefore, called for intra-player studies to *"establish the bowler-specific factors which contribute to fast ball release and features of body segment dynamics"* (p.403). However, there was consensus in terms of the phasic order of the bowling action: run-up, bound (pre-delivery stride), delivery stride (which is made up of back-foot contact (BFC), front-foot contact (FFC)), and ball release) and the follow-through.

Bartlett et al. (1996) also signposted the many papers directly linking the 'mixed' bowling action to increase spinal injury risk, and it is these findings that went a long way for national organisations such as the England Cricket Board (ECB) to create recommendations for screening for mixed actions and coaching interventions to remove them (Ransom et al 2009). However, there was little other information proposed for the use of evidence-informed cricket coaches, other than *"screening and intervention"* (p.403); no authors considered *how* this might be done in a practical setting.

Later reviews have also failed to assist fast bowling practitioners and their evidence-informed coaches. Glazier & Wheat (2014) updated the initial review of Bartlett and colleagues, offering a deterministic model of the fast-bowling action. Whilst such models do provide the coach with an idea of priorities in their coaching design, by defining the key mechanical factors leading to specific outcomes, they do not offer direct suggestions for technical input i.e., they suggest *what* is important in the fast bowling technique but not *how* to do it *when* and *where,* and do not follow the practice of many cricket coaches who are likely to follow a phasic approach to technical intervention.

With a lack of empirical evidence, coaches have been left to use 'coaching manuals' for guidance. The most recognised of these is the Marylebone Cricket Club (MCC) coaching manual, which initially proposed one technique /'style' of bowling. This is classified as 'side-on', which is typified by a relatively low run-up speed at the start of the delivery stride, a rear foot position which is parallel to the popping crease, and a shoulder alignment at rear foot strike that points down the wicket, such that the angle between the wickets and the line joining the shoulders is approximately 180° [Bartlett et al 1996; p. 404]. This technical action was later adapted to include the 'front on' approach made popular by many leading fast bowlers around the world (Bartlett et al 1996; Ferdinands, Kersting & Marshal 2014). These performance descriptors were based upon how the bowler aligned him/herself on the bowling crease in relation to the batter. Elliott and Foster (1989) noted that there were in fact three common techniques which included side-on, front-on and what was classified as a mixed action, where a bowler would use either a side-on upper body position or a lower body front-on position or vice versa, causing a large counter-rotated position between pelvis and shoulders. This action has been strongly correlated to spinal injury (Bartlett et al 1996). Bowling action classification was further developed with researchers and coaches proposing a mid-way action that positioned a bowler at front foot contact (FFC) in a position mid-point between a fully side-on action and a front-on action. It was believed that this positioning would reduce stress on the lumbar vertebrae whilst allowing fast ball release velocities (Johnstone et al 2014). Fast bowling techniques promoted in these manuals would appear to have come about through trial and error, mimicking leading players and a sense of tradition, rather than from a theoretical or empirically driven perspective (Bartlett

et al 1996, Glazier & Wheat 2014; Ferdinands 2008). However, it was unclear whether or not they represent a whole-body optimal model of fast bowling.

The fast-bowling technique is considered to be made of six (Bartlett et al. 1996) or eight (Anderson, 2019) phases:

Bartlett et al (1996)	**Anderson (2019)**
Run-up	Run-up
Bound/gather	Pre-delivery/gather
Back foot contact (BFC)	Back foot contact (BFC)
Front foot contact (FFC)	Front foot contact (FFC)
	Front foot flat (FFF)
	Acceleration phase
Ball release (BR)	Ball release (BR)
Follow-through	Follow-through

Table 1. Comparison of phase models of Bartlett et al. and Anderson (2019)

The *'delivery stride'* is another phase of fast bowling referred to in the empirical literature and coaching manuals and is the collection of phases from Backfoot contact (BFC) to Ball release (Woolmer, Noakes & Moffett, 2008).

There has been a clear focus within the literature on kinematic and kinetic variables that occur during the delivery stride (BFC to BR) in investigations to date (Anderson 2019; Glazier & Wheat 2014; Bartlett et al, 1996), meaning that more is known about those phases than some others. This is problematic for the coach if they wish to use the empirical literature to support their analysis or technical coaching interventions. For example, for the run-up phase, only the velocity of the centre of mass has been recorded, but nothing is known about an optimal distance or angle of this run-up in relation to the target or if any kinematic patterns in the running technique are optimal or not. Additionally, we don't know if the change in angle or change in run-up velocity markedly alters the BFC. Similarly, very little if anything is known the follow-through phase through to the point of Backfoot Re-contact (BRC), with only Epifano, Middleton and Anderson (in prep.) having taken any measures here. Without these measures it is unclear what a coach may use to analyse a bowler's technique or from what to draw an effective coaching intervention from.

Deterministic modelling is an approach that determines the relationships between a movement outcome measure and the biomechanical factors that produce such a measure (Chow & Knudson, 2011; Hay 1986). By highlighting the key biomechanical determinants to a movement outcome, a coach can prioritise work in those areas that have the greatest impact and ensure that the player's technique maximises the particular biomechanical factor (e.g., horizontal force production or angular velocity of a body part). Glazier and Wheat (2014) proposed a deterministic model for fast bowling; however, they chose to use a proximal to distal approach from ball release speed back to the angular velocity of the pelvis. While this approach gives an indication of the movement patterns relevant for faster bowling techniques, it does not acknowledge the key factors most responsible for the performance outcome. It doesn't provide information for coaching interventions either.

Worthington, King, and Ransom (2013) identified the four key kinematics factors that accounted for 74% of the release speed variations. They were the fastest bowlers have a faster run-up and maintain a straighter knee throughout the front foot contact (FFC) phase. The fastest bowlers were also observed to exhibit larger amounts of upper trunk flexion up to ball release and to delay the onset of arm circumduction. Felton et al (2019) compared the kinematics and release speeds of a group of elite male bowlers against their female counterparts. The key differences were that males have significantly faster release velocities which was attributed to their faster run-up velocities and techniques that allowed them to maintain more linear momentum from the run-up into the ball release.

Therefore, it becomes apparent that while deterministic models could be created from the evidence base, we may need to create different ones for male and female fast bowlers. It is also unclear whether the kinematic variables suggested by Worthington, King and Ransom (2013), are the same kinematic variables that determine release speed or even if it is safe to do so. Schaefer et al (2020) compared and adult and junior fast bowlers' techniques and found that the kinematics and kinetics at BFC are significantly different between the adults and the junior fast bowlers, with the juniors having several different kinematic patterns for BFC. Pyne et al (2006), also compared adults and junior fast bowlers from an anthropometric and isokinetic perspective and found the key determinants to greater muscle mass and greater isokinetic strength in adults as the key factors. So again, the evidence base is not able to give coaches of junior fast bowlers any further insight.

Ransom et al. (2009) set out to improve the technique of a group of identified young elite fast bowlers over a two-year period. Prior to the study, thirteen of the fourteen bowlers had been analysed to have a 'mixed' bowling technique, a technique that has been correlated to spinal injury (Bartlett et al 1996). They set out to improve four areas of technique:

- improved shoulder and pelvic alignment at BFC
- less back collapse (flexion)
- front knee collapse (flexion)
- more upright FFC trunk alignment (less side-flexion).

The bowlers were not given specific coaching instructions as they received coaching not only from the research team, and staff at ECB Cricket High Performance Institute, but bowlers were also receiving coaching from coaches located at their home clubs. Results of the study showed that after the intervention nine of the fourteen bowlers were demonstrating a 'mixed' action. The biggest changes occurred around BFC; however, very little change had occurred later in the techniques at FFC and BR. In addition to this, the average release speed over the two-year period was only 5kph, which, if maturation effects of these bowlers between the ages of 16 and 20 years of age is considered, it suggests that the coaching intervention had little impact on improving release speed and may even have reduced its potential outcome. The researchers suggested that the lack of impact on the technique may be due to the maturity of the bowlers, and that younger bowlers may be easier to change.

Felton, Shine and King (2017) also looked to build a coaching intervention to improve fast bowling technique but used a forward dynamics solution approach to work with an individual elite adult fast bowler. A planar 16 segment torque-driven computer simulation model of the FFC was used to estimate release capabilities. The model suggested that the bowler could change his bowling release speed from 80mph to 94 mph. This would be done through delaying the extension of both shoulders at FFC, as well as having a straighter front leg with a larger delivery stride. This position allowed the front leg to stay straighter (less knee flexion) throughout and more trunk flexion to occur. Discounting strength as an impactful factor, coaching took place with the bowler over the next twelve months. The bowler increased release velocity by 10% from 80 mph to 88 mph. While this is clearly an

excellent intervention for the bowler in terms of release speed, it is unclear whether the intervention will have reduced the risk of injury or altered the bowler's ability to bowl a number of different 'delivery types' (e.g., outswing, inswing, and yorker).

Different delivery types require subtle variations of the bowler's technique (Woolmer, Noakes & Moffett 2008). It is unclear how much of an impact each delivery type has on the bowler's ability to produce maximal ball release speeds. In fact, a tactic for many fast bowlers is to use 'slower-balls' a delivery disguised to the batter as a normal speed delivery, but through manipulation of the release technique, results in much slower release rates, often fooling the batter (Wigmore & Wilde 2019; Woolmer, Noakes & Moffett 2008). All these things need to be understood by a coach if they are to assist the performance of their fast bowlers. A promising finding from javelin throwing, a technique with some similarities to fast bowling, by Elliott and Bartlett (2006) (discussed later) is that while there are clear parameters for an optimal throw, there are a myriad of possible parameters to make a nearly optimal throw in terms of distance. If we equate distance with release speed in fast bowling, it suggests that bowlers may be able to produce similar release velocities, with many subtle kinematic changes. This may allow the bowler to bowler several different delivery types whilst maintaining a similar velocity throughout.

Technical factors are not the only thing for fast-bowling coaches to consider in their coaching practices:

"Fast bowlers have the highest injury rates in cricket; therefore, reducing these injuries is a priority for coaches and the support staff. Improving physical conditioning and monitoring bowling workload are primary preventative strategies to reduce overuse injuries" (Soomro et al., 2018).

However, there is limited information available to coaches about what should be included in a strength and conditioning (S&C) programme for fast bowlers (Mukandi et al 2014). Mukandi and colleagues do suggest that any programme should be individualised and develop not only performance enhancement but reduce muscular imbalances due to the unilateral demands of fast bowling (p.104). Soomro et al (2018) looked at the S&C practices of lower-level cricket coaches in Australia and found that while most coaches were aware of the need for resistance training in young fast bowlers and a programme that stuck to the

recommended bowling restrictions (workload), only 13% of coaches in the study prescribed the actual recommended workload for bowlers. Pote and Christie (2016) conducted a similar study in South Africa, looking at the S&C practices of cricket coaches at schoolboy and university levels. They found that although some forms of conditioning, workload monitoring and injury prevention were being implemented, the correct practices were not being used. In addition to this it was noted that most coaches didn't have the qualifications or experience to deliver the appropriate training (p. 3464).

At the professional level of the game in the UK, Australia and South Africa as well as the many highly lucrative franchise tournaments, specialist S&C coaches are used (Wigmore and Wilde 2019; Weldon et al 2021). If at the lower level of the cricket sees little or poor S&C programming, it would suggest that for many coaches working with fast bowlers new to the professional game, that S&C programming would become a priority. Weldon et al 2021 surveyed thirty-three S&C coaches from seven different countries, currently working in professional cricket. They found that these coaches had degree level knowledge as a minimum, with 40% having cricket qualifications too. The bulk of their work focused isometric strength exercises, Olympic lifts and basic hops and bound-type plyometric training. Programmes were individualised in relation to the player's role. Very little work was done to enhance flexibility/mobility outside of a warm-up protocol.

While they recognised the demands of the playing programme, one of the other issues that they faced was the perceptions of what head coaches perceived S&C to be and what should be involved within it. Therefore, as with the previous studies of Pote and Christie (2016) and Soomro et al (2018), but for different reasons, a better understanding of what is S&C in cricket is and what should and shouldn't be included, is clearly needed as part of coach education, particularly for coaches of fast bowling.

1.3 Underpinning coaches' knowledge - Biomechanics in coaching

There are strong recommendations for (cricket) coaches to have an underpinning in the principles of biomechanics, if they are to be able to successful understand and coach sports techniques effectively (Arora et al. 2014; Knudson & Morrison, 1997). Arora et al (2014) suggest that a sound understanding of the biomechanics involved in the fast-bowling

technique is critical to coaching design and intervention implementation if coaches are to reduce the incidence of serious injury.

Knudson (2003) suggested that there were three 'frameworks' covering the key principles of biomechanics, that coaches should know if they are to analyse and make technical interventions (see Table 2 below).

Table 2. Comparison of general principles of biomechanics.

Knudson (2003)	Hudson (1995)	Norman (1975)
Movement principles		
Balance	Balance	Stability
Coordination continuum	Coordination	Continuity of joint force
Force–motion		Combined influence of force and its application time
Force– time		
Inertia	Compactness	Direction of force application
Range of motion	Range of motion	Summation of joint force
Segmental interaction	Nature of segments	Summation of body segment velocities
	Number of segments	Production of angular momentum
Projectile principles		
Optimal projection	Path of projection	Conservation of momentum (linear and angular)
Spin	Spin	Manipulation of weight distribution
Speed of motion		Manipulation of segment angular momentum
	Extension at release	

Norman, (1975) suggested that it was possible to use his ten biomechanical principles to facilitate teaching and to focus coaching on causes of errors and the dynamics of human motion, rather than meaningless discrete body positions presumed to be key technique points (Knudson, 2007). Hudson (1995) similarly identified ten 'core concepts of kinesiology', that she felt essential for coaches to understand. Each concept should be viewed as a continuum between mechanical objectives, and must be observed visually by the coach, so that the athlete can be facilitated to change their movement patterns to a more optimal position on the continuum (Knudson, 2007). Finally, Knudson (2003) set out

nine principles, which he further sub-divided into body motion principles and outcome-projectile principles (Knudson, 2007).

While these give clear ideas to coaches in how biomechanical principles can be used to analyse and improve a technique, there are clearly some issues for aspiring coaches regarding terminology. While Norman (1975), Hudson (1995) and Knudson (2003) all use similar concepts to describe biomechanical phenomena that impact upon movement, there are similarities and differences that could lead to confusion. This confusion is not only restricted to these overall concepts, but to specific individual concepts themselves. Knudson (2007) himself noted:

"…the confusion in trying to describe the mechanism of sequential coordination observed in high-speed movements. Explaining the contribution of each segment to speed at the end of the limb has been attributed to coordination of temporal impulses (Hochmuth and Marhold, 1978), the kinetic link principle (Kreighbaum and Barthels, 1985), summation of speed (Bunn, 1955), proximal-to-distal sequencing (Marshall and Elliott, 2000), and transfer of energy or momentum (Lees and Barton, 1996; Miller, 1980), to name just a few" (p.111).

Nicholls et al (1999) demonstrated that qualitative methods can be validated against quantitative measures when using a clear checklist of kinematic elements and temporal factors of a baseball pitch, which is quite like fast bowling in cricket. However, Lees (1999) noted that while qualitative technique analysis does use biomechanical principles at its heart, it is subjective nature and is often not used in coaching practice. Both Lees (1999) and Hay & Reid (1982) suggest that the use of deterministic models (Chow & Knudson, 2011) may assist the qualitative process by giving a framework to use; however, it there must be no confusion that the deterministic model should provide a complete model of the technique.

Glazier & Wheat (2014) suggested a deterministic model of fast bowling, following their systematic literature review. Their deterministic model looked at one of the key requirements of a bowler, which is to "take wickets", and then determined that the two key variables related to achieve this were release velocity and accuracy. From here they identified the key factors relating to accuracy (release angle, release speed, and aerodynamical factors) and to release speed. This is then where they departed from the

prescribed approach of deterministic modelling of identifying the key biomechanical factors that determine the phenomena, instead taking a proximal to distal approach of the body parts responsible down the chain of events. There are several issues with this approach however, four most critical factors are:

1. Depending on the game situation, a bowler's focus may not be to take wickets, but instead restrict the runs conceded from their bowling. This could lead to several different approaches taken by the bowler.
2. Taking wickets is dependent on several variables out of the control of the bower, such as the batter (their capabilities and decision making), the game context, the environment, the conditions of the playing surface, the condition of the ball, the capability of fielders and the decisions taken by the umpires.
3. The proximal to distal approach does not give the coach or bowler any indication on which factors are most critical in their bowling technique and which play less of a role. This could lead to many wasted training sessions if the key variables are not focussed upon.
4. Deterministic models do not give any indication of how each factor fits together with the next.

Quantitative measures go some way to overcoming the subjective issues of qualitative analysis. However, there are still issues using this approach. While the subjectivity is removed, researchers tend to focus on limited kinematic and kinetic variables rather than the technique (Lees, 2002). Therefore, while we may get to know, in detail, the key correlates to performance, we do not get an understanding of the technique. This issue is demonstrated in cricket research as there are limited aspects of the whole bowling technique that have been empirically studied. As both Anderson (2019) and Glazier & Wheat (2014) pointed out, outside of the velocity of the centre of mass, little has been explored about what is optimal in the run-up phase of the bowling action. There is little coverage of the gather/bound phase, and research of the follow-through phase to backfoot recontact (BRC) (Epifano, Middleton & Anderson, in prep) is virtually non-existent, with researchers focussing their work on the delivery stride and release mechanics. Therefore, without a quantitative focus on the complete technique, there is little use of this approach to cricket coaches.

Lees (1999) suggests that predictive, computer-aided models may be able to solve some of the issues of quantitative approaches and give visual representations of the whole technique. Felton, Shine & King (2017) and Felton, Yeadon & King (2020) have used a forward dynamics solution using a planar 16 segment torque-driven computer simulation model of the front foot contact (FFC) phase of fast bowling. It was found that this computer-generated model was able to replicate the complexity of a bowling action and was used to increase the bowling performance of an individual fast bowler by 10% (80 mph to 88mph). While this approach clearly has exciting possibilities for the coaching of fast bowling in the future a few words of caution are necessary. Firstly, while we have empirical data to suggest that a higher run-up velocity related to higher release speeds, we do not know if there is a ceiling to this. In addition, the bowling 'action type' may impact upon this as Bartlett et al (1996) suggested that side-on bowlers tended to have lower run-up velocities than 'front-on' bowlers, but no with clear explanation of why this would be the case. It is also unknown if the angle of the run-up has an impact or not on the run-up and subsequent outcome of the bowling action. Similar arguments can be made about the 'Gather/Bound' phase as there is little information to base the model upon. And finally, as stated earlier, virtually nothing has been established regarding what should or should not happen in an optimal 'follow-through' phase. So, it is possible that the kinematic positions described in the release position of the model may lead to sub-optimal positions in the follow-through phase, which may then be, in part, one of the possible causes of injury. Until there is rigorous investigation of the follow-through phase, we cannot be sure that these models are entirely safe for use.

The data set of 'elite' performers may also be questionable, as those identified as 'elite' have been done so based on their cricketing performance and not the relative biomechanical merits of their techniques or absolute bowling speeds. It may be possible for bowlers at sub-elite levels to have a superior biomechanical technique but not meet the same performance measures in game situations and therefore have not been part of the initial data gathering to build the rules by which a model was built. Additionally, it is possible for bowlers at the sub-elite level to have greater release velocities than the elite bowlers, but not have the same skill set, and therefore not be ranked as such. Finally, most research in this area is based on bowlers from the UK and Australia, where there is a long and

established history of coaching orthodoxy, leading to bowlers with similar techniques whereas, in countries with less established coaching regimes, more unorthodox bowlers are able to flourish (Wigmore & Wilde, 2019). It is unclear how much impact truly unorthodox techniques would have on the validity of these predictive forward dynamics approaches.

Finally, an important consideration when looking at technique is that it is matched up with the technical intention of the performer:

"Practically, the correct use of biomechanics can become an important point of support in understanding technical training, which can lead to performance. The biomechanical characteristics of the movement must always be linked to the tactical intention" Liușneaa (2017).

That implies that fast-bowling coaches must keep a tactical, game-related idea of the context in mind when analysing the efficacy of the fast-bowling technique.

1.4 Skill acquisition – *'How do fast-bowlers learn and develop?'*

For a fast-bowler to improve, they must acquire and advance their skill base (Chow et al, 2016). Skill is defined by McMorris & Hale (2006) as *"the consistent production of goal-orientated movements, which are learned and specific to the task"* (p. 67). Similarly, a good sport technique is defined as *"adequate and efficient movement patterns to solve defined tasks in particular sport situations"* (Loland, 1996; p. 55).

Therefore, skills have more of a consistent outcome focus than technique, are learned and developed through practice, and this practice should be specific to the task. How this skill acquisition occurs has been theorised in many ways, with the three most common explanations being *motor programs, motor schema, and dynamical systems approaches.*

1.4.1 Motor programs:

Keele (1968) defined a motor program as a set of muscular commands that allow movements to be performed without any peripheral feedback and thus, the movement becomes automatic. This motor program is stored in the brain, in long-term memory and becomes the template by which all related movements are compared against (McMorris & Hale, 2006). Practice then allows multiple episodes of comparison against these motor programs until the skill is established.

While this approach held some intuitive appeal to early investigators, there were a few issues with this approach. For the approach to remain true, athletes would need almost an infinite amount of motor programs for each different skill, to be used in differing environmental and game related conditions, for example, a wicketkeeper diving to the left vs diving to the right, catching high vs catching low and so on. Issues around the observed different timing, speed, sequencing, and range of movement between skilled performances led researchers to move away from this idea and towards a more generalised motor program approach, e.g., diving, running, sliding etc.

1.4.2 Motor Schema:

Due to the issues raised about the implications of motor program theory, Schmidt (1975) sort out a way to explain how adaptations of similar skills and novel skills could be created. His Motor Schema theory postulated that we created generalized rules (schema) to groups of movement patterns (McMorris & Hale, 2006).

Schmidt suggested that there are two types of motor schema: those that chose and initiated movements (*recall schema)* and those that evaluated and adapted ongoing movements (*recognition schema*). Schema were seen to develop and improve through repeated performances including understanding the desired outcome, the initial conditions and response parameters.

The adaptiveness element of this theory, brought with it the recognition of the external conditions that need to be fed back into the movement system to be able to adapt to the given context. Thus, the *recognition schema* need to be able to identify errors and bring about changes where possible.

Critics to this theory suggest that the concept of motor schema are too ambiguous and vague and that it is unclear how exactly performers and acquire and choose between available schemas (Plant & Stanton, 2013), for example, how would a batter choose between different shot types and tactical options (e.g., sweep shot, move out to drive or to defend) to any given delivery bowled at them?

1.4.3 Dynamical systems:

A dynamical systems approach comes from ecological psychology, that looks at how a human interacts with their environment rather than memory, as postulated in the previous theoretical discussions of motor learning and skill acquisition.

In this approach it is said that the environment gives the performer opportunities to perform (affordances), but that the performer most perceive the opportunities available as no two situations are ever identical. As the performer must directly perceive these affordances, skill-practice thus allows performers to become *attuned* to the affordances (opportunities to act) from the environment (McMorris & Hale, 2006).

This is a useful paradigm for understanding how sports performers develop movement skills. This approach considers the performer, the coaching environment and the coach as a complex interacting systems. The coach's role is to design coaching practices that enable the performer to navigate through the learning environment, building competence, by recognising patterns in the environment (Chow et al., 2016). *Constraints* within the environment dictate then the actions (Renshaw et al., 2019) that result (see later discussion of Newel's Constraints theory). This means that the player must learn to attune to the relevant affordances and constraints to bring about skilled performance. The coach is a central figure in improving performance, and that the coach's practices and decisions are critical to this, as they often create the way in which affordances and constraints within the coaching environment are presented.

1.5 *'How coaches coach'* - Effective coaching practice and analysis processes

Effective coaching is defined as *"the consistent application of integrated professional, interpersonal, and intrapersonal knowledge to improve the athletes' competence, confidence, connection and character, in specific coaching contexts"* (Cote & Gilbert 2009; p.316).

A coach's professional knowledge includes knowledge of the sport, including rules, tactics, and common techniques, as well as factors such as governance, and also includes such things as knowledge of the athlete, such as their stage of development or motivation and also knowledge of sport sciences and how they support that sport (ICCE, 2012).

A coach's interprofessional knowledge relates to their knowledge and ability to interact with others (Cote & Gilbert, 2009). Coaching does not occur in isolation, and coaches must traverse the difficult reciprocal interactions between players, support staff, parents, spectators and other key stakeholders (Jones et al., 2011). Therefore, a coach must have knowledge of interpersonal communication and relationship building, social context, and coaching methodology as a conduit between the coach and athlete (ICCE 2012).

Finally, a coach's intrapersonal knowledge relates more specifically to the coach themselves, their introspection and reflection, and how they wish to coach (Cote & Gilbert 2009). This area requires the coach to be cognisant of their coaching philosophy and beliefs, and the impact that they have on the coaching environment. They must also consider the role of lifelong learning (ICCE 2012).

The coach's ability requires then, to pull these three knowledge bases together, and apply them (Abraham, Collins & Martindale, 2006). To bring this about, coaches need to have four core coaching skills (Lara-Bercial & Bales 2021):

- **Teaching skills** (*These include setting up appropriate practices, explaining, demonstrating, providing feedback, differentiating, and designing activities)*
- **Management skills** (*Strategising, setting goals, planning, organising)*
- **Leadership skills** (*Modelling, communicating, applying emotional intelligence, cultivating self-awareness, practicing empathy, motivating, safeguarding)*
- **Analytical skills** (*Observing, recording, analysing, evaluating, self-monitoring).*

While helping athletes develop technical and tactical skills is a critical role played by a coach, there is little written suggestion to coaches of how this is best done (Farrow, 2021). Yet analytical skills are a key component of coaching work. Rarely do coaches have access to biomechanical labs/equipment or expertise, so qualitative approaches are more likely to be used.

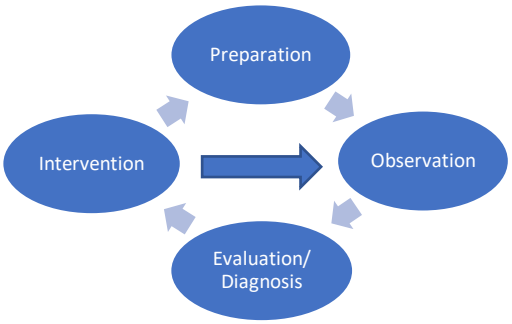


Figure 1 Integrated model of qualitative analysis (Knudson & Morrison, 2007)

While Fig.1 suggest a cyclic nature, coaches may make a series of jumps between stages, such as from intervention to analysis, and backwards and forwards between observation and analysis (Farrow, 2021).

Observation may take place by the naked eye, from various qualities of video capture, and using computer/mobile applications. The video capture can then be used as part of the observation, evaluation and even intervention stage if the coach so wishes. However, this use of technology is only of value if the coach can interpret the available biomechanical information and turn it into skilled performance via coaching intervention (Farrow, 2021). Therefore, observational skills alongside biomechanical knowledge are critical to the quality of this cyclical process. Differences in professional judgement have been shown in expert and non-expert tennis coaches when analysing serving for speed (Farrow 2021) and in gymnastic judges (Ste-Marie, 1999). In both cases, experts were better at identifying the connection between biomechanical principles and elements of the technique. Fetisova et al (2021) also looked at tennis serve technique, and while they found that the more novice coaches could identify the key technical components of the serve, experts were better able to piece the elements together, understanding both the technique as a whole and the biomechanical principles involved. Pulling these findings together we start to see that the knowledge and understanding of the biomechanical principles behind a sports technique is critical to the highest quality of analysis, understanding and interventions in technique coaching. If a coach is not able to understand the 'big picture' of the technique and the biomechanical principles that impact upon it, the coach is left looking for *"meaningless discrete body positions presumed to be key technique points"* (Knudson & Chow 2007).

1.5.1 Teaching Skills

Coaching and Teaching involves designing the learning, delivering the learning, and providing feedback to enhance the learning (Penney 2006). The following section is broken up into three sections: *Learning activity design, Feedback*, and *Feedback as a constraint.*

1.5.1.1 Teaching skills – learning activity design

Once the coach has conducted suitable analysis and evaluation, decisions must be made by the coach as to whether intervention is required for the particular athlete at that given time and within the situational context. If a coach does decide that a technical intervention is required, *how* that intervention is to be delivered also requires consideration. While many coaches will follow the traditional and entrenched practices currently seen within their environments (Woods et al., 2020; Vickery & Nichol, 2020; Townsend & Cushion, 2017; Renshaw & Holder 2010) that tend towards drill-based or net-based practices (Vickery & Nichol, 2020), coaches may wish to set up environments more *representative* of the conditions a cricketer may find in an actual game.

The importance of ensuring that practice conditions replicate the game environment was illustrated by Pinder, Renshaw, and Davids (2009) in a study looking at how batters behaved in typical practice and match conditions. The study had batters face a *'bowling machine'* (ball projection device commonly used in cricket practices) and facing real bowlers. They found that batters changed their techniques significantly, intercepting the ball in different positions and with different heights of bat-swing. Both have a clear impact on batting performance. This highlights the importance of information-coupling with a match or match-like environment.

The ecological dynamics approach looks at the relationships and inter-connectedness of the performer and the environment in relation to the task which they perform. This approach also conceptualises performers as complex entities made up of multiple biological systems that tend to self-organise to provide adaptive behaviours, corresponding to environmental and task constraints (Davids et al. 2013). These constraints challenge the performer to come up with functional movement solutions appropriate to the informational field, which suggests that performers should sample relevant information from the performance environment to lead to skill acquisition (Woods et al., 2020; Davids et al, 2013). This means

that training tasks should allow performers to use movement variability to explore and create opportunities for action, rather than constraining them to passively receiving information (Davids et al., 2013; p. 21).

For coaches to meet these requirements, a coach can use *Representative Learning Design* (Pinder et al., 2011; Robertson et al., 2019), as a framework for practice. Pinder et al (2011) used the term Representative Learning Design (RLD) to describe a way of designing learning practices that replicate the environment being prepared for within the learning practices. For learning to take place, activity needs to be situated in real-game context (Chow, 2010). Learning takes place through the interaction of the learner with the environment and is important in cognitive as well as physical learning tasks (Chow et al, 2016). It is equally important in recall as it is in learning, that is, it is easier to recall learning in a similar environment that the learning took place (Smith 1982). Thus, it is important that players could practice in game-like settings so that they can establish the relevant opportunities for appropriate action:

"…our research using cricket bowling and batting has shown us that the development of appropriate technique requires learners to practice tasks where perception and action are maintained via environments representative of the competitive performance" (Renshaw & Holder 2010).

Pinder et al (2011) go on to point out that RLD allows for *functionality* and *action fidelity* in interventions, coaching and training in the context the skill/learning that is to be acquired. This allows the learner to interact between the chief constraints of the task, the environment, and the learner (see Fig.2), coupling together appropriate information (Newell 1986; Davids, Chow and Shuttleworth, 2005).

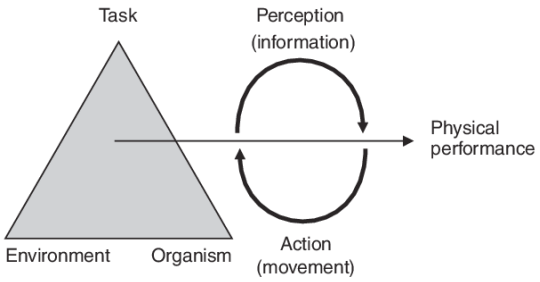


Figure 2 Newell's model of constraints.

This may go to explain why so many experts reflect upon the games of cricket they played as children that helped develop their abilities as experts when adult (Phillips et al 2014). They also recognised that expertise is a unique non-linear process, with a strong focus of the adaptability of expert performance (p.89).

1.5.1.2 Teaching skills - Feedback

"In specialist sports coaching, the type and manner of augmented information that the coach chooses to use in communicating and training with individual athletes can have a significant impact on skill development and performance" (Otte et al, 2020).

Feedback is a key *tool* that a coach may use to facilitate awareness and learning in a performer, and may involve verbal dialogue, physical demonstration or video/computer imagery (Farrow, 2021). The purpose of feedback is to augment the information that is available but not necessarily noticed by the performer. This will often vary due to the awareness, knowledge, and experience of the player. Initially, for example, a bowler maybe unaware of their body alignment during the bound/gather phase of their bowling technique. As they become more aware and increase in the capability of building their own internal feedback, the coach may feedback on such things as timing of the phases, or exact locations of where the ball pitched on the wicket.

A second consideration for feedback is *when* a coach should give feedback (Farrow, 2021). This to a large extent depends on the player, their experience, the skill being executed, and the context of the learning. Video feedback can be useful to give real time feedback from an external perspective, but the coach may also choose to withhold feedback to promote more intrinsic feedback from the player themselves. Additionally, training design will also have an impact on the type and amount of feedback that is required, with more technique focussed *training form* (e.g., skill drills) practices eliciting more than the more random and variable *playing form* (e.g., small-sided games and scenario plays) type of practices (Vickery & Nichol, 2020).

1.5.1.3 Feedback as a constraint

> *"In an ecological dynamics rationale, practice is seen as a search for functional performance solutions, and augmented feedback is outlined as instructional constraints to guide athletes' self-regulation of action in practice"* (Otte et al 2020; p. 1).

Feedback and verbal instruction can be considered as a constraint to learning (Chow et al 2016). While feedback allows a player greater insight into the informational field available, they have the capability of being overused and impede athlete development by reducing opportunities for self-regulation (Otte et al 2020). This is often seen when using traditional pedagogies that look to provide players with an 'ideal' technique (Davids et al., 2008).

This then places a coach in a challenging position to ensure that they provide appropriate levels of verbal instruction and feedback for the player and their contexts, and therefore, deciding *when, how* and *why* to provide what feedback is critical (Otte et al 2020).

Otte et al (2020; p. 7) suggest that there are seven forms of feedback that can be used by the coach:

1. **Instructive (direct)** (e.g., in golf*, "Try both legs to carry equal weight. Then move arms and hands together in one unit, while keeping the wrists solid"* (internally focussed) or from baseball, *"When the pitcher's front foot lands, look at the arm position, and the way the shoulder turns"* (externally focussed)
2. **Task-orientated** (e.g., from soccer, *"Can you pass the ball to the next free player in front of you right after receiving it?*)
3. **Q&A approach** (e.g., from rugby *"Show me how you possibly could have kept possession of the ball for our team in the last game situation"*
4. **Trial & error** (e.g., from basketball, *"Try different ways of throwing the ball to your teammate behind the defender"*)
5. **(Live) video feedback** (e.g., from hockey, *"Look at how you moved your hockey stick in this video sequence*)
6. **Model Learning** (e.g., from volleyball, *"Watch my run-up and jump before serving the volleyball over the net"*)
7. **Analogy** (e.g., from soccer goalkeeping, *"Attack the ball by diving into it like superman!"*).

Each of these forms of feedback offer strengths and weaknesses and therefore the coaches decision making needs to consider these, alongside the key constraints of task, athlete, and environment (Newell, 1986). Coaches also need to consider the amount of feedback that they use across a session or even a yearly programme, as Knudson (2007) points out:

"Coaches should attempt to use cue words and phrases and avoid long dissertations on the techniques and biomechanical rationale for their suggestions…. …. Paralysis by analysis can be created by using confusing or excessive verbal feedback, even if it was based on sound biomechanical principles and sport science knowledge".

This then illustrates another element of the complexity of sport coaching

1.6 Coaching expertise – *'How do coaches know what to do'*

While coaching expertise is difficult to define with any clarity due to the multitude of potential domains, contexts and roles in which a coach may work (e.g., head coach (amateur or professional, specialist fielding coach (juniors and/or seniors), specialist fast bowling coach (male and/or female), head of academy and so on), it generally refers to a level of knowledge, skills and coach behaviours that make the coach highly effective in their role and make that coach stand out from less experienced or accomplished coaches (Lyle & Cushion 2017). In other words, coaching expertise is defined as the *"capacity to be highly effective in the coaching domain"* (p.97). The domain in this study is in elite sport, where each coach is working with fast bowlers who are playing at a professional 'first-class' level or representing their country at an international level; therefore, considered as high-performance coaching.

Lyle and Cushion (2017) explored what effective coaching is in the high-performance domain, and came up with nine factors that demonstrate expertise:

- **Domain specificity** (expertise is sport specific and needs to be effective in the high-performance domain where matchday performance and marginal gains are often critical).
- **Experience** (experience as a high-performance player is often useful to understand the environment but not essential).

- **Personal qualities** (*Coaching function* – well-organised, continually challenging, willing to change, motivation, non-judgemental, attention to detail, reflective, organisation, very responsive, trust, likeability, evident expertise, not frightened to make decisions, adaptive, innovative, robust under pressure, open to new ideas. *General factors* – humility, extremely tenacious, hardness, single-mindedness, go the extra mile, growth mindset, motivated, drive and passion, good listeners, fascination with coaching, passion for sport and people, fast track learning, understand what they don't know, confidence in ability, aware of limitations, self-awareness, don't have ego).
- **Approach/philosophy** (*Ways of working* - consistent philosophy, reflect in action, aware of expectations, acknowledge what is going well or badly, accept that you can't get perfection, management of expectations, consistency of approach, continually evaluate, constant questioning of self, self-correcting. *Functions* – Clear vision and direction, planning, relationships, openness, and commitment to learning).
- **Functional skills** (General (breadth and depth of knowledge and skills), performance planning, managing the learning environment, and managing relationships).
- **Sport-specific knowledge** (immersion in the technicalities of the sport to have the highest technical and tactical knowledge of the sport; the capacity to predict future directions in performance standards).
- **Intellect** (higher order intellectual skills, well-read, reflective, intelligence, EQ).
- **Knowledge** (knowledge of the underpinning sport science and multi-disciplinary approaches).
- **Synthesis and pertinence (alignment)** (Coach's actions/decisions must match the needs of the athlete and the situation/context. This involves understanding the context (including short-, medium- and long-term perspectives) and then shaping of interventions accordingly).

Overall, this suggests that coaches need a pre-requisite level of knowledge, and ensure that their actions are aligned, adapted, and applied to the needs of the coaching context (Lyle & Cushion, 2017; p.104).

1.6.1 Coach development and experiential learning

As alluded to so far, coaches need time and experience to learn their trade and build up both knowledge and competence in sport coaching. Expert coaches use cognitive processes based on tacit knowledge (Nimkulrat, Niedderer, & Evans, 2015). As this knowledge is non-verbal it can be difficult for experts to articulate how and what they are doing (Wood, Rust, & Horne 2009).

Collin and Evans (2009) suggest that there are five steps of specialist expertise: (1) beer-mat knowledge, (2) popular understanding, (3) primary source knowledge, (4) interactional expertise, and (5) contributory expertise. Interactional and contributory expertise are considered to be specialist expertise, where contributory expertise is gained through practice and enables the "expert" to contribute to, or do things within their domain of expertise, whereas interactional expertise is gained by engaging with contributory experts through interview, discussion, and conversation (Nimkulrat, Niedderer, & Evans, 2015; p. 4).

"To accumulate contributory expertise in professional practice is to physically engage with practical activities within that professional domain. On the other hand, interactional expertise is accumulated by engaging in the practice of contributory experts through observation or language-based conversation" (Nimkulrat, Niedderer, & Evans, 2015; p. 5). Therefore, coaches wishing to be expert must engage in practice within their domain (i.e., coaching) in order to build expertise, alongside conversation and interaction with other experts. Therefore, coaching and playing are different domains and require different expertise.

Many coaches, particularly in the high-performance domain of sport coaching, tend to move from being a high-performance athlete into a coach in the high-performance domain (Chroni, Pettersen and Dieffenbach, 2020; Blackett, Evans & Piggott, 2017). Blackett, Evans & Piggott (2017) highlighted the number of advantages that a route from high-performance player to high-performance coach have, which include an ability to gain players' respect, ability to develop practical sense and an elite sporting habitus commensurate with the requirements of the field of elite sports coaching, and the perpetuation of specific playing and coaching philosophies (p.744).

However, there is a growing body of evidence to suggest that the best players do not always make the best coaches (Ewing 2019). Sometimes the corollary also applies, in that some of the best teachers were not very good students themselves (Hodgson, 2014). Playing is not the same as coaching, and studying is not the same as teaching (Rynne & Cushion, 2017) (p. 248). Rhyne & Cushion (2017) further illustrate this point when they suggest that *"No evidence exists that a person can only coach at the highest levels if they have performed there. More specifically, there is no established threshold to be crossed to be eligible for future coaching success".* One of the reasons for players not being able to become expert coaches, certainly initially, is due to their lack of experience within the domain of coaching, and so struggle to build contributory expertise. As Blackett (2021) says *"you don't have to have bene a horse to be a jockey... …. you don't have to have been a piano to be a pianist"* (p.156).

Ewing (2019) gives the following real-world examples of some of the leading coaches in high-performance cricket, who had less than high-performance records as performers:

"Indeed, some of the best cricket coaches in the world today never played international cricket. For example, Mickey Arthur (South Africa, Australia, Pakistan); Graham Ford (South Africa, Sri Lanka, Ireland), Paddy Upton (assisted with South Africa and India, head coach Sydney Thunder, Delhi Daredevils, Lahore Qalanders). If one looks at results, titles and ICC rankings, it is difficult to look past John Buchannan as one of the more successful Australian cricket coaches in recent times, despite also never playing internationally and only averaging 12 with the bat in 7 first class games".

So, while playing experience may offer some form of development and experience from which a coach may operate from, these are not sufficient for a coach to build expertise. It is also not always a smooth transition from high-performance athlete to high-performance coach (Chroni, Pettersen and Dieffenbach, 2020). Many coaches recognise that they have insufficient knowledge and skills, even following fast-tracking onto coach education (Townsend & Cushion, 2017; Chroni, Pettersen and Dieffenbach, 2020). In Chroni, Pettersen and Dieffenbach (2020) study, the high-performance coaches that they interviewed felt that they would have benefitted from more formal preparation/education in the areas of communication, teaching, gender differences and psychology, and this would have

complemented their sport experience knowledge, particularly when working with different athlete populations (p.771).

1.6.2 Coaches' learning – *'From where do coaches learn?'*

Cushion et al (2010) suggest that coaches learn through three modes, *formal, non-formal and informal.* Formal learning refers to the learning that takes place on prescribed activities, such as national governing body coaching awards or university sport coaching degrees and master's degree programmes. This type of activity is undertaken with the purpose of learning. Non-formal learning refers to self-directed activities that are undertaken for the purpose of learning, this includes such things as reading books, attending conferences, listening to podcasts, and watching documentaries. Finally, informal learning takes place in everyday activities that expose the person to experience factors that they subsequently learn from. This includes coaching experience, informal mentoring and observing coaches in practice.

Walker, Thomas and Driska (2018), in their systematic literature review found that coaches preferred informal learning activities. They suggest that coaches didn't like formal learning activities as they tended to be *'decontextualised'* and not applicable to many personal coaching situations. Lower-level coaches did see the importance of formal education in their early coaching years. Stoszkowski and Collins (2015) also found that coaches preferred and tended to gain most knowledge from informal learning. However, what isn't clear is how coaches' access or use each mode of learning or how each mode maybe used together, for example, informal discussions during breaks between coaches while at a formal learning activity, which then leads to non-formal study (Walker, Thomas and Driska, 2018). It should be noted that just because there is a preference for a learning mode, that it in fact is an optimal way for that specific coach, or coaches in general to learn. We also do not know which mode is most effective (singularly or in combination) to coach learning. Stoszkowski and Collins (2015) also noted that there is a lack of critical judgement to the quality and fidelity of the informal learning. They also suggest that, while informal learning opportunities through mentorship, appropriate measures must be put in place to ensure that this informal development is "*sufficiently open-minded, reflective and critical".* Higher education has much to offer here in terms of providing formal coach education, as well as scaffolding to assist the informal practices preferred by the coaches.

1.6.3 Coach education

While not the favourite source of learning for many coaches, formal coach education is often a requirement as licence to practice. Formal coach education in cricket covers courses run by the National Governing Bodies (NGB's) and tertiary education at Colleges and Universities. The level to which they are available, and the content varies between countries. Employers tend to look for NGB qualifications but are more likely to value playing career credentials than formal knowledge (Wicker, Orlowski, and Breuer (2016). In addition, there are no requirements for cricket coaches to 'update' their knowledge through continual professional development (CPD), like in other professional areas such as the medical professions e.g., doctors, and physiotherapists (Anderson, 2020). This means that coaches maybe fast tracked onto coaching qualifications run by NGB's and then proceed to coach using the same methods for decades, with no recourse to update their knowledge. While this clearly has ethical issues regarding coaches best serving their players, this is also a potential risky approach as the world of sport faces more litigious times (Wigmore & Wilde 2019; Anderson 2020).

McMahon et al (2020) point out that fast-tracking high-performance athletes is seen as a positive approach in that it can help perpetuate culturally entrenched ideologies, allowing coaches to best fit into normalised practices. However, it is this perpetuation of culturally entrenched ideologies that is problematic, as many forms of abuse or harassment have been normalised in these sporting contexts (p.265). A more recent case in cricket is that of former Yorkshire and England Under 19 cricketer, Azeem Rafiq, who sort compensation following allegedly suffering years of racial abuse and bullying while an employee of Yorkshire County Cricket club (Governement.uk, 2021). The initial response from the club was that Rafiq's experiences were 'banter', i.e., a normal environment within the club.

The International Olympic Committee suggest that the reduction of harassment and abuse is a priority and one of the key roles of coach education (Mountjoy et al, 2017). Therefore, coach education needs to hold a greater importance to both high-performance coaches, and to governing and high-performance sports teams, if the International Olympic Committee's aims are to be met.

As cited earlier, coaches do appreciate the value of knowledge and skills that can be gained through formal education (Chroni, Pettersen and Dieffenbach (2020). Galvan, Fyall & Culpan (2012) explored the perceptions of high-level cricket coaches on the New Zealand Level 3 Cricket coaching course, which is the highest level of coaching qualification in New Zealand. The coaches under investigation saw the value of moving away from the privileged position that technical skill development approaches had previously taken in coach education, with a move to a greater breadth of coaching knowledge. Coaches also suggested that they benefitted from a greater knowledge of educational learning theory (Coach as 'educator'), the concepts supporting athlete empowerment, and reflective practice as a means of informing an ever-evolving coaching philosophy (p. 123).

However, there did appear to be some misunderstanding from the coaches of these areas, particularly around the application of such theoretical bases. Therefore, it was suggested that coaches may need more support in these areas. Just attending a course where this type of conceptual material is covered, does not mean that coaches will be competent or even chose to use it, much in the same way that Knudson (2007) argues that coaches are in no position to apply biomechanical principles in their coaching, just because they have attended a course or read materials:

"Let us not kid ourselves and assume that, because students or coaches have listened to a few lectures on the biomechanics of sports, they can apply this information in their qualitative analysis of human movement" (Knudson 2007).

Townsend and Cushion (2017) studied members of an ECB (UK) Level 4 high-performance coaching award (the highest level NGB coaching award in the UK) using a Bourdieusian analysis. They found not only some misunderstanding of the theoretical content, as with Galvan, Fyall & Culpan (2012) study of equivalent coaches in New Zealand, but also other approaches to subvert the learning process. The coaches used "what worked in the past" to dictate what goes on in the future and become the 'norm' for coaches (p. 536). This then gave rise to an anti-intellectual agenda towards anything falling outside of this including the new learning material on the course. Townsend & Cushion (2017) gave a specific example of these subversive actions:

"A specific example of this was found in the biomechanics modules, which caused major conflict for the coaches: yeah, we challenged the biomechanics content … biomechanics is a bit more science—cricket isn't science—and I found that a bit frustrating, as did I think a number of the coaches on the course you know, you can't just have … cricket is not just 'that' … you know … x and y. It's just not- it doesn't work that way for me, not through my eyes anyway. (Thomas) Obviously things like biomechanics can throw up a few issues, whether you come from biomechanics viewpoint first of all, or a coaching viewpoint first of all. (Nigel) Here 'science' and 'coaching' were dichotomised in an attempt by the coaches to subvert and modify legitimate classifications of 'coaching knowledge' and secure symbolic capital, and therefore their position within the field" (p. 536-7).

Throughout, the coaches resisted any new knowledge that challenged any of their deeply held beliefs or previous 'successful approaches' (Cushion & Partington, 2014; p. 537). The power of their previous experience gave coaches ways to (re)produce knowledge but also created a self-interested ignorance (p. 537).

This is, in part, why Galvan, Fyall & Culpan (2012) call for *"drawing on the critical paradigm to enhance the reflective process and provide coaches with a more explicit and informed reasoning for change. This would require an acute, finely balanced programme that would be flexible enough to move in such a direction when the coaching participants were ready"* (p. 138). This matched Townsend and Cushion (2017) call that *"coach education needs to be interrogated, critically explored, and reflected upon, to contribute to a more sophisticated understanding of coaching in order to progress the field and inform practitioners"* (p. 543). Carson and Walsh (2019) also joined the call for greater assistance for coaches in coach education programmes with reflection and its use:

"This reflection needs to assist with the integration of theory to practice. Greater planning may be required in formal coach education settings to ensure novice coaches are developing critical thinking skills and become continually engaged in learning. Within these courses hands-on practical experience needs to be meaningful."

If coach education could be both individualised and continuous in its approach to allow the coaches' space and time to not only understand the theoretical knowledge base but apply it, and then critically reflect upon these practices, higher standards of evidence-based and

well-considered coaching practice will be produced. This may, however, require ways of making coaches accountable for keeping their knowledge and skill-base up to date.

1.7 Coaching philosophy

A coaching philosophy is the principles, beliefs, values and behaviours that guide a coach in their coaching practice (Jenkins 2011). However, these beliefs and values may not always reflect upon the coaching behaviours that are enacted (Lyle, 1999). While Lyle (2002) believes that coaching philosophy is bound in a coach's values, he notes that a coach may not always be able to follow behaviours aligned to their values. Cassidy, Jones, and Potrac (2009) suggest that a coach's values maybe compromised due to employer's demands or public sentiment. Coach philosophy will impact upon how a coach, plans, delivers, and reflects upon their coaching practices, the content of their sessions, how they analyse performance in their players, the tactical and technical priorities as well as performance goals for a team, and so on.

Gould et al (2017) suggest that a coach's beliefs guide not only the behaviours of the coach, but also the outcome of their athletes. They studied the renowned wrestling coach J Robinson, and found that his coaching philosophy, drove his coaching behaviours as well as what he prioritised within his coaching. Robinson greatly valued psychological skills within his athletes, so dedicated much of his coaching time to develop these within his athletes. It was seen that experiences gained from a 35-year coaching career helped Robinson build and develop his philosophy as well as his coaching practices. Robinson also had a clear idea that coaching was his purpose in life. It was also seen that his coaching philosophy built, grew, and changed over time.

Jones, Armour, and Potrac (2004) noted that a coach's background and education influence a coach's philosophy and coaching practices. For example, those with a teaching background are more likely to focus on athletes as learning and coaching as a learning process. Finally, a coaching philosophy reflects the assumptions that a coach holds around life, sport, and his/her athletes. It is important that a coach has good self-awareness to identify their assumptions and beliefs (Martens 2004).

However, Cushion and Partington (2016) strongly criticise the literature in this area, suggesting that it is an oversimplification of the process. They suggest that there is an

overemphasis of coaches' agency and reflexivity to be able to follow a coaching philosophy and that there is the downplaying of the significance of social structure on coaches' dispositions. They question the acceptance that coaching practice is an entirely conscious activity. They suggest that by "*subjecting beliefs and justifications of existing and ongoing practice to abstract rational and detached (i.e., philosophical) reconsideration, theory can in fact inform and transform practice by ihnforming and transforming the ways in which practice is experienced and understood"* (p.861). They believe that this critical reflective process will allow coaches to move away from habits and unquestioned rhetoric and move towards more critically transformative practices.

1.8 Enskilment –*'The coaching journey'*

Enskilment is an ecological-anthropological worldview of skill, learning and education in sport (Woods et al., 2021). This worldview follows the idea that *"learning is inseparable from doing and/in place, meaning individuals become more actively self-regulating in performance through deepening their attentiveness to environmental features"*, that is the learner, the learning and the learning environment interact with one another and are inseparable from one another. Enskilment can be viewed as a practical tacit knowledge or 'know how' that progressively emerges as an individual becomes more familiar with the task at hand and the surrounding context (p. 3). This requires an attending or responding to the pertinent things in the environment, building and using an *'educated attention'* (Woods et al., 2021). An example of this would be:

"A cricket batter would need to educate their attention to information about the arm and wrist position of the bowler, the rotation of the ball in flight, its bounce off the surface of the wicket, and the position of fielders to successfully score runs" (Woods et al., 2021; p.4).

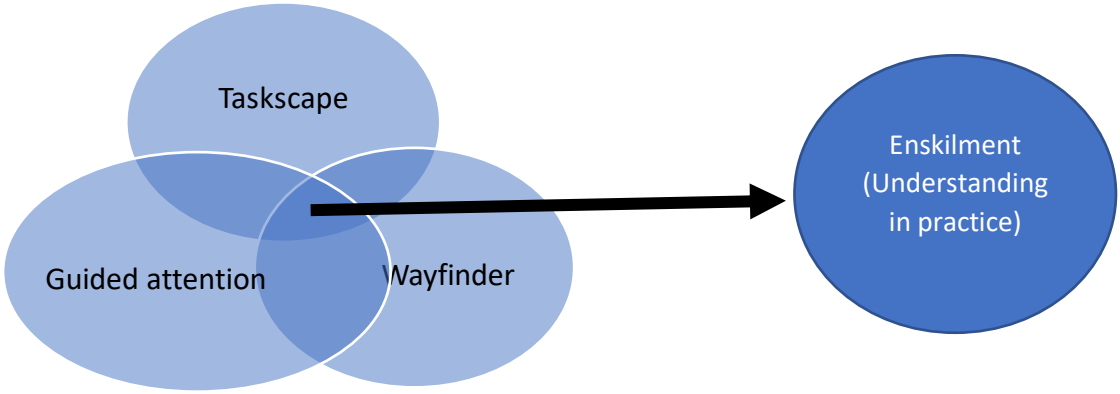
Therefore, the role of coach is not to solve problems for a player by giving prescriptive instruction or continual feedback, but to help them grow an intimate 'knowledge of' the performance landscape and its possibilities for action (p.4).

Woods and Davids (2021) suggest that this knowledge is gained by *dwelling* in the environments in which the knowledge is used, thus, *"we consider how the growth of enskiled inhabitant knowledge emerges as people dwell in their environments, guided by experienced others (i.e., sports trainers, teachers and coaches) who shape how they learn to*

perceptually learn" (p. 3). This suggests then that *both* the player and the coach must be *inhabiting* the environment, with the coach having spent some time living within the environment to be able to guide the way for the player.

This *'wayfinding'* is one of the three components of enskilment, the other two being *'taskscapes'* and *'guided attention'* that become *entangled* together (Woods et al., 2021; p.5).

Figure 4 Enskilment (Woods et al, 2021)



The *Taskscape* is the performance environment in which the performer must *dwell.* The taskscape contains an ensemble of all the mutually interlocking tasks, as no tasks can be completed in isolation. The *Wayfinding* is the way in which an individual actively passes through the *landscape*, learning as they go along, using their perceptions, cognitions, emotions, and actions. Wayfinding involves the individual *navigating* the landscape. Finally, *Guided Attention* involve a more experienced other (e.g., coach) leads a less experienced companion out into the world, guiding their attention to things directly as they are in the context I which they are (p.5).

Enskilment then, happens at the intercept of these three components as they become entangled (see Fig.4). It is worth noting here that the enskilment of a player and a coach happen on similar but different landscapes, as the coach moves more to Guided Attention:

"These perspectives point toward the very core of enskilment, which is founded on a relational, interactive way of being. It is a worldview that calls for humility, genuine inquiry and an embracement of the unknown. This approach accepts that at any time, an enskiled

individual is both prepared and unprepared for the demands of the taskscape—prepared in that they are responsive or 'tuned in' to the opportunities for action, but unprepared in that they appreciate nothing is given in an environment that is constantly changing" (p.8).

This then gives us a framework from which to view coach-athlete relationships, pedagogy, representative learning task design and a coach's professional judgement and decision making.

Summary:

Fast-bowling is an important component of the game of cricket, with fast-bowlers being highly desired by teams for success (Johnstone et al 2014). Fast-bowling is a multi-phasic technique, that is correlated with high frequencies of injuries recorded in the literature (Glazier & Wheat, 2016). Coaches are required to understand the technical and biomechanical requirements of this technique, alongside game-specific/tactical knowledge. Coaches must analyse sports performance, including conducting rudimentary biomechanical analysis of a fast-bowler's technique, and then design coaching interventions based on these analyses. This calls for coaches to also have knowledge of skill acquisition, and sport pedagogy to ensure that coaching interventions are appropriate for the player.

Coaches have personal coaching philosophies that direct their coaching practices. These personal philosophies influence the coaching interventions chosen, and impact upon the coach-player relationship.

This study therefore sets out to further understand how expert cricket coaches navigate these many knowledge and skill-bases to provide effective coaching to fast-bowlers performing at the highest levels of professional cricket.

Chapter 2 - Methodology and Methods

The aim of this chapter to illustrate how the methods chosen are best suited to not only unpick the experiential knowledge of expert cricket coaches but be able to analyse and report the data in such a way that the cricket coaching community can understand and embed the findings in their coaching practices.

2.1 Metatheory:

Metatheory is the theory and assumptions that are made about the nature of the social world (ontology), assumptions of the nature of the knowledge of/within the social world (epistemology), and our approaches that we use to gain this knowledge (methodology/methods) (Bingzhaou, 2006; North, 2013a; North 2013b; Peters et al, 2013; Ahmed & Ahmed, 2014).

All research makes assumptions about the nature of the world we live in, and these assumptions impact upon the methods of research we use and the results that we obtain (North, 2013b). However, the metatheoretical assumptions of research are rarely if ever articulated in the peer review literature (Darlston-Jones, 2007; North 2013a). This is particularly pertinent in the sport coaching research literature as North (2013a) found. In his study of the most frequently sited coaching research papers, only 4 of the 18 reviewed stated their metaphysical position, and these were from the sociological and thus interpretative paradigm (North 2013a). North (2013a) found that the papers followed either a *positivistic scientism* of the psychology field or *interpretivism* of the sociological field. Abraham and Collins (2011) found similar in their earlier analysis of the field of sport coaching research, suggesting that the research came from cognitive psychological, sociological, or behavioural paradigms.

While previous research has been important for the development of this immature field of study, it is not just the findings that have influence but also the philosophical underpinnings, which has implications on the application of this research in sport coaching practices (North 2013a). For example, psychologically related research findings will find simplistic mental models and processes for the coach to follow, which it can be argued oversimplify the coaching process and fail to recognise the socio-political complexity of sport coaching (Cushion and Lyle, 2010).

This was equally apparent when examining the early sport coaching research that followed a behavioural approach to examine what expert coaches did in their practice (e.g., Lacy and Darst, 1985). Following this positivistic approach, researchers were able to examine the behaviours of a coach, such as the number of times the coach gave instructions or feedback. However, this research failed to give any explanation as to *why* the coach chose (or otherwise) to demonstrate these behaviours rather than others (Abraham & Collins, 2011).

Finally, sociologically informed researchers' aim is to interpret the complexities of the social world, and that is just what they found (North, 2013a&b). While an understanding of the complexities and multi-levels of influence that the social world has on the coach, it is argued that these approaches over-emphasise the complexity of coaching, including a blanket politicisation and complexity that coaches do not often recognise (Lyle, 2007; North 2013a). Lyle (2007) strongly argues that although coaches do indeed get placed in challenging and complex situations, this does not mean that coaches cannot or do not try to navigate the environment, in fact the coach will have some heuristics (rules of thumb), and pre-planned approaches to cope with this complexity and to bring some form of order to the coaching environment.

2.2 Pragmatism

Pragmatism was made popular as an approach to research by the early works of 1990,1991). It looked to provide practical answers and solutions to 'real-world' problems that people faced every day, rather than answers to absolute truths (Giacobbi, Poczwardowski, and Hager, 2005).

The relativism vs realism debate has been at the centre of the creation of a pragmatist approach. With its origins starting in constructivist ontology, with links to phenomenology, traditionally pragmatism holds a relativist position (Crotty 1998), pragmatists do not deny *reality*; just because something has been socially constructed, it does not necessarily make it less *real*. As Crotty (1998) illustrates, in baseball such things as *'balls'* and *'strikes'* are socially constructed and exist because of the rule structure of the game. The fact that players (and associated coaches) can be paid millions of dollars to produce or reduce these can be seen to confer their reality (p.64).

Pragmatists deny that there is a single reality which in turn means that researchers cannot determine whether their theories are closer to the *truth* than the theories of their peers. Pragmatists are looking for answers and solutions to 'real-world' problems, not a loyalty to the tradition of one approach over another. Therefore, pragmatists have abandoned discussions that concern theory and reality in favour of methods, theories and approaches that are more useful to us within specific contexts (e.g., answers to practical problems) (Giacobbi, Poczwardowski, and Hager, 2005). That is, pragmatists put the research problem first and apply whatever methods that is relevant to finding a practical solution (Grecic and Grundy, 2016). Pragmatists look to build or extract theory from practice and then inform practice, to build a more intelligent practice (Grecic and Grundy, 2016). That is not to say that pragmatism cannot be used to answer deep ontological existence questions (Mitchell, 2017). This approach mirrors those of the Sport Coach, who's 'job' is to find the best means, ethically and morally appropriate to the context, that enhance learning and performance in their athletes (Lyle, 2002). This is, much in the same way that pragmatists look to find the practices that work best through reflection and experimentation (Crotty, 1998), the coach searches to develop practices that do likewise (Lyle, 2002).

The pragmatist standpoint of being able to hold both relativist and realist positions means that mixed methodologies can be used effectively (Giacobbi, Poczwardowski and Huber, 2005); and is often the stated reason for holding this epistemological position. However, this leads the way to the criticism of an *'anything goes'* approach and what has been seen as a lack of criticality (Crotty, 1998). However, through the critical reflection of experiences and culture, using differing epistemological positions, it can be argued that pragmatism is, if anything, in a position to be a more thorough analysis due to its multiplicity of viewpoint.

Importantly, pragmatists also recognise that scientific inquiry is contextual in nature and that the past and current social, historical, and political conditions also strongly influence the scientific process. This again aligns with sport coaching research as it recognises the macro and micro politics and messy complex mix of influential factors on the coaching process (Jones, Potrac, Cushion and Ronglan, 2011; Cassidy, Jones, and Potrac, 2016). Dewey (1931) noted that past general ideas are the basis for organising future observations and experience, while Rorty (1982) claimed that all inquiry begins with and is guided by the previous discourse that researchers inherit from their predecessors (Giacobbi,

Poczwardowski, and Hager, 2005; p. 21). However, it is important to note that the *pragmatism* we are discussing here is what Jenkins (2017) called *philosophical pragmatism* rather than the everyday understanding of *pragmatic,* which involves practical approaches that are results or outcome focussed e.g., do what it takes to win at any cost, which Jenkins referred to *crude pragmatism.* As coaching sport does not exist in a vacuum, the moral and ethical practices, and approaches, expected for everyday life, must also be followed. This has not always been the case as has been seen in the latest expose of abuse in high performance gymnastics (Varley 2020).

Therefore, we can see that pragmatists value research based on their practical solutions as well as their social and moral consequences. The solution is more important than the philosophical framework from which the solution was found. This perspective then, allows pragmatist researchers to design research based on the problem presented and the research question asked, rather than from an ontologically demanded methodology. Pragmatists, accept that their findings are fallible and subjective in nature (Nelson, 2017); an objective search for *truth* is not the aim, while consensus across the community is (Giacobbi, Poczwardowski, and Hager, 2005). Pragmatists also commonly use a mixed-methods research approach to unpick a research problem (Rorty, 1990; Giacobbi, Poczwardowski, and Hager, 2005; Grecic and Grundy 2016).

Another key ingredient of the pragmatist approach to research is that it is situated within a *community* and should inform and positively impact this community's stakeholders (Grecic and Grundy, 2017). This aligns to the purpose of the Professional Doctorate, within which this study sits, which is to inform and improve practices within the professional field of study (Gill and Hoppe, 2009).

Finally, interaction with the *field* and its stakeholders is an essential part of pragmatism's approach to validity (Giacobbi, Poczwardowski, and Hager, 2005). Rather than using rigid criteria and processes to claim validity, pragmatists look to application and dialogue with the stakeholders, in an on-going process. It is through a process of 'abduction' that pragmatists look to build their validity (Jenkins, 2017; Turner 2017). Abduction is defined as a type of reasoning where one goes back and forth between induction and deduction, first converting observations into theories and then assessing those theories through action and dialogue (Morgan, 2007; Jenkins, 2017). For abduction to occur, Jenkins (2017) calls for a

'Pragmatic Temperament' (flexible mind-set) and 'Communities of Inquiry' in which to engage. In support of this, Hall, and Grey (2017) suggest that only through engagement *with* coaches can we expose the complex relations between actions, interactions and consequences in emergent and naturalistic coaching contexts, and thus support more critical and intelligent action (p. 48).

In summary, pragmatists evaluate research based upon its practical, social, and moral consequences. They consider the problems in the field and the specific research questions as being more important than the underlying philosophical assumptions (ontology and epistemology) of the method. Bingzhaou (2006) points out that ontology and epistemology are not like sweaters, to be worn whenever we see appropriate, but like a skin that makes us who we are. Therefore, personal philosophies of the researcher and ontologies used in the research process should align with one another. As the principal researcher in this study is also a coach practitioner, and coach educator in the field of cricket, who has the desire to integrate the findings of this study in his coaching and educational practices, a pragmatist approach is most relevant.

Darlston-Jones (2007) also suggests that researchers need to understand who they are, what they hold to be true, and to understand their own biases and prejudices, before they carry out research (p.25). The lead researcher is also an evidence-based practitioner, coach educator and pragmatist by nature; therefore, the pragmatist approach to research is the most closely aligned.

The use of expert's experiential knowledge is seen as a highly valuable additional and often under-represented source of knowledge (Greenwood, Davids & Renshaw, 2012). Expert coaches hold highly specialised levels of declarative and procedural knowledge (Nash and Collins. 2006), which they are required to elucidate (Williams and Davids, 1995). Coaches must also understand and harness the complexities that impact their coaching practices and impact upon their knowledge bases (Cushion and Jones, 2001). Expert coaches are therefore in position to assist researchers in providing direction in theory building while identifying limitations in research design and findings (Greenwood, Davids and Renshaw, 2012; Greenwood, Davids and Renshaw, 2014).

The aim of this study is to unpick the issues of coaching the technique of fast bowling in cricket. By using the experiential knowledge of expert coaches, several suggestions for coaching practices can be used to inform the field and start ongoing dialogues with the stakeholders (in a *Community of Inquiry*), following *philosophical pragmatic* principles (Jenkins, 2017).

2.3 Methodology

Whilst an alignment between ontology, epistemology and methodology is essential for high quality research, the methods chosen must be suitable to the research question. Pragmatism calls for the use of methods, best aligned to understanding and finding answers to the research problem (Giacobbi, Poczwardowski, and Hager, 2005; Grecic and Grundy 2016; Jenkins, 2017). The research aim here is to explore expert coaches' conceptions of what the fast-bowling technique in cricket is and involves, how it can be successfully 'coached' and finally, to explore how the coaches came to these conceptions.

Qualitative research methodologies provide the means for deep understanding of life, by being able to ask more than the *'what'* type questions asked through quantification and allow us to ask the *'how' and 'why'* questions of life (Darslton-Jones, 2007).

While there is no 'one-way' of doing qualitative research, it can be agreed that qualitative research involves interpreting phenomena, in natural or 'real-world' settings, from people's perspectives (Ahmed & Ahmed, 2014). It can also be argued that this interpretation occurs in a conceptual framework, as there is never *theory-free* knowledge (North 2013a; North 2013b; Ahmed & Ahmed 2014). As there is such a diverse spread of approaches in this area, the applicability of any method is mainly dependent on the research question or problem itself (Snape & Spenser, 2005; Ahmed & Ahmed, 2014).

In order to extract meanings, attitudes and values from humans for interpretation, which cannot easily be observed or measured directly, it is believed verbal communication can be used, and that interviews are a true and accurate record of those meanings and perceptions (Ahmed and Ahmed, 2014). Interview and content analysis is the main qualitative process used in sports research (Biddle et al. 2001; Smith & McGannon, 2018) and in health care research (Wuest, 2011).

These methods are not without their criticisms (Diefenbach, 2009); including interviewee selection, interviewee influenced by the interview situation, Interviewees are not a reliable source for information because of conscious and deliberate attempts to mislead the interviewer (p.882). Crutcher (1994) suggested the issues maybe: (a) whether the information in the verbal reports reflects thinking accurately- (b) whether asking subjects to report on their own thoughts changes and alters the course of thought-the reactive-effects issue; and (c) whether verbal report data can be treated as objectively as other behavioural data (p.241). Finally, Opdenakker (2006) notes that we need to consider both the synchronicity/asynchronicity of the interview and the modality used i.e., face to face, online, or telephone, alongside other messenger-based communication channels.

This study looks to remove much of this criticism through purposeful sampling of participants, interviewer credentials, and face to face interviewing (live and virtually). Diefenbach, (2009) biggest concern with interviewee selection is that of ensuring an appropriate voice is heard, i.e., is the interviewee selected because of their world view and is it their world view that the research is aimed towards. Purposeful sampling, using experts in the field goes a long wahy to accomplish this. As stated previously, expert practitioners are an important but under-represented source of information in the research process (Greenwood, Davids and Renshaw, 2012) and it is their 'world view' that this piece of research aims to unpick.

Interviews require social interaction between two or more people, with the interviewer always being an active part and influence on the process (Diefenbach, 2009) and therefore are always involved and never uninfluential. However, as Diefenbach (2009) argues, it is the nature of these interview situations that mirror and reveal their thoughts in a social setting. In addition to this, the relationship between interviewer and interviewee are essential to put the interviewee at ease and to establish both parity and rapport through the interview process. Having the same interviewer for each interview, who has experience of elite cricket as a player and coach, go a long to achieving this goal as they share common language, terminology, and experiences.

Opdenakker (2006) noted the key advantages of face-to-face interviewing allows for all parties in the interview process to have access to the non-verbal cues as well as the verbal. This is seen as an essential part of the communication process, allowing the interviewer to

use them to prompt and gain deeper understanding (p.3). While, synchronicity is essential for this process, due to modern technology, video-based online technology, allows for interviews to take place between people on different parts of the planet.

Legard, Keegan and Ward (2005) call for three features in an interview, namely flexibility, interactivity, and comprehensibility. Flexibility calls for an openness to *'go with the flow'* a little to give space so that topics can be explored more freely. Interactivity recognises that interviews are a co-construction, i.e., the content is generated between the interviewee and interviewer, and therefore it is essential that this is an effective working relationship. Finally, comprehensibility calls for the interviewer to use effective techniques and probes to un-pick the real depths of the discussion areas, to ensure that as full a view of the meanings, values and experiences are unearthed in the interview.

Whilst interviews can vary from totally structured at one end of the continuum to unstructured at the other, it is believed that semi-structured interviews offer the ideal balance between flexibility and freedom to build 'in-depth' discussions and explore new meanings (breadth), while still maintaining a focus on the topic at hand (Ahmed & Ahmed, 2014). This allows for what Legard, Keegan and Ward (2005) consider to the 'generative' features of in-depth interviews as they are likely to lead to new, unexplored thoughts that unfold and add value to the findings.

It must be recognised however, that interviews create negotiated, contextually based and theory laden results (Fontana and Frey, 2000). Therefore, the inter-relatedness and capacity of interviewer and interviewee become critical (Ahmed & Ahmed, 2014). Rapport between co-constructors (interviewer-interviewee), built on mutual trust and respect, is essential, but must be balanced as not to bring about potential biases (Burgess, 1995). Having common ground, such as experiences and beliefs between the two co-constructors can also help with the issues of rapport as it allows for sharing of experiences and builds common ground (Edwards, 1993).

Other issues with co-construction, is the potential power-balance of the relationship as well as mixed gender issues (Wuest, 2011; Ahmed and Ahmed, 2014). Great differences in power status and hierarchy can negatively impact on the likelihood of the interviewee giving full and honest disclosure. This study looks to at least minimise, if not overcome some of

these issues by ensuring that the interviewer and interviewees are of the same gender, and that the interviewer (and author) has performed at first-class cricket, coached at a similar level, and has a good understanding of research and the research process.

Knowledge claims that researchers make are critical for the evidence base that applied practitioners will look to use in their coaching practice (Ronkainen and Wiltshire, 2019). Qualitative research has looked to defend the charge of being too subjective, anecdotal, and not generalisable through methodological procedures and philosophical positioning (Smith, 2018; Ronkainen & Wiltshire, 2019).

It is argued that as qualitative research sits in completely different paradigms to its quantitative counterparts, traditional methods of validity, reliability and generalisability are not appropriate, and qualitative research needs to use its own measures of quality (Denzin and Lincoln, 2005). For example, no matter how closely an interview guide is followed, no two interviews can ever be the same, due to the individual nuances, experiences, beliefs, and attitudes of those being interviewed. Smith & McGannon (2018) argue that as each interview can never be identically repeated, we can never have *reliability* as it has been traditionally viewed from a *scientific* eye, that is, we can never use this type of measure. Therefore, we should refute the need for reliability in an unapologetic stance as it does not make sense for qualitative research (p.112).

Ideas such as trustworthiness, rigor and quality of qualitative research have been used (Smith & McGannon, 2018; Ronkainen & Wiltshire, 2019) for this task, and it is rigor that will be attempted in this study.

To maintain *rigor*, qualitative researchers have turned to the methods of *member checking*, *inter-rater reliability*, and *universal criteria* (Smith & McGannon, 2018). Member checking (respondent validation) is usually carried out with participants of the study double checking the validity of interview transcripts, and then later, the validity of interpretations of the analysis. It is believed that this process will control for biases and fact checking 'truth' (Lincoln & Guba, 1985).

Inter-rater reliability is a method that aims of ensuring that results are reliable in that they are reproducible and consistent, by employing inter-coder agreement; a triangulation in many ways (Campbell et al., 2013). This means two or more competent researchers,

operating in isolation to separately code the text without negotiation initially. Then any discrepancies are discussed until consensus is agreed (Smith and McGannon, 2018).

Universal criteria were initially sited by Lincoln and Guba (1985) and then more commonly in the sport literature by Tracy (2010) as the *"eight universal hallmarks for quality qualitative methods across paradigms"* (p.837). These eight hallmarks are: (1) worthy topic, (2) rich rigor, (3) sincerity, (4) credibility, (5) resonance, (6) significant contribution, (7) ethics, and (8) meaningful coherence. It is believed by Tracy (2010) amongst others, that universal criteria can be applied for judging any form of qualitative inquiry. This way all qualitative research may be judged.

Whilst these three approaches to methodology have been widely used across the sports literature, they are not without their problems and controversies. Smith and McGannon (2018), Ronkainen and Wiltshire (2019), Smith (2018) argue, from different perspectives, that there are critical issues with member checking (respondent validation), inter-rater reliability (triangulation/ multiple coding), and universal criteria.

Member checking assumes that this is a neutral and objective process without bias. However, this process is carried out by humans, with pre-conceived biases, theory-bases, and subjectivity. Also, as member checking is carried out by humans who hold differing levels of social power, it is difficult to decide who, if either, takes priority. Should it be the interviewee as it is their testimony, or the researcher who has greater knowledge of the research process (Smith and McGannon, 2018)? Therefore, member checking was used to ensure reliable transcription only in this study.

Inter-rater reliability is also ineffective for ensuring reliable qualitative research (Smith and McGannon, 2018). The first issue lies around the issues of unitization, i.e., the blocks of text used to represent meaning. While two researchers may draw similar meaning from a block of text, the units that they use to represent that meaning can be wholly different; conversely, the same units could be seen to have different meanings. Additionally, as each researcher will come into the analysis with their own individual worldviews (ontology), experiences and knowledge bases, value judgements as to which account is more representative or valuable than another becomes problematic (Madill, Jordan and Shirley, 2000).

This then makes inter-code reliability very difficult if not impossible to bring about reliable agreement (Smith and McGannon, 2018). Inter-rater reliability also inherits the same issues as member-checking, i.e., it involves humans with their own subjectivity and biases, not to mention potential differences in gender, age, nationality, knowledge, experience and training. Additionally, there is little if any consensus of how much member checking and inter-rater reliability consensus is enough. For example, do we assume that a study with 92% consensus is stronger than a study with 87%? Which in turn is stronger than one with 85%?

Universal criteria are also problematic if they are to be applied to all forms of qualitative research. As different forms of qualitative research hold different ontologies and epistemological positions, some criteria will be more pertinent and useful than others. This then can lead to some studies being promoted ahead of others that may in turn be excluded, even if they produce new knowledge and make a difference in society (Smith & McGannon, 2018). There is also the risk that this 'checklist' approach can lead to a 'technical exercise' bringing about stagnant and insipid research projects (Burke, 2016). One solution could be just to choose the criteria that are relevant to the study at hand, however, that would defeat the 'universality' of the criteria, and, there is no clear guidance as to which criteria is appropriate which type of qualitative research.

Ronkainen and Wiltshire (2019) argue, from an ontological perspective, that to maintain academic rigor and quality to qualitative research, the research must demonstrate *ontological plausibility, empirical adequacy,* and *practical utility*. Ontological plausibility calls for the use of plausible theories that can more reasonably describe what is happening. Therefore, the research account becomes valid by being ontologically plausible. Because 'causal mechanisms' are often unobservable, the idea of plausibility becomes more appropriate.

Empirical adequacy requires researchers to gather sufficient observational data to support the claims made, and that these recordings are seen and heard as accurately as possible. Due to the nature of different qualitative approaches, the 'sufficiency' of any research project will be different, and therefore difficult to pin down. However, Ronkainen and Wiltshire (2019) argue that ideas of mixed methods, prolonged engagement with/in the environment and ensuring that the most suitable participants are used, go a long way to

increasing the confidence that the researcher has collected adequate data (p.10). Madill, Jordan, and Shirley (2000) suggest that sufficient data is required to be collected and expressed to build a qualitative version of 'internal validity' to the research and bring about a 'consistency of meaning' (p.17).

Finally, practical utility calls for research that not so much represents the world but gives the means for doing things in the world. That is, the more capable the research is of giving us not only practical approaches, but explanations for the real reasons why events and experiences come to be the better that research quality (p.11).

Another issue posited at qualitative research is its lack of *generalisability*, due to the often unique and subjective nature of much qualitative research. Whilst qualitative research does not generalise in the way that quantitative research, Smith (2018) points out that there are many kinds of generalisability, and then qualitative research is capable of being generalised. *Naturalistic generalisability* refers to recognition of similarities and differences to the results that the reader is familiar, i.e., the research resonates with the reader's personal experiences. This requires the author to provide sufficient rich contextual details and theoretical explanations of reality, which causes the reader to reflect upon their own experiences and make their own connections (p.140).

Inferential generalisation (transferability) refers to the extent which one set of results in their specific context, transfers to another. An example could be the results and experiences of a pedagogue's use of non-linear pedagogical approaches in a PE setting being *transferred* to a sport coaching context. In order to do this, the researcher must provide direct and rich testimony, that is written in a way that in invitational and accessible to the reader.

Analytical (concept) generalisation occurs when a researcher generalises a set of results to an established concept or theory. This may be used to not only generalise the set of results with an accepted theory but can also be used to adapt or develop an established theory across different contexts (Smith, 2018; p. 141).

One issue that qualitative research generalisability is that it requires reader engagement, i.e., both researcher/author and reader are actively involved in making the generalisations.

To facilitate this, the author can make suggestions to the reader where they may make generalisations (Smith, 2018; p. 142).

A final strategy to ensure generalisation has occurred is to follow up the piece of research by seeking feedback from individuals and communities with whom the researcher wishes to generalise to. This would cause issues for the researcher in terms of extending the time to publish the work etc; it does however give the researcher increased credibility to their research findings (assuming the community relates to the findings).

Thematic analysis is one of several analytical approaches used within qualitative research to identify meaning across a dataset that offers the potential for nuanced, complex, interpretative analysis (Braun, Clarke, and Weate, 2016), and it offers an accessible and theoretically flexible approach to analysing qualitative data (Braun and Clarke, 2006). Thematic analysis is also not tied to any theoretical or epistemological framework and comes with no methodological stipulations for processes such as sampling or data collection (Braun, Clarke, and Weate, 2016; p.191). This approach then lends itself to several ontologies, particularly pragmatism.

Braun, Clarke and Weate (2016) argue that they have created a robust research process for identifying patterns and interpreting them in several different ways, but releases these from specific or inbuilt, ontological or epistemological anchors (p.193). This then pushes the researcher to identify and make choices about how they will engage with the dataset under which theoretical framework.

Thematic analysis does not work well for certain types of research, such as those based on individual narratives or stories, or in creating theories (Braun, Clarke and Weate, 2016); theory building is best made using grounded theory (Glaser and Strauss, 1967; Holt and Tamminen, 2010).

Thematic analysis is most used to analyse data collected from semi-structured interviews, is they combine to form an excellent method of gaining and analysing in-depth accounts of personal experience (Braun, Clarke and Weate, 2016; p. 196).

The process of thematic analysis involves the researcher making several decisions depending on whether the researcher identifies and explores obvious meanings and

explicitly-stated ideas, concepts, meanings and experiences (*semantic focus*), or the meanings that underpin the things being explicitly stated (*latent focus*). Whichever focus is followed, the researcher must identify a *theme*. A theme captures something important about the data in relation to the research question and represents some level of patterned response or meaning within the data set (Braun and Clarke, 2006; p.82).

Braun & Clarke (2006) and Braun, Clarke and Weate (2016) suggest that thematic analysis follow a six-step process:

Table 3- Phases of thematic analysis (Braun & Clarke, 2006)

Phase	Description
1. Familiarizing yourself with your data:	Transcribing data (if necessary), reading and re-reading the data, noting down initial ideas.
2. Generating initial codes:	Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code.
3. Searching for themes:	Collating codes into potential themes, gathering all data relevant to each potential theme.
4. Reviewing themes:	Checking if the themes work in relation to the coded extracts (Level 1) and the entire data set (Level 2), generating a thematic 'map' of the analysis.
5. Defining and naming themes:	Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme.
6. Producing the report:	The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a scholarly report of the analysis.

Thematic analysis is not a linear step by step process as displayed in table 1, but a process that goes back and forth between the stages and across the stages. For example, the write-up (phase 6) should and often does start in phase 1, as initial ideas. Thematic analysis is an *active* process and not a passive one where themes 'emerge' from the data set, although some authors have claimed this (Braun and Clarke, 2006).

Identifying and constructing themes maybe done *inductively* or *deductively* depending on the research question and metatheoretical approach, which needs to be stated as any theoretical framework carries certain assumptions. Theme identification should also occur across the entire data set; however, the more occurrences a theme has does *not* mean

greater importance (Braun & Clarke, 2006). What is important is that the theme's *meaning* in relation to the research question is identified. While this process can be conducted deductively, it is believed that by following an inductive process (*bottom up)* the themes are not pushed into a theoretical frame but are drawn from the data itself.

This process repeats until *saturation* has occurred, i.e., a point where further analysis fails to add any more to the theme (Nelson, 2017). Saturation in qualitative research has been problematic to define (O'Reilly and Parker, 2012; Fusch and Ness, 2015; Hennick, Kaiser and Marconi, 2017; Nelson, 2017; Saunders et al., 2018). It must be made clear at this point that although thematic analysis and grounded theory have several similarities, they are not the same thing and call for several different processes, including conceptions of *saturation*. Saturation in qualitative research is generally assumed to mean that data should be collected until nothing new is generated (O'Reilly and Parker, 2012). In grounded theory, saturation is the point at categories are accounted for, the variability between them is explained and the relationship between them are tested and validated so that a theory can emerge, rather than point at which no new ideas emerge (O'Reilly and Parker, 2012; p.192). This study will look for thematic *meaning* saturation as defined by Nelson (2017) and Hennink, Kaiser and Marconi (2017).

Braun and Clarke (2006) also provide a 15-point checklist (see Table 4), that gives clear direction of what makes good thematic analysis and follows the principles of academic rigor in qualitative research discussed above.

Table 4 - A 15-point checklist of criteria for good thematic analysis (Braun & Clarke 2006)

Process	**Number**	**Criteria**
Transcription	1	The data have been transcribed to an appropriate level of detail, and the transcripts have been checked against the tapes for 'accuracy'.
Coding	2	Each data item has been given equal attention in the coding process.
	3	Themes have not been generated from a few vivid examples (an anecdotal approach), but instead the

		coding process has been thorough, inclusive, and comprehensive.
	4	Themes have not been generated from a few vivid examples (an anecdotal approach), but instead the coding process has been thorough, inclusive, and comprehensive.
	5	Themes have been checked against each other and back to the original data set.
	6	Themes are internally coherent, consistent, and distinctive.
Analysis	7	Data have been analysed / interpreted, made sense of / rather than just paraphrased or described.
	8	Analysis and data match each other / the extracts illustrate the analytic claims.
	9	Analysis tells a convincing and well-organized story about the data and topic.
	10	A good balance between analytic narrative and illustrative extracts is provided.
Overall	11	Enough time has been allocated to complete all phases of the analysis adequately, without rushing a phase or giving it a once-over-lightly.
Written report	12	The assumptions about, and specific approach to, thematic analysis are clearly explicated.
	13	There is a good fit between what you claim you do, and what you show you have done / i.e., described method and reported analysis are consistent.
	14	The language and concepts used in the report are consistent with the epistemological position of the analysis.
	15	The researcher is positioned as active in the research process; themes do not just 'emerge'

Thematic networks have been proposed an effective and illustrative way to present thematic analysis (g; thematic networks are a way of organising thematic analysis of qualitative data in a diagrammatical and relational manner. A thematic network is

developed by starting with *Basic themes* and working inwards towards a *Global theme* (see Fig.5)

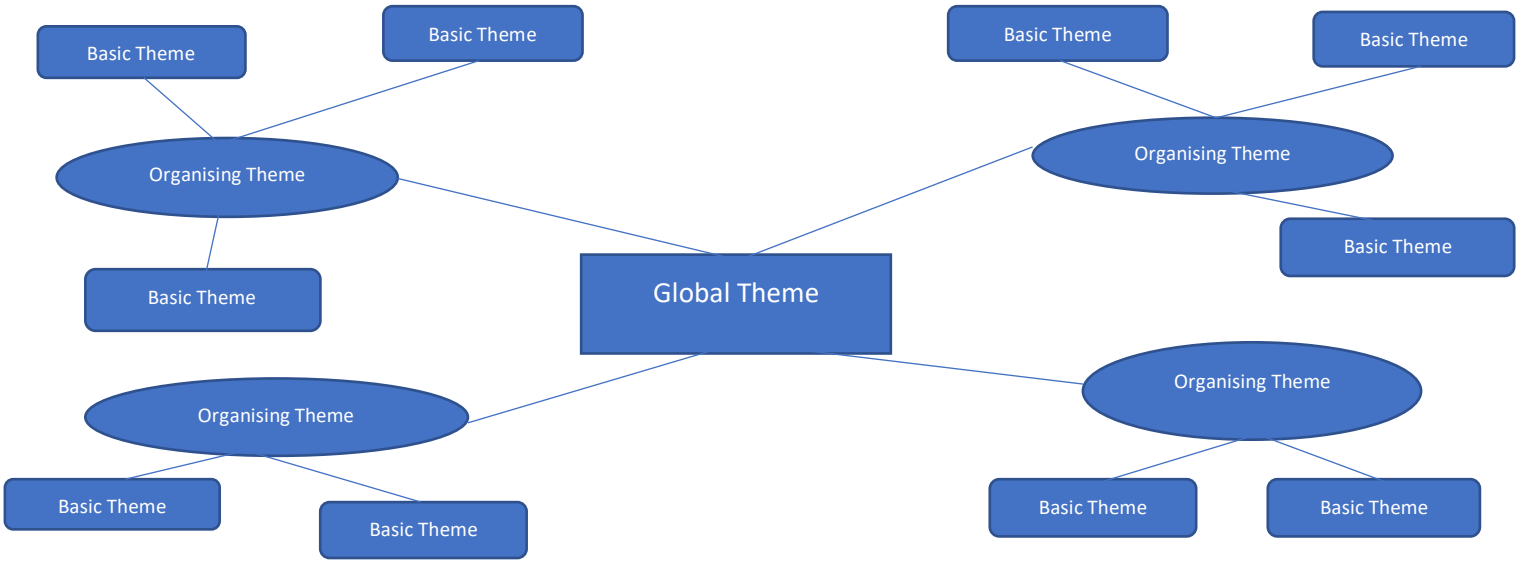


Fig. 5 Structure of a thematic network (Attride-Stirling, 2001).

One of the key advantages of the thematic network is that it gives a clear picture of the relationship between themes. Academic literature has long been criticised for its inability to impact on practice, often due to the inaccessible language that findings are couched in (Williams & Kilgour, 2014; Lyle, 2018). By having a diagrammatical representation of the themes and their relationships, it is hoped that a thematic network approach will go some way to making findings more accessible to practitioners (with or without an academic grounding).

2.4 Methods:

Research Questions/Aim:

What are expert coaches' conception models of the *ideal* fast bowling technique? Where does this conception model(s) come from (how did they acquire it)? And how did they coach this technique?

Objectives:

1. Conduct semi-structured interviews with expert cricket coaches
2. Perform a thematic analysis of the data set

3. Create thematic networks that illustrate, the model of technique, coaching processes and knowledge acquisition.

Study population and Sampling:

Twenty international cricket coaches were recruited to this study. Purposeful sampling was used, with coaches being selected by institutional position they held and the population of fast bowlers that they coached, as well as their experience and qualification level. Assistance was gained from the Lead of Specialist and International Coach Development at the England Cricket Board, and through contacts from the Lead Researcher and Supervisory Team. Elite fast bowlers have been considered in the empirical literature to be those operating in First Class and International cricket and in First Grade Australian state level, and these are the population most researched (Anderson, in press).

Braun, Clarke and Weate (2016) suggest that although there is no hard and fast rule for sample numbers in qualitative research, a bare minimum for thematic analysis would be six participants, but more likely to be a minimum of fifteen to fit with many journal requirements. Hennink et al. (2017), when examining sample sizes required to reach saturation in qualitative research, found that nine studies were required for *code saturation* (sufficient data to draw final codes i.e., "heard it all"); but took sixteen studies to reach *meaning saturation* (sufficient data to "understand it all"). This study demonstrates a sufficient sample to cover these levels. For other commentators, sample quality is deemed a more appropriate measure of the rigor of the sample, as is seen in Table 5 the participants have extensive highly successful careers in this domain.

Table: 5 Participant information

Participant:	**Background details:**
1	(UK) County player and county coach and current county fast bowling coach. 18 years coaching experience from grassroots to County
2	(UK) Former County player (51 First Class games). Current county bowling fast coach. 7 years' experience coaching County Academy and County 1s XI.
3	(Australia) Sydney First Grade Head Coach, working with players at First Grade, and State 1st and 2nd XI bowlers. . 20 years' experience coaching first grade, State 2nd XI and state bowlers.

4	(India) Former International Cricketer (164 Tests; 344 ODI's; 1 T20I; 298 First Class Games); Former National Under 19 Head Coach. Current National Academy Head Coach.); Coaching at International level for 8 years.
5	(India) Former International Cricketer (2 Tests; 4 ODI's; 48 First Class games); Lead National Fast Bowling Coach. Coaching fast-bowlers for 26 years.
6	(India) Former International Cricketer (Test Squad; 92 First Class games); Current First Class team Fast Bowling Coach. 11 years coaching experience.
7	(UK) Former County Analyst. Current County and Academy Fast Bowling Coach. 4 years coaching experience.
8	(UK) Former First Class Cricketer (83 First Class games); Current County Fast Bowling Coach; Current ECB Women's National Fast Bowling Coach. 4 years coaching experience.
9	(UK) Former First Class Cricketer (102 First Class games). Former Under 19 National Fast Bowling Coach. Former Holland International Fast Bowling Coach. Current ECB Specialist Fast Bowling Coach, Current First Class Fast Bowling Coach. 17 years coaching experience.
10	(UK and Pakistan) Former First Class Cricketer (34 First Class games). Current Pakistan Women's Fast Bowling and S&C Coach. 4 years coaching experience.
11	(UK) Former First Class Cricketer (169 First Class games). Current First Class Fast Bowling Coach. 9 years coaching experience.
12	(UK and New Zealand) Former First Class Cricketer (171 First Class games). Current First Class Fast Bowling Coach. 14 years coaching experience.
13	(UK) Former First Class Cricketer (167 First Class games). Current First Class Fast Bowling Coach. 6 years coaching experience.
14	(West Indies) Former International and First Class Cricketer (Test Squad; 68 First Class games). Current First Class Fast Bowling Coach. 7 years coaching experience.
15	(UK, Bangladesh, India, Pakistan) Former International Head Coach (Bangladesh); Former International Fast Bowling Coach (Bangladesh and Holland); Former First Class Fast Bowling Coach (UK, India, Pakistan and Bangladesh). Former First Class Cricketer (28 First Class games). 30 years coaching experience.
16	(NZ, India, UK; Australia) Former International Cricketer (NZ; 18 Tests; 82 ODI's; 20 T20I's; 60 First Class games); Former International Class Fast Bowling Coach (NZ). Former First Class Fast Bowling Coach (NZ; UK; India). Current First Class Fast Bowling Coach (Australia). 10 years coaching experience.
17	(NZ; Australia; UK; India) Former International Cricketer (1 Test; 42 ODI's; 4 T20I's; 78 First Class Games). Former First Class Fast Bowling Coach (NZ; UK). Current Fast Bowling Coach (Aus). 7 years coaching experience.
18	(Australia and UK) Former First Class Cricketer (33 First Class Games). Former International Lead Fast Bowling Coach (UK). Current

	International Lead Fast Bowling Coach (Australia). 26 years coaching experience.
19	(NZ and Australia) Former First Class Cricketer (Australia) (23 First Class Games). Former National Academy Coach (NZ). Current National Lead Fast Bowling Coach (NZ). 14 years coaching experience.
20	(India) Former Test and ODI International player; Coach at MRF Pace Foundation for 30 years.

Note: National demarcation is attributed to the countries in which the coach has played and coached at an elite level.

Interview guide:

1. Initial ice-breaker. This will invite the coach to discuss their development as a cricket coach from a chronological perspective. This will allow the coaches to feel at ease and enhance conversation flow.
2. Fast-bowling technique 1 – Is there an optimal bowling technique? (For performance and injury prevention).
3. Fast-bowling technique 2 – If so, what is it? And how does it work? If not, why not?
4. Fast-bowling technique 3 – How do you know? (The answers above)
5. Fast-bowling coaching – How do you go about coaching the fast-bowling technique? Does this change for novice and expert bowlers?
6. Fast-bowling – Other – Is there anything else that you wish to add? This will allow the coach to add to any points that they have made or wish to expand on something that they have reflected on during the process of the interview and wish to add more.

Prompts: Prompts were used throughout, such as *"can you expand upon….", "what do you mean by….", "does this change in different environments….".* Opportunities to re-explore certain points were also given. As the lead author has over 30 years coaching experience and a former first-class player himself, personal examples and reflections were also used to help expand on points and keep the conversation flowing. This lived experience within the field helped the lead author follow Connectivity Humanness and Empathy (CHE) principles (Brown and Dannaher, 2019). CHE principles allow *"effective rapport-building and respectful and reciprocal relationships with participants in the research"* (p.76), which should result in more rigorous and reliable data.

Pilot Study:

A pilot study was conducted with a former elite fast bowler who had moved into career as a full-time cricket coach. The semi-structured interview followed the interview guide (see Table##). It was discovered that during the interview, the interviewee provided many answers giving physical demonstrations. As these demonstrations were clearly used as an illustrative and important part of the answers given but were not something that could be used for thematic analysis, it was recognised that further prompts during interviews would be needed to get participants to verbalise the meanings of these physical demonstrations.

Interview Conduct:

Interviews were conducted face to face or via online messenger applications for those coaches not situated in the UK. All interviews were recorded, and the contents transcribed *verbatim*. Interviews lasted between 12 and 46 minutes.

Data Analysis:

All interviews were recorded via Otter Application and transcribed *verbatim.* A six-phase thematic analysis following principles set out by Braun & Clarke (2016) and Braun, Clark and Weate (2016) was conducted under a pragmatic metatheory framework.

Once transcription of each interview had been completed, transcripts were sent to the participants to check to not only ensure agreement of contents, but as an *aide memoir* to facilitate further critical reflections. This follows the process of *member reflections* proposed by Smith & McGannon (2018) to enhance academic rigor.

The fifteen-point checklist (Table 4) was followed throughout the thematic analysis, alongside the use of *critical friends* from the research supervisory team (Smith & McGannon, 2018).

The initial stage of transcription was carried out by the lead author. This allowed for greater familiarisation with the raw data and allowed for initial ideas around coding categories to be considered. Once all interviews had been transcribed verbatim, codes (themes) were drawn from each interview and placed in individual note form. Once these codes/themes had

been drawn out from each interview, they were collected together, as answers for each question.

This then started the analysis period where answers were clustered together for their similarity of meaning. Clusters of answers were then analysed to draw out a category for that cluster. Finally, thematic networks were drawn from the final thematic analysis stage to enhance write up of the results. These thematic networks were then analysed for meaning and coherence in relation to answering the question that they represented.

Thematic network diagrams were then sent to each participant, to verify the meaning drawn from their collective answers. Any misunderstandings or questions from the thematic networks were answered and further updates to these models were made.

The final report then drew analysis of the thematic network models and the specific answers given by the coaches, to best illustrate the answers given.

Chapter 3: Results 1- Technical Factors

The results are presented around the three key questions of the study; *what is the ideal fast bowling technique? How do you coach it? How do you know about the technique and how you coach it?*

3.1 What is the ideal fast bowling technique?

The one message that came out clearly throughout the interviews, was that coaches believed that there was no ideal fast bowling technique. Only one of the nineteen coaches (Coach 8) suggested that there might be a *theoretical* ideal technique:

"Yeah, stereotypically, yes, I think there is. But at the same time, it's very rare that you get that. So, for me the most important thing about coaching fast bowling is you've got to be adaptable to each individual's technique."

Coach 18 suggested that the fast bowler's technique needed only to:

"One that takes wickets and keeps them on the park".

Coach 16 and 13 supported the notion of there being no ideal technique when he stated:

"…everybody just does it differently" (Coach 16).

"No, in my opinion it's very unique. It's unique to the individual. I believe there are certain principles that all fast bowlers have been able to follow, but how they actually get into that position is all about them" (Coach 13).

Coach 14 supported this:

"…biomechanically everyone is made up a little bit different. Some guys have tight hamstrings and some guys have loose hamstrings, you get where I'm coming, everybody's made up physically different. So, what works for you probably won't work for me".

As there was a consensus of no overall ideal fast bowling technique, interviews then focussed on the technical aspects (*the ABC's*) the coaches were looking for in their bowlers and looking to improve. Figures 1a&b illustrate the fundamental elements of a 'good technique' and Figure 2 the elements of a 'poor technique'.

For the fast-bowling technique coaches focussed on 6 phases (see later notes on the 'combined BFC/FFC – Delivery stride phase). The six-phase model of the bowling technique matches that identified by Bartlett et al. (1996).

A model of the fast-bowling technique mentioned by the English Fast Bowling Coaches, the ECB Fast Bowling Matrix, identified several key factors in a bowler's technique:

"If you look at the some of the research has been done by the ECB, you can have a look at a few of those things, , run up, you're looking at length of delivery stride, you're looking at the hinge of the top body part, so how far they come from back to forward. You are looking at bowling arm delay, so where is that bowling arm when they land their front foot, obviously, the lower the better. And then you're looking at chest drive, a braced front leg, and the position of release" (Coach 1).

3.2 Internal model of a 'good' fast-bowling technique.

This section will look at the internal model of the fast-bowling technique collectively pulled together by this cohort of coaches, for what they considered a 'good' and a 'poor' technique.

While coaches didn't believe that there was an ideal bowling technique, they did appear to have a clear idea of what they thought made up a 'good' bowling technique (see Figure 1a). This is in line with findings from tennis (Fetisova et al 2021), sprinting (Waters et al 2020; Thomson, Bezodis & Jones, 2009), golf (Smith et al 2012; Smith et al 2015), ice hockey (Mell et al 2017) gymnastics (Cote et al 1984) swimming (Moreno et al 2006) volleyball (Bian, 2003) and climbing (Mitchell et al 2020). In these studies, expert coaches had clear internal models of the relevant sports technique, which was made up of the key kinematic variables identified in the respective sport-related biomechanical literature. They were quick to point out that a bowler may only have certain (kinematic) number of elements of their technique that followed the model.

Coaches identified six phases of the bowling technique in line with Bartlett et al (1996), and these phases will structure the following discussion. It should be noted that the 'delivery stride' phase is a combination of BFC and FFC, but coaches also spoke of this as an entity,

showing an ability to chunk together phases into larger blocks of the movement skill, and so will be discussed as a phase.

3.2.1 Run-up

Four themes were drawn from the dataset; direction; running technique; acceleration and individualisation, only one of which relates to the limited literature in this area (velocity of CoM, e.g., Worthington, King & Ransom 2013).

Coaches were keen to point out the importance of the run-up phase. Coach 20 suggested that the run-up is the most essential part of the technique:

"Basically, fast bowling is all about run up…. run up, run up is very important, because 70% of your effort and your efficiency is in your run up".

3.2.1.1 Direction

The direction in which the run-up occurs in relation to the intended outcome was deemed important.

Coaches 1,4,6,7,8,10, 13 and 16 all suggested that the run-up should be in a straight line, aligned to the target area (the batsman's stumps).

In contrast, Coaches 9,11,12 and 17 all suggested that angled or curved run-up was acceptable if that was the individualised preference of the individual bowler.

"Curving's a difficult one, because sometimes people feel more comfortable curved run ups. If they do, I'm happy as long as there's not a sharp dip in right at the end. So, we can work with that" (Coach 9).

"I guess the one thing I would look at, you can have an angle on it and you can have a straight bowl, I think whatever works for you" (Coach 11).

However, Coach 4 and Coach 16, argued that although some bowlers did use a curved run-up, that it would have a negative impact and lead to compensation further down the technique

3.2.1.2 *Running technique*

Coaches 6,10, 13, and 18 all discussed the importance of the running technique in the run-up phase.

"I try to make sure that if the bowler is running with the proper running technique, I think run up is more important than actually loading and bowling, because if you don't have a good running technique while the bowler is running, a lot of things can't be sorted" (Coach 6).

"…making sure that you are moving as effectively and as efficiently as you can and then being able to take your bodyweight into a jump and keep the momentum going towards the target" (Coach 18).

Coach 19 expanded this running technique further:

"…so, the little jog on the spot or small steps at the start. Lean forward, pump your arms, and that's basically it. So, make sure the shoulders are in front of the hips, and you've got a small lean, so we can try and get the acceleration with quite a natural feel.

In addition to this, carrying the ball in hand can have an impact on the running technique in the run-up:

"you'd be amazing how many times you watch a child, or a player run and then you put a ball in their hands and then the running mechanics completely change" (Coach 11).

3.2.1.3 Acceleration & Velocity

Discussions of both acceleration and velocity within the run-up were discussed:

"Run straight at that target, keep your head going at the target, keep your arm going at the target, and just making sure that he's accelerating a little at the back and in his run up" (Coach 16).

However, the acceleration was seen as a point of reaching an 'optimal' running velocity going into the bound phase.

"a nice smooth run-up which generates pretty good speed into his run-up. But not too quick, because if you're too fast then you're not extremely balanced at the time of your action, it

should be just right, good enough for you to create pretty good momentum and to transfer that momentum into your bowling" (Coach 5).

Additionally, Coach 5 said:

"I would look at a nice smooth run-up which generates pretty good speed into his run-up. But not too quick, because if you're too fast then you're not extremely balanced at the time of your action, it should be just right, good enough for you to create pretty good momentum and to transfer that momentum into your bowling you need a very strong action".

However, the bowling technique used to deliver the ball appeared to have an impact on what the coaches believed to be a good run-up velocity:

"The guys that are side on, they might not have to run in as quick to generate as much force because they're relying more on the force that they generate from back foot contact".

3.2.1.4 Individualisation

The need to allow individualised approaches to run-up were not only for run-up directions, but also for run-up velocity, run-up mechanics and the type of delivery being bowled:

"I think it all depends on the bowlers. Each one is different. In my experience if you look at Mohammed Shami he comes bounding in, or if you look at Bumrah there's hardly any acceleration in his run-up. So, again, the ability to generate speed to have a very strong action is what I would like to see" (Coach 5).

While Coach 19 also suggested that the type of delivery might also impact on the run-up speed:

"…also, execution of skills, so for example a Yorker, a lot of the guys will tend to, just the last few steps of their run up just slow down a bit, because you're trying to hit a 10 cent piece on the line".

3.2.2 Bound/gather

Coach 20 deemed the 'Gather' phase as the second most important:

"So, run up is something which helps you to get through the crease, but there is a second thing, the second most important is the load up, which people say gather or whatever it is. The load

up helps you to land your back foot landing at the right place and the right posture, and the front foot in line with the back foot, which gives alignment to hips and upper body alignment…If the load up is in front of the shoulder and in the eye level, which is very good, because your hand is a very heavy lever".

There were three themes identified as important to the bound or gather phase, namely, the length, head position and the arms.

3.2.2.1 Length

In terms of the length of the bound/gather phase (i.e., jump), Coach 12 suggested:

"...in the bound you've got to try and basically give yourself enough time to align feet, shoulders, hips".

3.2.2.2 Head position

Coach 17 suggested that the head position and direction was important for the bound/gather:

"(You want the head to be going forward) if you can. Ideally you want the head to be either just in front or neutral, and that's not always the case."

However, these positions varied depending on the bowler's intended alignment at the crease, i.e., different for front-on to side-on bowlers:

"If they're a front on bowler then you want to make sure the head doesn't come back too far when they take off, because of course at the point of impact with the back foot there's going to be a transfer of weight forwards, but the head goes backwards, which then makes transferring over the front knee more difficult. So, if they're already back before they jump, then they go further back when they land, which then means they exit out the side".

And for side-on bowlers:

"if you're side on, then if you imagine your body has a halfway line down the middle, if you can keep the head as close to the halfway line, or in front when they do hit, transfer over the front will be much easier".

3.2.2.3 Arms

The function of the arms (bowling and non-bowling) received the most attention from the coaches; individually and in relation to one another.

In relation to one another, Coach 1 wanted to see the two arms separated apart from one another as much as possible:

"I'd look at how they… they jump or bound or leave the crease, what position and we have a thing here at (A County), myself and (A Coach) … and do a lot of bowling with, with a position that they get into in the air with their arms, we look for a really clear split of the arms".

Coach 20 wanted to see the arms at around shoulder to eye level:

"If the load up is in front of the shoulder and in the eye level, which is very good, because your hand is a very heavy lever".

Coach 5 also focussed on the relationship of the two arms and believes that the bowling arm dictates what the non-bowling arm will do:

"I strongly believe that the non-bowling arm is dictated by what the bowling arm does. So, if you want the non-bowling arm to be in the plane or in the sense that if you want the non-bowling arm to be aligned towards the batter, most bowlers align towards the batter".

The bowling arm was a critical aspect of the bound/gather phase, as it was used to create the 'load' or load-up' position:

"… loading begins with your bowling arm because you have to load up with your bowling arm. Ideally the bowling arm would be somewhere close to the chin" (Coach 5).

Coach 19 agreed:

"Yeah, the gather I focus a lot mainly on the bowling arm in the gather…. ideally, I want the bowling arm to be in front of the body in its gather. I want it either in front of the body, or I want it at an angle of less than 90 degrees through its path".

Coach 19 further expanded to relationship of the bowling, not only with the non-bowling arm but also the knees:

"…what I want to try and do is I need the levers to work together. So, what I mean by levers is that I need the elbows and the knees to work together. So, one of my descriptions for people that I'm coaching is that you turn into a puppet. So, once you take off, you go from using opposite arms to opposite knees. Then once you jump in the air there's a period of hang time where basically the levers change over to basically there's a piece of string that's attached to your right elbow. If you're a right arm bowler there's a piece of string between your right knee and your right elbow, and a piece of string between your left knee and your left elbow, and that's the changeover of that. And ideally what I want, the first thing I look at is how long is the bowling arm?".

Finally, Coach 19 also suggested that the non-bowling arm, like the bowling arm, should also be in front of the body in the gather:

"… when you've got your arms and proper load up, which I suppose should be your front arm. So ideally again your front arm, you want that to be pointing out in front, pointing to the target".

Coach 19 went on to further elaborate that it was the elbow of the non-bowling (front) arm that he wanted out in front of the body, as this aided alignment later in the bowling technique, allowing the non-bowling arm to be pulled into the font hip and not out to the side of the body (see the discussion of poor technique later for a further elaboration).

3.2.3 Back foot contact (BFC)

The coaches identified three first order themes for Back Foot Contact (BFC): body position, centre of mass, and temporal factors.

3.2.3.1 Body position

The body position (posture) of the bowler at BFC had three second order themes relating to body position, which were: posture, the arms, and the back leg.

Coach 3 was the only coach to mention the position of the body relative to the crease. He believed that the backfoot had an optimal angle to land at in relation to the crease:

"…for me it's a 45-degree position with your back foot".

The coaches appeared to view BFC from the perspective of being 'side-on' to the bowler that is at right angles to the direction of the bowlers' technique. Coach 7 suggested *"if you can draw a line from the top of their head down to their back knee and that is one straight line and it goes through their back hip, if that makes sense, they tend to be in quite a strong position".* Similarly, Coach 1 saw a 'strong position' at BFC as:

"…getting into a position where, as you land at back foot, you're in a really strong tall, almost lean back position with a front arm that's very high, which then allows you to propel forward over a front knee and using your arms that can move late and really fast", and so too did Coach 2:

"… on back foot contact I'll look for an upright position". The reason for having this upright position was, according to coach 7, that it allowed the bowler to bowl faster:

"If they are upright, in my experience guys that land from on back foot contact find it easier to bowl quicker if they're upright, so if that straight line basically goes straight up".

This upright position also enabled the head to go forwards rather than laterally, which enables a more effective and safer action (Coach 17).

In terms of the arm positions, Coach 19 wanted both arms (bowling and non-bowling), and in particular the elbows pointing forwards towards the target: *"so you want……the front arm, elbow, (at) the target, and in front, out the front of the body".*

Linking the arms and the body position together, and where they link to the next parts of the bowling technique, Coach 1 suggested:

"So, you're getting into a position whereas you land at back foot, you're in a really strong tall, almost lean back position with a front arm that's very high, which then allows you to propel forward over a front knee and using your arms that can move late and really fast, which almost acts as that catapult with that body hinge forward".

The final second-order theme relating to body position was that of the back leg. Coach 8 considered a back leg with minimal flexion at the hip, knee, and ankle i.e., *"not collapsing"* was in essence a strong back leg position:

"…a strong back foot contact… I think that's a real big one for me is your back foot contact needs to be strong and you're not collapsing".

Coach 8 believes that part of the ability of the bowler to not 'collapse' at BFC was, in part due to the physical capabilities at the ankle joint:

"So, you need quite a bit of ankle stiffness there. I would always look to develop the person, the athlete first. So, you need ankle stiffness, you need to be able to absorb ground forces".

Additionally:

"I want the back knee to be facing the batsman once you've landed, so you've got to have that just like a pre-turn, before you throw a punch, you'd twist your back leg. I like to see the back foot doing that as well and that usually happens naturally if you've got the momentum".

The position/posture that the bowler finds themselves in at BFC also impacts on the next sub-order theme, 'Centre of mass'.

3.2.3.2 Centre of mass

Coach 7 suggested the CoM of was one of the most important things that he was looking at with a bowler:

"… the two things that I'm watching for, as I said centre of mass is a big thing, and first and foremost alignment…. I'll be quite interested to look at back foot contact, where their centre of mass is positioned in relation to their contact point with the ground".

Coach 7 also noted that the CoM could vary between front-on bowlers and side-on bowlers as well as the previously mentioned difference in run-up velocity:

"…side-on guys, if their centre of mass is slightly behind themselves, so they're in a slightly lent back position, again they've got that straight line from the top of their head to their back knee, but they're leaning back almost. They're the guys that can then generate that pace as well or have a better opportunity or better chance of doing that…. I think if your front-on guys, back foot contacts are upright potentially, I think that is a better option for them, just because of the time it takes for them to get through the crease. So, they're the guys where I think there's more value in them running in quicker and being in a more upright position. The guys that are

side on, they might not have to run in as quick to generate as much force because they're relying more on the force that they generate from back foot contact".

Coach 17 focussed more on the position of the head, ensuring that it move forwards and not to the side as this could increase lateral flexion of the spine and with it increase the chance of injury:

"…at the point of impact with the back foot there's going to be a transfer of weight (CoM) forwards, but the head goes backwards, which then makes transferring over the front knee more difficult. So, if they're already back before they jump, then they go further back when they land, which then means they exit out the side (lateral flexion). And if you're side on, then if you imagine your body has a halfway line down the middle, if you can keep the head as close to the halfway line, or in front when they do hit, transfer over the front will be much easier".

3.2.3.3 Temporal factors

The final sub-order theme for the BFC phase related to the temporal aspects of BFC. Coach 10 believes that:

"I think your landing on the back foot has to be very short and snappy. You don't want to spend too much time on the back foot because then the energy goes down into the ground from your run-up".

This idea linked closely with what Coach 17 described as the knee drive. He wanted to see this happening quickly from BFC to release in order to improve spinal alignment at release:

"So, when your back foot hits in an ideal world you want as fast a leg transfer as possible, because the longer you spend on that back leg the more force tends to go slightly up the side the left, rather than over the front. And not everyone can do that, taller bowlers struggle with the faster feet. But if you can get that back leg driving as quickly as possible, the right knee driving as quickly as possible towards the target, then that tends to help with the weight transfer".

3.2.4 Front-foot contact (FFC)

The coaches revealed three sub-order themes for the FFC phase of the bowling technique: Heal strike, Braced front-leg and bowling arm position.

3.2.4.1 Heel strike

How the front-foot makes contact with the ground is seen as important.

Coach 11 focussed on the foot itself:

"Heel strike at point of contact…They talk about I think with a heel strike and a braced front leg and a longer delivery stride, those peak forces…. So, the peak force is going vertically through the body would still be quite high, but there will be as longer a period of time (to absorb it)"

The efficacy of a heel strike in FFC was first recognised by Worthington, King & Ransom (2013a), this movement pattern accounted for lower peak force at ground contact and longer time to peak force, which is believed to reduce the likelihood of lower back injury and was why Anderson (2019) saw this as an important phase in the fast-bowling technique.

3.2.5 Delivery stride

The delivery stride was also considered as a whole stage as well as being broken down and is illustrated in Figure 1b.

There were four second-order themes of the delivery stride, all with further sub-themes, recognising both the complexity of this phase of the fast-bowling technique and the technical knowledge of the coaches.

The four second-order themes were *alignment, stride-length, knee drive* and *kinetic factors*.

3.2.5.1 Alignment

The alignment of the delivery stride had six subthemes, *feet, spine, head, Centre of mass, hip and shoulders,* and the *bowling arm.*

3.2.5.1.1 Feet

The alignment of the feet in the delivery stride was most consistently recorded in this phase, with Coaches 3,4,5,9,11,12,13, and 14 all explicitly stating the need for the back-foot and front-foot to be aligned to one another. Coach 13 used the analogy of a train track:

"Bowling for me is about getting from A to B in a straight line in the most efficient way possible. So, that's all the way from a run-up from take-off to back foot contact to front foot contact to follow through all has to stay in a straight line. I call it staying in the train track.

Coach 18, while relating to the academic literature (e.g., Bartlett et al., 1996) suggested that how the feet aligned with each other dictated the type of bowling action:

"…you've got three different types of actions that come within the literature, a front-on action, a side-on action and a semi-open or midway action".

Coach 3 felt that it was important not only for the bowler to have front and back foot aligned with one another, but that the delivery stride was in line with the target for the delivery:

Coach 12 also wanted to see the delivery stride to be aligned to the wickets:

"(Everything) aligned to the stumps basically".

Although Coach 5 agreed with this, he wanted the bowler to align themselves to the batter rather than the wickets:

"…If his alignments are locked towards the batter, if he's got excellent alignments where the back foot and front foot landing are mostly in the same plane, then I would consider that extremely good".

3.2.5.1.2 Spine

Spinal alignment was also considered an essential part of the delivery stride. Coach 17 in particular wanted the spine to be in alignment to reduce the risk of injury. This meant the feet, hips and shoulders all holding alignment:

"… then you can remove a lot of the sharing force on the left side of the back. If you leave that right leg behind, you create a big sharing force on the left-hand side of the back".

3.2.5.1.3 Head

Coach 16 and Coach 17 noted the importance of head position, and wanted the head to align with everything else in the delivery stride:

"For me the first thing I look at when I'm looking at a fast bowler is the head position. So, I look at what the head does because the body follows the head. And once you have an understanding of where the head is going, then you can understand what the body wants to do, or why the body is reacting the way it's reacting" (Coach 17).

"I think simple things like…getting your head and weight down at the target" (Coach 16)*.*

3.2.5.1.4 Centre of mass

Coach 7 discussed the importance of aligning the feet to the target so to allow the centre of mass to move in that direction also:

"I'm big on centre of mass…so, if I'm watching a bowler from behind, the two things that I'm watching for, as I said centre of mass is a big thing, first and foremost alignment".

Similarly, Coach 18 wanted his bowlers to:

"…keep your momentum going towards the target and then obviously rotate your arms, keep your bodyweight going forward and be able to deliver a ball in the intended area".

3.2.5.1.5 Head and shoulders

Coaches were particularly interested in the alignment of the hips and shoulders, with Coaches 3,7,12 and 14 speaking explicitly about the importance of hip and shoulder alignment.

Coach 12 summed up the consensus:

"… hips, shoulders are…I believe… <u>they've got to be aligned</u>…

…your hips and your shoulders are aligned, there's no counter-rotation, so whether you're front-on the hips and shoulders have still got to be aligned….

…. My philosophy is just trying to be as aligned and as efficient as possible".

The key reasoning behind this was to reduce the risk of injury (see later).

3.2.5.1.6 Bowling arm

The alignment of the bowling arm to the target was the next second-order theme related to alignment, with Coaches 4,5,13,14, and 18 all discussing its importance.

Coach 18 wanted the bowling arm to rotate towards the target as part of an aligned overall technique:

"An ability to be able to, one, keep your arm straight and effectively keep your momentum going towards the target and then obviously rotate your arms, keep your bodyweight going forward and be able to deliver a ball in the intended area".

3.2.5.2 Stride Length

The second of the second-order themes had three further sub-themes, these *were individualised stride length, height,* and *length.*

3.2.5.2.1 Individualised stride length

Coaches 2, 10, 11, 13, and 18 all suggested that the length of the delivery stride was an important aspect of the fast-bowling technique. Coaches 2,10, 13 and 14 all suggested that the stride length should be individualised.

"In terms of bowling stride, I would say there's an optimum for each individual" (Coach 10).

Coach 20 believed that the individual's ideal delivery stride length was in fact related to the individual's running stride-length:

"So, whatever his run up stride is, based on that the release stride will be there on the delivery stride, and then he'll be able to get into a good, and his body is behind the hand, and then he is able to bowl the ball where he wants to".

While the coaches believed that the length of the delivery stride should be appropriate to the individual, Coach 11 also suggested that there may be some speed advantages with a longer delivery stride:

"It tends to be the longer the delivery stride length, tend to be the quicker the bowler". However, Coach 11 did not state whether that was relatively longer or in absolute terms.

3.2.5.2.2 Height

The third and final aspect of the delivery stride was that of height; specifically, the height of the bowling arm at delivery based on the delivery stride positioning, with a higher position being better:

"…they have to be tall, so their height and their release creates their maximum bounce" (Coach 3).

3.2.5.3 Knee drive

The third second-order theme of the delivery stride was the *knee drive.*

'Knee-drive' was considered to be a critical element within the delivery stride for Coach 17. This was in relation to both 'good' and 'poor' technique:

"if you're looking at knee drives, knee drives are really big. So right knee drive for a right-hand bowler. If you've got really good right knee drive, then you can remove a lot of the shearing force on the left side of the back. If you leave that right leg behind you create a big sharing force on the left-hand side of the back, it also stops your hip rotation and stops your shoulder rotation being able to come right round. It means you have to go into more of a side on position. When I said side on, your shoulders come round each other rather than over the top".

Coaches 7 and 17 agreed that knee drive was visually demonstrated by previous top-level performers. Not only is the knee-drive hypothesised to create better alignment, but also weight (CoM) transfer:

…if you can get that back leg driving as quickly as possible, the right knee driving as quickly as possible towards the target, then that tends to help with the weight transfer".

3.2.5.4 Kinetic and kinematic factors

The fourth second-order theme of the delivery stride are *kinetic factors,* which are further sub-divided into seven subthemes: *Sequencing, timing & rhythm, Hip-shoulder separation, Arm separation, Vector quantities, Stability/balance, Front-side mechanics,* and *BFC to FFC time.*

Coach 7 summed up these factors when he said:

"I think of transferring the energy from the ground into the ball. So, the sequence pattern from your feet to your wrist. So, you've got your feet, they will rotate towards the batter, that will start your hip rotation, which is usually quite aggressive, and then working up the chain you get this torque effect which then translates into your shoulder, arm, wrist and back through the ball. And in every stage of that process, you want to conserve the energy, well, you want

to transfer the energy. So, when you say ideal bowling technique, I would say a technique which doesn't leak energy at any stage throughout that chain. So, for me that's ideal and usually if you're not leaking energy, it's safe as well".

3.2.5.4.1 Sequencing, timing & rhythm

The sequencing of body part movement, it's timing and the rhythm created were seen as significantly important factors within the delivery stride:

"…and then I'm looking for everything, just the timing of everything, so the working together (Coach 9).

Coach 12 also considered this important:

"…and there's another thing of rhythm and timing……I like moving parts; I like everything working together……which brings me back to my rhythm, my technique, the rhythm, timings and efficiency".

However, while these ideas fit closely with the basic principles of biomechanics (Knudson, 2013), this process was idiosyncratic to each bowler:

"Some are running quicker, some have the ability to run quicker, some will be slightly slower, some might have longer strides, shorter strides. So just trying to find out how they - I guess that tempo, that alignment, what suits them best to help them deliver the ball" (Coach 11).

The reason that these biomechanical principles were important was also related to anatomy:

"*If you muscle stretch and contraction in the right sequence, you've basically got a human rocket. And even the smallest guy who has no real muscular definition or you wouldn't say he's a big lad can bowl quickly. And sometimes a big lad you think he's going to bowl fast, and he lumbers up and he comes out like confetti in a wedding into a gale force wind. And you think how is that possible? Well, it's possible because their sequencing and timing is completely different"* (Coach 15).

3.2.5.4.2 Hip-Shoulder separation

Coach 10 was looking for hip-shoulder separation within the bowling stride. By this he meant the hips and the shoulders being rotated apart to increase a stretch across the

muscles and fascial connections, which has been termed 'X-factor' in golf (Lim, Chow & Chae, 2012))

"*… I look for hip/shoulder separation, so I want the arm to be delayed for pace. So, if you imagine like when you have that slingshot effect. So, if you look at the most extreme example, you've got Lasith Malinga who will rotate and snap his hips while his arm is still behind him…So, for example Shoaib Akhtar and Brett Lee, they've both got a very stiff back foot contact. They have both got a huge bowling stride, they both pull through the crease, they've both got a strong arm-pull, they've both got hip/shoulder separation, but they do it in a completely different way…. but I would like to see hip/shoulder separation".*

3.2.5.4.3 Arm separation

In a similar way, Coach 7 was looking for the arms to separate, i.e., increase the distance from each other:

And one thing that I think plays a massive part in the position of someone's centre of mass is their arm separation. So, we do a lot of stuff with the youngsters, trying to get them to get their arms far apart and I'll know there'll be pros that don't demonstrate that as well as some others. But in my experience the guys that get their arms far apart…their centre of mass is back so they've got the ability to split with their arms, their arm separation is really big and then they can fire forward towards their target".

3.2.5.4.4 Vector quantities

The coaches discussed several kinetic variables relating to the delivery stride such as torque, momentum, and power. All were relevant, but it was unclear if they were used inter-changeably with other variables or specifically. However, this is an issue also seen in sport science research, where terms such as power and momentum are used incorrectly (see Winter et al. (2016) for a detailed discussion).

"I'm a Big, big believer that we need a lot of momentum at the crease and try and get……. a lot of our young bowlers try and muscle it down. So, try and just give them a little bit more momentum at the crease which you" (Coach 2).

Whereas Coach 3 discussed power:

"…it is a case of seeing what their base is like… where…where… whether the direction of their power is all going towards the target…direction of where your force is going is important".

Finally, Coach 10 discussed torque:

"So, it's this energy called torque that is generated through the snap of the hips".

He did note however that there may be a different capability to produce torque between male and female bowlers:

"No, there's less rotational power for females. They're not able to generate as much pace through that torque mechanism that I spoke about".

3.2.5.4.5 Stability/balance

For Coaches 5 and 13, balance and being 'stable at the crease during the delivery stride were important:

"*…three things I look for particularly, if they've got all three, they've got a chance, if they've got two, they've got a chance, if they've only got one, they've had it, and that's pace, balance and movement"* (Coach 13).

"…that the balance at the time of delivery" (Coach 5)

3.2.5.4.6 Front-side mechanics.

Front-side mechanics were deemed to be important for the coaches, particularly Coach 13:

"… their front arm, how they use their non-bowling side, because that's where I believe a lot of pace comes from, how they generate a lot of their pace. So that's once they've hit back foot contact and they come through delivery drive phase, how do they use their non-bowling side. And again, that gives them two things: it can give them accuracy and it gives them power at the crease…So, if you can try and create a situation where they create this delay, and it goes out long - and Shoaib Akhtar used to talk about grabbing hold of the sight screen with his bowling hand and the batter's head - and then really pulling it back towards you. So, I believe the non-bowling side gives you two major things: accuracy, it gives you pace and power, but it's how you use it. And also, once they've got pace and they've got power how

they actually use this front arm can dictate the length they're going to bowl as well. So, the non-bowling side and the front arm is a huge part of the bowling action, a huge part".

3.2.6 Release

The release was seen as the most critical aspect of the bowling technique, in relation to ball release velocity, delivery type and accuracy (Glazier & Wheat 2014). This then was a key reason for coaches to work assisting bowlers with this phase:

"…also, to give them the release point, or help them with the release point, give them the most amount of chance to move the ball, whether it be off the pitch or in the air. So, you want it, one, to be accurate and, two, to have some form of movement area as well. So, I think technically that's potentially what you would look at" (Coach 11).

There were three second-order themes relating to the release phase*: bowling arm, non-bowling arm* and *the body.*

3.2.6.1 Bowling arm

The bowling arm second order theme had four sub-order themes: *Bowling-arm delay, Fingers & wrist, Arm rotation,* and *Delivery specific positions.*

3.2.6.1.1 Bowling-arm delay

The key requirement for release speed of the ball was related to arm speed. Coach 1 looked specifically to try and maximise the bowling arm speed:

"… using your arms that can move late and really fast… about maximizing that pace and control.

This arm speed came about, in part due to the delay of the bowling arm, which in turn had been caused by the hip-shoulder separation in the delivery stride:

"Going into the hip snap which will delay the bowling arm, so that will create…a stretch here…to protect the muscle it will contract fast because you'll sling your arm over which generates arm speed (Coach 10).

Coaches 1,2 and 11 all referred to the ECB Fast Bowling Matrix, a set of critical factors (attractors – see later) that were critical to ball release speed; a delayed bowling arm being one of them.

3.2.6.1.2 Fingers and wrist

Fingers and wrist were also seen to be critical at the point of delivery. Coach 13 and Coach 17 wanted to make sure that his bowlers *"keep their wrist right behind the ball",* while Coach 1 was very interested in the position and movement of the fingers at the point of release:

"… we would often check release. How does the finger come off the ball? We use some slow-motion cameras, you know, because if you're cutting the ball or it's not coming out quite right, then all of that energy you've built up this there's a lot wasted. So, the fingers are the key at the very last moment about maximizing that pace and control."

The positioning of the fingers and wrist were seen as critical not only for the release speed, but also essential for controlling the accuracy and type of delivery produced by the bowler:

"…to give them the release point, or help them with the release point, give them the most amount of chance to move the ball, whether it be off the pitch or in the air. So, you want it, one, to be accurate and, two, to have some form of movement area as well. So, I think technically that's potentially what you would look at, to say right well does it help them repeat and repeat with the outcome that they want" (Coach 11).

However, Coach 15 warned of the potential to over-emphasise the importance of the wrist's contribution to speed:

"And those commentators, 'oh he's flicked his wrist at the end, that's where the speed comes from' - that's absolute rubbish. Everybody flicks their wrist unless they're following a knuckle ball in which case, they're going to lock their wrist out to stop the rotation. So, everybody flicks their wrist, it's a red herring".

3.2.6.1.3 Arm rotation

Coaches 4, 5 and 6 wanted the bowling arm to rotate towards the wickets, although coach 4 recognised that there are several successful bowlers who do not necessarily do this:

"I think, ensuring that your arms… that right... the bowling arm…goes around in a circle and doesn't come across the body, important but again having said that I've seen a few other guys be quite successful being able to do that. I mean, Ben Stokes is a good example of someone else who's arm actually goes quite across so, so again I think it would be nice to have it a lot straighter. But, again, having said that, you know, there's enough guys to prove me wrong so I don't want to see that that's still definitely you have to do that". This was echoed by Coach 13, who wanted to see that the bowler *"keeps a clean bowling circle (towards the target)".*

3.2.6.1.4 Delivery-specific positions

The ability to alter the position of the wrist and bowling arm as well as the angle of the body, depending on the 'delivery type' (i.e., the direction of the ball and amount of deviation in the air or on landing) was recognised by coaches, and may have direct impact on the bowling technique. This is particularly relevant when bowler's change the format of the game (for example form three-day games to 20-over formats):

"…that bowlers …there are some changes and they trying to bowl, especially for a long period of time. So you can think about the IPL for example it's like a two months tournament with a 15/20 day build up so it's like two and a half months of just a white-ball cricket and trying to bowl yorkers and so on, and so on, that there sometimes changes in the way your body Sometimes not a physical issue… sometimes it's a state, as you haven't done it for a long time. Just go back to that. And I think it's a challenge…all these change of conditions…white ball to red ball to white" (Coach 4).

The changing tactical demands across the different formats for the bowler cause alterations in the technique:

"… they tend to fall away a little bit when they move from white ball to red ball as a large part of that is to bowl yorkers…maintaining those in-swinging Yorkers lower down so especially the guys bowling at the death... I find the starting a lot wider of the crease at times, and then start falling… cross rather than staying upright and just delivering it sort of wicket-to-wicket top of off stump. So, the body tends to twist a little bit, mainly because they're just trying to spear it in, into those Yorker areas…… so just to change the posture. You know sometimes the wrist position as well…., the ability to keep doing a lot of this sort of

slower ones …sometimes the wrist tends to roll… out of the way, they aren't able to keep their wrist behind the seam of the ball... With the red ball, he's trying to do…you are probably going to...Sometimes they find it a little bit… takes time for them to adjust, sometimes, is the other technical thing I find…the arm stays straighter rather than going a bit rounder… sometimes a bit rounder because, again, they're trying to go a lot more yorkers a bit more variation (Coach 4).

Coach 17 also believed that the angle in which the bowler gets in relation to the target and the distance from the wickets at the non-striker's end, plus the position in relation to where the umpire stands, all impact on release position (as well as whole body posture):

"I'm a big fan of more angle on the crease, because the closer you get to the stumps subconsciously the further your head goes away to keep your arm up. It's a subconscious thing, because you know that the best place for your arm to be is up high. So, you don't come in close to the stumps and then have your arm go round the shoulder and up the umpire. So, if you can get a little bit more angle, which means then all of you goes to the target for longer, it means that then when your bowl inswing or outswing, you can start it on the same line, it looks the same. Makes it make more effective".

3.2.6.2 Body

This second-order theme has four suborder themes: *Alignment (knee & head), Chest drive, Trunk flexion,* and *Knee drive.*

3.2.6.2.1 Alignment (knee & head)

The alignment of body parts was seen as a critical element, especially in relation to reducing injury. Coach 1 wanted to see (from a straight-on view of the bowler, as if he were the batter) a vertical alignment between the bowler's head and the knee of the front leg (left leg in a right-arm bowler):

"… the more your head is in a straight line over your front knee, the less likely you are to get injured, the further your head gets to the side, or lean away to the side, the more stress you put on your back, and the more likely you are to get stress fractures in the back".

This alignment at release was part of Coach 17's overall philosophy about the importance of the alignment of the head in the bowling technique:

"…ultimately, I still believe that if you can get the head moving in the right direction, you can eliminate issues there. And that makes people more efficient, which is one thing, the head makes you more efficient, but it also makes you more effective."

3.2.6.2.2 Chest drive

'Chest Drive' was an important factor for Coach 11 and Coach 1:

"…so, driving the chest towards the target" (Coach 11)

Coach 10 saw the Chest drive to increase the stretch and ultimately the speed by which the bowling arm came through following 'bowling arm delay':

"…you're actually driving the chest forward, which will enhance that stretch even further".

3.2.6.2.3 Trunk flexion

The 'chest drive', it must be noted is strongly related to the amount of 'trunk flexion' which was also illustrated as an essential part of the release phase:

"…a huge amount of trunk (flexion)… towards the target" (Coach 11).

Coach 1 described this as *"you're looking at the hinge of the top body part, so how far they come from back to forward".*

3.2.6.2.4 Knee drive

For Coach 17, the knee drive was an important aspect of the fast-bowling technique, throughout the delivery stride and into the point of release, as it helped maintain alignment and is seen in some of the best bowlers (see above)

3.2.6.2.5 *Non-bowling arm*

The third second-order theme for Release relates to the non-bowling arm. The non-bowling arm has with two sub-order themes being *Moving towards the target* and being *Pulled into the front hip*.

3.2.6.2.6 Moving towards the target

Coach 6 believes that it is important that the non-bowling arm goes straight towards the target as it dictates the subsequent path of the bowling arm at release:

"So, if you keep it straight, the non-bowling arm, if you keep it towards the direction, it's like steering, the bowling arm will follow".

Coach 16 agreed with that, stating that this is part of a bigger concern to have all body parts moving towards the target at the point of release:

"If you can get most of your body parts moving somewhere towards the target, then you've got a far better chance……looking to keep your non-bowling arm going at the target".

3.2.6.2.7 Pulled into the front hip

As well as the non-bowling arm going towards the target, coaches also wanted it to be pulled into the front side/hip.

Coach 12 wanted the non-bowling arm to be pulled into the body to aid with alignment at release:

"…the front arm tucked in so there's no side flexion, release position".

Coach 19 noted that there were some exceptions to this rule:

"Now there's some bowlers around the world that actually like, if you actually look at Pat Cummings, he's almost like a front arm bowler, because his non-bowling arm does not touch his body until after he's released the ball…And then literally I want their lock and release to be down into the side somewhere around the hip, either side of the hip, and then ideally I want that non-bowling arm that follows through, I want it to point back to where it came from. I don't want it to go around, I don't want to, if I see it going around to the side it usually means the bowler's got… something going wrong somewhere. I usually like that, it's not a perfect world but at least it's in the general direction of going back to where you ran up from.

3.2.7 Follow-through

The final phase pf the bowling action is the follow-through, that brings the bowler to rest following the delivery of the ball. The follow-through had two second-order themes; *'back leg'* and *the 'body-path'*. Its purpose is to bring the bowler's body to a halt following release of the ball so that the bowler may then be in a fielding position. Coach 20 suggested that the purpose is primarily as 'shock-absorption' following release:

"Follow through is very important actually, it's important because it absorbs the shock basically".

3.2.7.1 The back leg

Coach 10 wanted to see the back leg to continue to push forwards, but to decelerate the body as a whole:

"I would say the back foot, the back leg would drive through, in most cases, and I would want them to naturally decelerate. So, for example they follow through so they're not putting the brakes on when they're bowling, bowl the ball and then just actually follow through".

3.2.7.2 Body-path

Within cricket, there is part of the cricket pitch that players are not allowed to step on, known as the *'danger area'*; transgressors can be ruled out of bowling in an innings if they do not heed warnings from the umpire. Coach 18 saw that part of the technique within the follow-through was there to keep bowlers out of the danger area:

"… you do need to be able to rotate your body out of that position and out of the danger zone, otherwise you'll be in trouble'.

The second and final theme of the body in the follow-through phase was the 'flight phase' i.e., when both the bowler's feet were off the ground following the release of the ball:

*"Well, follow-through is, again, it should take you off your feet. If you've really, really completed and got all the way through it's an extension of everything else that's gone previously…. it just completes absolutely everything" (*Coach 13).

Summary:

The coaches in this study had clear ideas of the key components of what make a 'good' fast bowling technique. They identified the six phases of Bartlett et al (1996), with one coach also discussing heel strike (Worthington, King & Ransom 2013a).

Several studies (e.g., Fortiza et al 2021; Smith et al 2015) have demonstrated that coaches are able to identify the key kinematic elements of a sports technique. Fetisova et al (2021) noted that while novice and expert coaches were able to identify the key kinematic

elements of a technique, the expert coaches were noticeably different in their ability to chunk these elements into an understanding of the whole technique and had better understanding of the kinetic elements that this combination produces. The coaches in this study demonstrated similarly strong understanding of the kinematic elements of the technique and were able to chunk them together, particularly within the delivery stride.

The coaches were keen to notice the individuality of specific kinematic elements of the technique as well as the technique. Coaches also discussed other factors that have not been considered in the biomechanical literature including run-up angles, body positions within the Bound/gather phase, and the implications of the follow-through phase not running into the danger/protected area. The implications of this for coaches, coach educators and biomechanists is discussed later.

The depth of knowledge of the biomechanical principles that underlie these technical elements, was less obvious, with coaches using several biomechanical terms to mean the same thing, for example *'energy', 'momentum'* and *'power'* (see Discussion for further comments).

Figure 6a. Thematic network of a 'good' fast bowling technique.

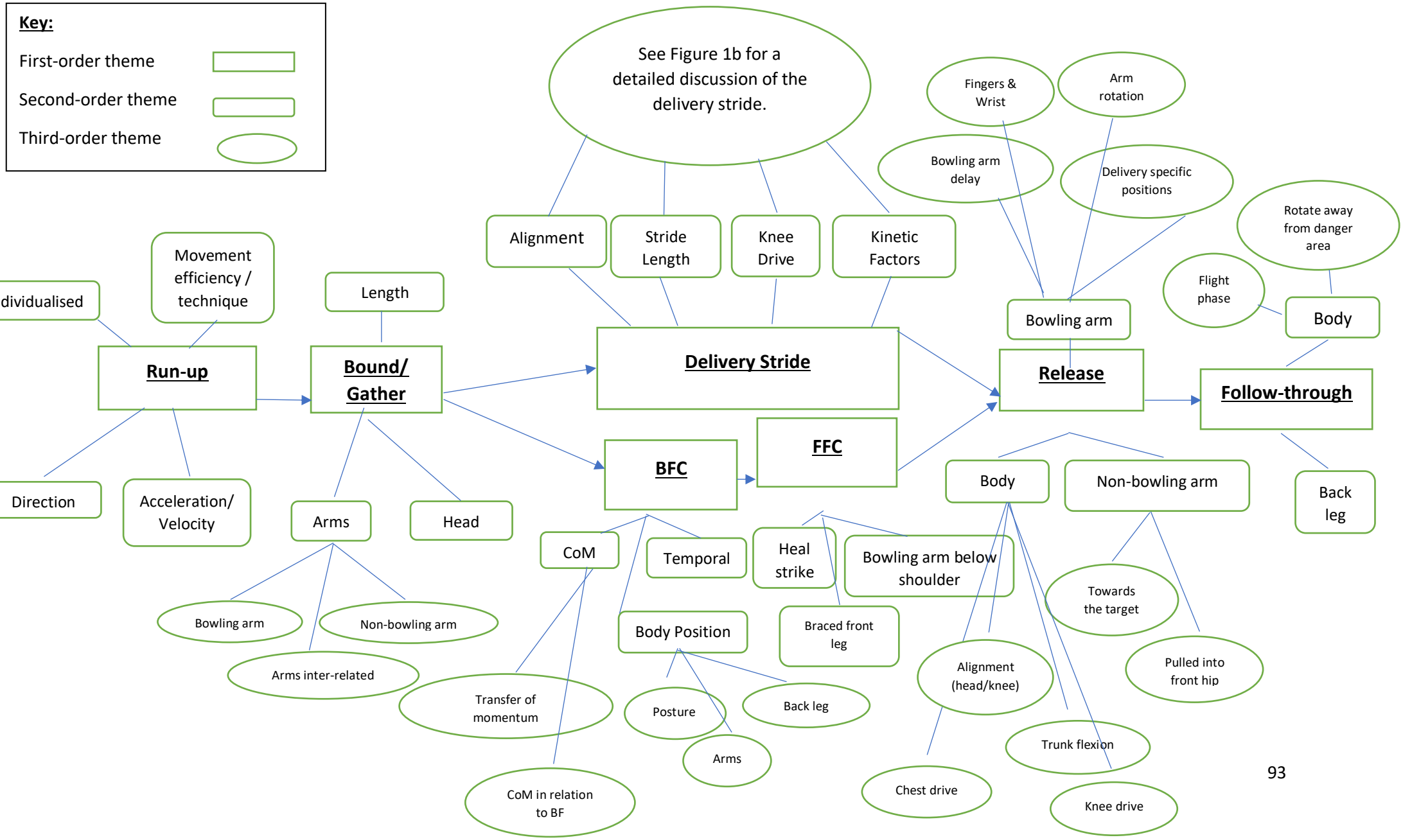
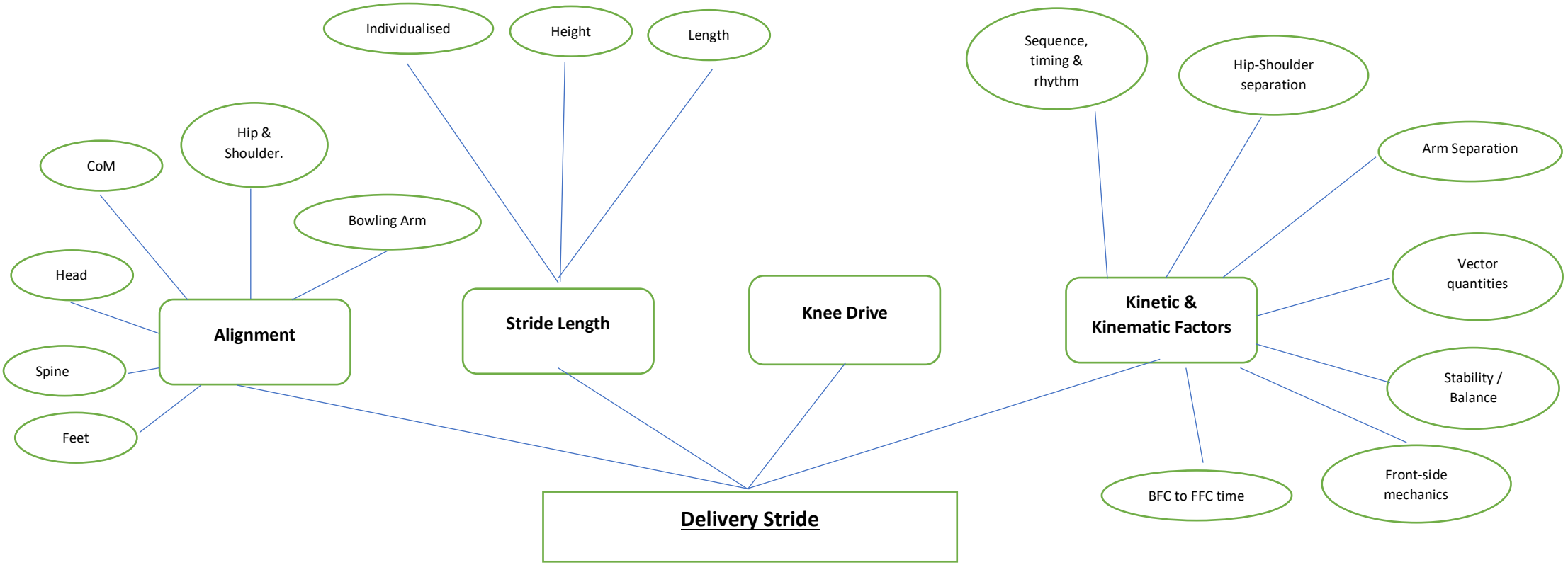


Figure 6b. Thematic network of the delivery stride



3.3 **Internal model of a 'poor' fast bowling technique.**

In describing what they were looking for in an ideal technique, coaches were also able to identify the elements of what they defined as a 'poor' or potentially dangerous technique. Coaches noted kinematic variables of potential danger in each of the six phases.

3.3.1 The Run-up

The Coaches formulated three second-order themes for the run-up: *Angle, Speed,* and *Running technique.*

3.3.1.1 Angle

The angle that a bowler takes between where they start their run-up in relation to the direction of the target, was seen as problematic by the coaches.

Coach 4 suggested:

*"…*you just want to be going in potentially straight lines right i mean that's the whole thing you want to be running straight. An angled run-up creates its own complications. "

These 'complications' were believed to impact upon the balance of the delivery stride.

3.3.1.2 Speed

Coach 5 viewed there being an optimal speed of run-up, and one that was too fast would cause issues:

"I would look at a nice smooth run-up which generates pretty good speed into his run-up. But not too quick, because if you're too fast then you're not extremely balanced at the time of your action".

3.3.1.3 Running technique

The way in which a bowler ran was also considered to hold the potential for a poor technique. Coach 11 saw issues in the run-up phase when:

"When you start getting those crossovers and arms not working together, so just some general running". He also had seen through experience that the mere presence of holding a cricket ball often change the run-up technique of bowers for the worse:

"…you'd be amazing how many times you watch a child, or a player run and then you put a ball in their hands and then the running mechanics completely change".

Coach 5 saw an issue when the "*arms come away from the side of the body".*

3.3.2 Bound/Gather

The Bound/Gather phase highlighted two second-order themes, where potential technical errors occurred, in the action of the *feet* and in the *'load-up'*.

3.3.2.1 Feet

During the bound, fast bowlers look to move from a Run-up phase and into the Delivery stride. One of the common errors in technique noted by Coach 15, in the bound was the feet crossing over each other rather than stepping through as described previously:

"And one thing I realised was I was looking at this stuff. They were making very similar mistakes all of them. They crossed their feet over". This Coach 15 was one of the causes for losing momentum and putting the bowler into a weak position in the Delivery stride.

3.3.2.2 'Load up'

The 'Load-up' position is a description of where the hands, in particular the bowling arm are in the bound.

Coaches 5, 6 and 20 saw the 'load up' as an area where potential technical errors could be seen:

"I think you've got to look at the way one loads. See because the first step where your body begins to load up is you use your hands to do that. So, if it's working in the same plane, if it's in one plane, you are most likely to have a pretty good action. But when the arm goes away from the body, as long as it is ideally close to the body, you tend to be in a very good plane. But when the arm starts moving outside then you start compromising and all other things happen. So, the only two things I look at controlling is the way you run-in and the way you load up...

…But some bowlers their loading goes behind the shoulder or behind the head. When that happens, your front arm goes across your body, which is again not a very great thing to do" (Coach 5).

3.3.3 Delivery stride

The delivery stride was spoken about as a whole and broken down into the two sub-phases previously described as *Back-foot Contact (BFC)* and *Front-foot Contact (FFC).*

3.3.3.1 Back-foot Contact (BFC)

The most common concern in this phase of the bowling technique was an 'excessive' amount of flexion from one or all the knee, hip or ankle joints.

"When they're able then to hit back foot contact, if they've gone too high, if they've jumped too high at the crease, for example, then the natural laws of physics tell you what goes up must come down, so they sometimes sink in their back legs" (Coach 13).

This greater range of flexion led to, coaches believed, a longer time spent at BFC:

"You don't want to spend too much time on the back foot because then the energy goes down into the ground from your run-up. So, imagine if you spend time on the back foot you dip and collapse the back leg… and as soon as your back foot dips and sinks into the ground you lose that power" (Coach 10).

Coach 7 also saw this flexion at BFC an issue, but in terms of the positioning of the bowler's centre of mass:

Finally, Coach 13 suggested that a lack of postural control at BFC may lead to injury:

"So, back foot stability and back foot contact are crucial, and that can have some effect on injuries if they've not been able to control that".

This inability to control BFC was also attributed to injury by Coach 10:

"…as your back foot dips and sinks into the ground you lose that power, and you have to regenerate it at the crease. Which is I think where bowlers start to compensate and maybe generate force in not an efficient way, and I think that's where the injuries can happen in a bit of inefficient technique and when you're trying to bowl quick your body's going to compensate because your brain just needs to find a way".

The inability to control BFC was in many instances attributed to lack of 'strength' and lack of 'joint stiffness' of the bowler, causing the Coaches to look to S&C expertise to help address the issues:

"So, you need quite a bit of ankle stiffness there. I would always look to develop the person, the athlete first. So, you need ankle stiffness, you need to be able to absorb ground forces. You need to do a lot of plyometrics" (Coach 10).

3.3.3.2 Front-foot Contact (FFC)

As with the BFC, for the Front-foot contact, coaches saw the front leg bending (knee flexion as an issue:

"… if he's bending down or his knees are bending or flexing (there is an issue)" Coach 6.

Coach 15 saw this as not only a technical issue, but one that could and should be changed through coaching:

"And they're changing not only because they look better but because they are better; in other words, they're not having those horrendous back foot, front foot positions they're likely to be in, you can see it".

3.3.4 Whole delivery stride

As in the discussion of a 'good' technique, the Coaches in this study also looked at the delivery stride as a specific phase of the fast-bowling technique. Three second-order themes were drawn from the coaches: *Mixed action, Lateral flexion,* and *Timing/Coordination of the limbs*

3.3.4.1 Mixed Action

The mixed bowling action was defined by Bartlett et al (1996) as:

"This technique, as the name suggests, is a mixture of the side-on and front-on techniques. It is characterized by bowlers adopting a front-on foot and shoulder orientation at back foot strike, which is followed by a realignment of the shoulders to a more side-on position during the delivery stride" (p.405).

The mixed bowling action is categorised as having a counter-rotation between the alignment of the hips and shoulders.

Coach 5 noted:

"When there is a difference between the back foot and the front foot alignments there is a lot of mixed action that comes in and there's a lot of counter-rotation also happening… to the front foot contact, if it's more or less in line. Of course, a degree of 25 degrees variance between the back foot and front foot doesn't really affect the thing. Anything more than that you start compromising on the power that you can generate and also the risk factor of injuries".

Coach 18 was aware of this and the empirical literature surrounding this, although noted slightly larger degrees of counter-rotation:

"There are some key areas that have been researched pretty heavily, which indicate that things like counter-rotation above 35 to 40 degrees isn't good when you're at an age which is under sort of around that bone development growth stage and around 24/25. So, you've got high counter-rotation which is in the literature".

3.3.4.2 Lateral Flexion

While counter-rotation leading to a mixed action can be considered as poor alignment in the transverse plane, an excessive lateral flexion of the spine, in the frontal plane was also seen as an issue with the fast-bowling technique and potentially injurious.

Coach 17 noted issues raised due to lateral flexion of the spine:

"…if you look at the left side, lateral flexion…it (the head) *tends to exit left really quickly, so you get shoulders pushing towards the left side, hips pushing towards the right side, and the momentum is left somewhere in the middle trying to go down the middle".*

And the cause of spinal injury:

"Fo*r me, the real problem causes are stress fractures, stress reaction, which comes from front foot contact and lateral flexion…"* (Coach 9).

Coach 18 believed that lateral flexion was particularly problematic when combined with counter rotation:

"So, you've got high counter-rotation which is in the literature, then also the other key one there you also have a lateral flexion at the point of release, so these are key fundamental areas where things are, those are left and your workload increases too high and too quick and your body hasn't adapted, that will give you and sometimes can give you an issue around injury, which you need to prevent. …and there's a technique there that indicate that counter-rotation and lateral flexion are two key areas that you probably will want to avoid as much as you possibly can if you want to bowl a lot".

Coach 17 believed that one of the causes for bowlers gaining a lateral flexion of the spine in their delivery stride is in relation to where they place and angle their delivery stride on the crease, relative to the stumps and the umpire.

3.3.4.3 Coordination/timing of limbs

The third and final second-order theme for this phase related to the bowler's ability or inability to co-ordinate their body in the delivery stride.

Misalignment of the delivery was particularly problematic for Coaches 12 and 20 in relation to injury:

"If your movement is correct, your forces are going to go in the right direction. If your movement is wrong the forces are going into the wrong direction. So that is where the body is going to fight (Coach 20).

Coach 6 saw this misalignment of the body and the forces placed upon due to a number of possible causes:

"…he's got too much stress in his back, he's got a very side-on short and front foot landing, but he's not getting out of, well he's getting into the danger zone. To get out of the danger zone he's putting too much stress on his back, and maybe his lower body is not transferring the weight, he's probably bowling with his shoulders".

This misalignment within the delivery stride could be also related to the movement of the non-bowling arm according to Coach 6:

"If you keep it straight, the non-bowling arm, if you keep it towards the direction, it's like steering, the bowling arm will follow. So, if I see the non-bowling arm dropping or falling in a

different angle, and you're trying to bowl only with your bowling arm, I have a feeling that you would probably stress yourself more on your right shoulder, on your bowling shoulder".

Coach 5 agreed with Coach 6 around the need to control the arms in the delivery stride, but believed that it was more important to control the bowling-arm which in turn impacts the non-bowling arm:

"the bowling arm is something which you can control, the bowler can control; whereas the non-bowling arm depends a lot on what the bowling arm does. So, I would only look to control the bowling arm".

Coach 15 suggested that there were several common errors that young bowlers were making in and around the delivery stride, most in the delivery stride phase itself:

"…over the course of about 14 or 15 years I probably worked with more than 1,000 students, one-to-one, because that's what I set out to do, and I kept notes from everybody. And one thing I realised was I was looking at this stuff. They were making very similar mistakes all of them. They crossed their feet over, they'd bend their front leg, they'd lift the back foot too early, they were pulling their arms on the wrong foot or whatever it was, and there's a common thread of about 13 things they were doing".

3.3.5 Release

Two common errors (second-order themes) were noted by the coaches at the point of release; these were a *lack of trunk flexion* and *lack of wrist behind the ball*.

3.3.5.1 Lack of trunk flexion

On discussing the bowling action Coach 7 suggested that those with a poor technique had lack of active trunk flexion:

"A lot of them, their trunk flection won't be the sort of trunk flection we're looking for in terms of that powerful fling over the top. It'll be just them falling over essentially".

3.3.5.2 Wrist behind the ball

On discussing issues with the fast-bowling technique, Coach 10 stated that an issue at the point of release was the alignment of the ball and the bowlers' wrist:

"…maybe if you lose your wrist so the energy going into the ball, you're just dropping it rather than having the force behind the ball".

Coach 13 also noted issues that can occur when the wrist is not aligned behind the ball:

"And then the fourth thing is wrist position and release…… So, if they load up to go across their chest, they go up behind their heads or it takes them out of the train track, they are going be in the lap of the gods in their wrist position".

3.3.6 Follow-through

The coaches noted two sub-themes relating to the follow-through phase: *The Danger (protected) area* and *the non-bowling arm.*

3.3.6.1 The Danger (Protected) Area

One of the key areas of concern for this phase of the bowling technique was that of infringing Law 41.13.1, which states:

***"41.13.** 1 It is unfair for a **bowler** to enter the **protected area** in his/her follow-through without reasonable cause, whether or not the ball is delivered"* (MCC, 2021).

Coach 18 saw this as a key feature of the follow-through:

"…being able to then stay out of the danger zone".

3.3.6.2 Non-bowling arm

While there was relatively little discussion of any kinematic factors relating to the follow-through, Coach 19, was keen to look at the movement of the non-bowling arm in the follow-through and particularly its direction:

"…ideally, I want that non-bowling arm that follows through, I want it to point back to where it came from. I don't want it to go around, I don't want to, if I see it going around to the side it usually means the bowler's doing… something's going wrong somewhere".

Summary:

Coaches clearly identified factors in each of the six phases of the fast-bowling that were considered a poor bowling because they either increased the risk of injury or reduced the velocity of release.

Most of the factors in each phase related to their impact on the position of the spine. With fast bowlers being susceptible to spinal injury, coaches were keen to identify potential causes.

The Danger (protected) area in cricket is a constraint on the fast bowler in their follow-through phase, with bowlers not allowed to run into that zone of the wicket. This is a constraint not seen in laboratory-based biomechanical studies of the fast-bowling technique.

Model of poor technique

Figure. 7 Thematic networks of the elements of a poor bowling technique

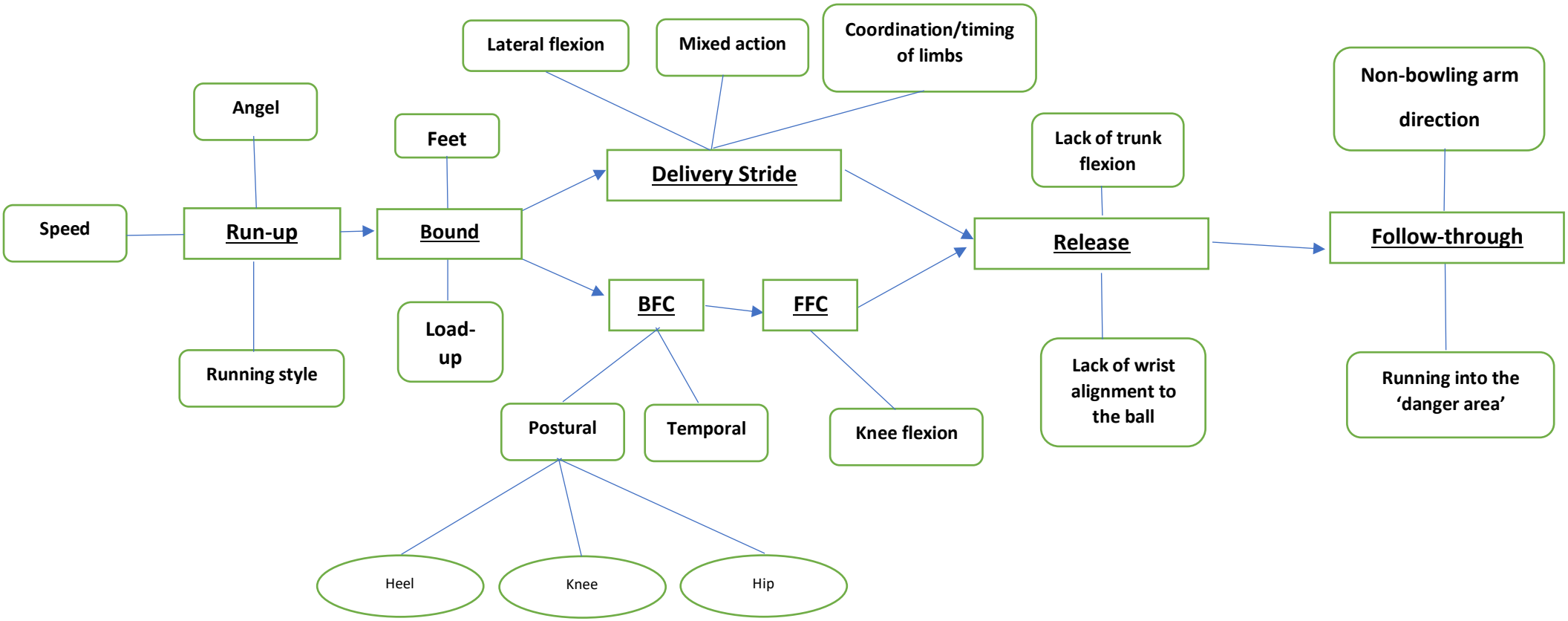
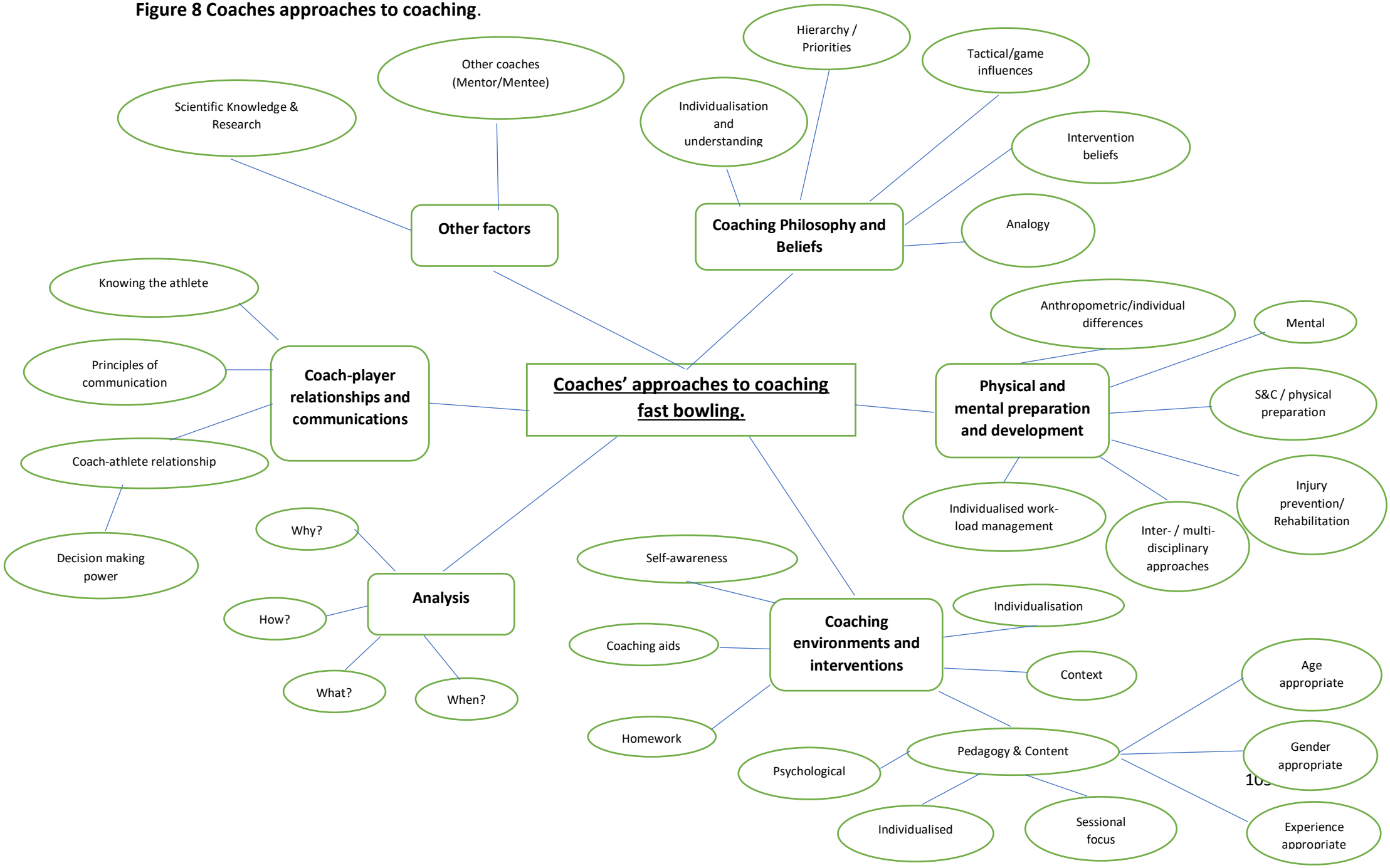


Figure 8 Coaches approaches to coaching.



4. Results 2 - Coaches' approaches to coaching.

The second area of interest in this study was in respect to, *how* coaches go about coaching the technique of fast bowling. Figure 2 shows athematic network of coaches' approaches to coaching fast-bowling. There were six first-order, twenty-one second-order and four third-order themes that were identified in relation to the approaches that the coaches took in their coaching practices. The six first-order themes were *Coaching philosophy and beliefs, Physical and mental preparation and development, Coaching environment and interventions, Analysis, Coach-athlete relationships, and communications,* and *Other factors*.

4.1 Coaching Philosophy & Beliefs

The Coaching philosophy and beliefs of the coaches were further sub-divided into five second order themes*: Individualisation and understanding, Hierarchy/Priorities, Tactical/game influences, Intervention beliefs,* and *Analogy.*

Coaches held firm beliefs about their coaching practices. These beliefs had a clear impact on their conceptions of the fast-bowling technique and how they coach it.

Coach 3 saw that the role of fast bowling coach was for the welfare of his bowlers:

"That's the important thing to, you know, making sure we're looking at the welfare of the bowler".

And, to enhance the bowler's potential:

"… but maximizing their potential is something that I think coaches need to be aware of".

As far as the nurture vs. nature argument goes, all coaches in this study believed that coaching could be used to improve a bowler's speed and performance outcome, with Coach 15 adamant that fast bowlers can be coached to bowl faster:

"When I started out literally nobody else was talking about it and it was a 10-year push uphill to even get people to acknowledge that you could bowl faster, and you weren't just born a fast bowler and there's things you could do to improve what you've got".

4.1.1 Individualisation and understanding

Every Coach in this study spoke of the need for an individualised approach to coaching the fast-bowling technique. This matches the results of Bennie and O'Connor (2010) who found that coaches focussed on the development of the person. This stemmed from the belief that developing the player as a person is likely to result in on and off-the field success.

"…it's very unique. It's unique to the individual. I believe there are certain principles that all fast bowlers have been able to follow, but how they actually get into that position is all about them. So that's my coaching philosophy is to really get to know that player, whoever they may be, get to know them as an individual, how do they learn and then really find out what their unique X factor is and look to enhance that. Whatever they do very well, get them to do it more often" (Coach 13).

The coaches clearly recognised both the individuality of the fast-bowling technique and the need for the coaches to understand everyone's technique.

"…for me the most important thing about coaching fast bowling is you've got to be adaptable to each individual's technique. We've seen some of the most weird and wonderful of bowling actions be some of the most successful" (Coach 8).

Reasons were given to these natural differences:

"Every fast bowler is unique; every human being is unique…. Also, angle changes, and your left-handed angle changes, some people are born athletes, some people are not. They have different running techniques. So, I think as a coach you need to adjust, you need to understand the nature, the dynamic of the particular bowler, and you adjust accordingly" (Coach 6).

Understanding these components and how they contribute to the fast-bowling technique was seen as essential to the fast-bowling coach. Coaches found that there was some assistance in this task of knowing from the fast bowler themselves, particularly the more expert and more experienced bowlers:

"…they've fundamentally got their understanding and awareness of what they're doing within their own actions" (Coach 13).

Coach 12 sited past experiences where there had been a suggestion to use a particular element of a technique, but this led to several problems as bowlers couldn't adapt easily:

"A lot of years ago a new technique came in with Brett Lee where it (bowling arm) *was locked in. Well, I believe then forces go different ways because you're trying to force the ball, which brings me back to my rhythm, my technique, the rhythm, timings, and efficiency".*

4.1.2 Hierarchy / Priorities

Coaches had a clear hierarchy of priorities that they used to be making coaching decisions and prioritise certain coaching interventions. Coaches use hierarchies to help them deal with the complexities that they face, while integrating their decision making (Abraham and Martindale 2006). Creating hierarchies allows coaching to use a broad array of information to identify and solve problems in their coaching practices.

The key priority for coaches was the performance outcomes of their bowler over all other considerations, including a priority over speed of release and the technique used:

"So, the result of what they're doing has to be good enough. And there's plenty of examples of people that don't have these traits that find a way to be successful in cricket" (Coach 1).

For Coach 18 the key ingredients for bowling *are: "…* (a technique) *that takes wickets and keeps them on the park… I suppose what you're looking at there is an ability to take wickets on all surfaces I suppose… their number one job is to take wickets".*

Coach 4 did not see wickets as the key measure for a successful/effective bowling outcome:

"rhythm and accuracy, a lot of it will come down to even the bowler's own perception of it, you know, just the way the ball sometimes just hitting the glove, when you're collecting it or just the rhythm or the feel of it…not so much wickets…I mean wickets is dependent on a lot of things".

Coach 2 viewed skilled outcome as equally as important as speed:

"…it's not all about as… that it's not all about pace. We especially at (A County)*, get some people coming through very… very skilful and they're never going to go and be international cricketers, so you might get some do is like* (A Bowler) *bowls at 80 mile an hour but his skills*

are as good as anyone that control for (A County) *that is as valuable as somebody bowling and nearly eighty-eight mile an hour 90 mile an hour".*

Coaches 6 and 16 echoed this sentiment:

"… being successful and not getting injured too often. So, if the guy's not getting injured, if the guy's bowling fast, putting the ball in the right area, I really don't think you need to mess with them" (Coach 6).

"So, it's less about the look for me, it's more about the performance down the far end, and making that as good as we can" (Coach 16).

Therefore, the focus for these coaches was to make their bowlers more effective:

*"And the reason we do things… is to make them more effective" (*Coach 17).

Coaches saw the processes and elements involved in a successful performance outcome as multi-faceted:

"Because (there are) *so many other things to throw into the mix. Ultimately, you could be lacking in a lot of the areas that you'd like to see in a fast-bowling action but excel in one or two of them. And then as a result be highly successful. You got also got to throw in all of the mental strength, you've also got to throw in inner drive and the will to want to do well, the competitive element, all of this stuff that in many ways you…can't measure it on a scale of one to 10. Their match play, so you know, understanding the situation the game and reading what's going on…erm…So I think there were there were so many different elements to throw in there. And I would say that the fast-bowling technique, if you like, it's just one of many things you have to consider"* (Coach 1).

One of the reasons that coaches did not prioritise technical work, was that a bowler's technical competence did not predict future outcomes:

"And you also realise that actually that (ideal technique) *doesn't necessarily make you a great fast bowler"* (Coach 8).

Coach 16 did not prioritise the bowler's technique at all:

"Well in all honesty technique is one of the last things I look at".

This came about due to observations of bowlers whom he believed to have poor techniques, but escaped injury:

"I've known so many bowlers, some who are just injury prone because of the way that they bowl, and I mean that because they bowl 150km an hour, or they just take a huge amount of effort. And other guys who you look at their technique, and you think 'how has this guy not got a back injury?'…and they don't".

The discussion of unusual and unorthodox bowling techniques also identified priorities for coaches, with coaches clearly stating that the outcome was more important than the technique used. Coach 9 prioritised outcomes over the orthodoxy of the technique used:

"I wouldn't change them if it works hundred percent. If you can find me somebody completely different who's out there but can still bowl a ball in the right area at whatever pace, I'm happy as Larry".

Coach 14 also prioritised outcomes and speed of release over the technique used:

"…a guy who naturally bowls fast… as long as they're not getting injured and they're bowling above 90 mile an hour plus, you do not want to tamper too much with that natural action".

Coach 6 agreed with this, also suggesting that outcome, speed of release and injury prevention were of greater priority than the technique used:

"So, if the guy's not getting injured, if the guy's bowling fast, putting the ball in the right area, I really don't think you need to mess with them".

However, Coach 9, while agreeing 'natural is best', did suggest that safety was a greater priority:

"*My other big priority is, I'm saying natural is best, but natural is only best if it's safe. So, I would look at first and foremost as to whether that action is safe".*

Coach 11 alluded to a similar conclusion, that bowlers can fail to follow a more 'ideal' bowling technique but be successful, and it was this success that was more important than improving the technique:

"…having that real individual understanding that …understanding of that… a lot of people would defy that (good technique) *and still be very successful…. and so just understanding what makes them tick, how they work and how you can best get them going and being as consistent as possible and achieving what they want to achieve".*

Coach 15 took this one step further and suggested that an unorthodox technique might even give some bowlers an advantage in performance:

"So, there is a trade-off sometimes with someone who has an awkward looking action because let's take Jasprit Bumrah for example, …there's parts of the action he could do better to be more effective in delivery. But there's an awkwardness to his action which probably gives him a couple of wickets a game if you've never faced him before".

The elements that lead to good performance, according to these coaches were accuracy/control, balance, pace, and movement; all of which were viewed as more important than release speed:

"…the first thing I'd look at is outcome and what is it. And then I'll try and break it down into the four, the four things that I'd look at in no particular order, but to make them into a good quick bowler would be pace, bounce, control, and movement, and do they tick those boxes" (Coach 11).

Coach 13 went a step further, stating that when working with young bowlers, speed was a much greater priority than accuracy:

"I'm a great believer, if a bowler, I don't want them to slow down and get accuracy for example, which a lot of coaches say don't they? "Oh…" you know "slow down a little bit mate, you're all over the shop!" Well, that's crap! they all end up then the same as everyone else! So, if they bowl quick, I'm promoting them to bowl quick, I want them to carry on bowling, we need to manage that obviously. And I believe you can coach accuracy at a later point".

Coach 6 promoted the opposite approach to Coach 13, suggesting that accuracy was a priority for him when working with young bowlers:

"I would just ask them to bowl. I would just ask him to bowl, put the ball in a certain right area, and I would see how he's adjusting. And there my expertise would come when he's adjusting. So, if he can put the ball in the right area, I would see how many times he could do it out of

10, if he can put the ball in the right area say out of ten, four to five, I'll be happy as a novice. So, if I see how he's adjusting, so I just need to, I mean, three little things".

Coach 8 noted that having an excellent technique did not infer a great bowling performer:

"…you also realise that actually that (good technique) *doesn't necessarily make you a great fast bowler; it just makes you a safe fast bowler".*

Coach 15 also saw a relationship between speed and accuracy:

"Because speed and accuracy go together, the shortest distance between two points is a straight line. That gives us accuracy; it also gives us speed because it's the quickest thing" (Coach 15).

Coach 17 also noted a priority of outcome (effectiveness) over efficiency:

And the reason we do things, we look at things from a biomechanical point of view, is to make them more effective. Not more efficient but more effective in cricket terms. So, you can create efficiency by doing things long enough, you learn to become more efficient through that, but you really want to become more effective".

In addition to performance outcomes being a priority, married to this for the coaches was the importance of injury prevention, alluded to earlier by Coach 9:

"What you're trying to do with any bowler is make them as efficient and as effective as they can. Because ultimately bowling is about being effective down the other end, not how good your technique looks. So, the big thing for me is getting the best out of the bowler. Trying to do something that keeps on the field" (Coach 16).

Coach 7 also believed in the importance of reducing injury, but felt that improving a technique's safety, could also improve performance:

"I think you'd tick both boxes by producing someone with an efficient action. You reduce forces and the amount of lateral flection, so you make them less likely to get stress fractures potentially, whilst also increasing their ability to effectively stay in a straight line towards their target, and therefore bowl a ball where they want it to go. So, I think they're very similar".

Coach 4 suggested that there needed to be a differentiation between the level of injury that the bowler had, and to only change technique of bowler's following a major injury and not a minor one. He went on further to suggest that quite often changing a technique often just moves the site of injury to another area of the body.

Finally, Coach 18 saw technical skills as only one part of the holistic development approach that he looked to take:

"…you've got your personal traits, so life skills, you've got technical skills, you've got tactical skills, you've got mental skills and you've got your physical skills, so they're the five fundamental ones that you probably need to look at in regard to how you're developing that person holistically around that".

4.1.3 Game/Tactical influences

The tactical influences that different game situations can project, has an impact on the techniques used by the bowlers, according to coaches in this study. Coaches noted this especially after periods of time playing one format of the game (e.g., limited overs cricket) and then moving into another format (e.g., 4-day cricket).

"And we find that when …they play three months of IPL or white ball cricket, and they're so focused on bowling Yorkers or slower ones that are subtle changes in their actions or in their movements they suddenly get back to red ball cricket., they go off a little bit and then you sort of show to show them that and then maybe try and get them to go back to bowling again … hitting top of off stump… I've seen definitely that bowlers …there are some changes and they trying to bowl, especially for a long period of time. ...so, it's like two and a half months of just a white-ball cricket and trying to bowl yorkers and so on … that there are sometimes changes in the way your body … and if that is not watched can keep going and going and going and going." (Coach 4).

"…the format can affect stuff like that as well,. On a four-day game you tend to bowl fourth stump. In a T20 game you want bowls to go middle stump, so the angles have knock on effects to different formats. I think bowling Yorkers and different types of deliveries have an impact on the bowling technique as well. So, if you're playing T20 cricket for example, I think guys like Bumrah angle the ball in, , they drop their arm down. So, their arm angle changes. And so,

when you're doing that, then move back to four-day cricket you see bowlers who, the position on crease is different. They're not swinging the ball because it's been adjusted from a different format" (Coach 16).

Coach 19 noted that certain deliveries such as the 'Yorker' saw bowler's make changes in their run-up speed:

"…also, execution of skills, so for example a Yorker, a lot of the guys will tend to, just the last few steps of their run up just slow down a bit, because you're trying to hit a 10-cent piece on the line".

As these changes in technique have injury implications, Coach 9 also noted the importance in aligning his work with that of a strength & conditioning coach:

"But, alongside my job as a bowling coach, a strength and conditioning coach, their jobs would be 'are they in a strong enough position to be able to hold those positions?', and if they are, and then I'm comfortable with them trying to do that and trying to hold that".

4.1.4 Intervention Beliefs

The coaches had clear beliefs about what type of coaching interventions were best used and when.

The age and experience of the bowler seemed to be of critical importance for coaches when deciding what interventions to take and when.

Several coaches saw that trying to change an 'established' technique of an experienced player was very difficult:

"(What) *my experience though has told me is that it's harder and harder to change an action the older you get"* (Coach 4).

Coach 6 agreed with this assertion, but suggested that working with novice bowlers was much easier to work with in terms of technical intervention:

"I would say it is comparatively easier to coach a novice. Because he is going to, if he has not done it, there is no muscle memory, it is easier to work with. He's going to forget things, you've got to be repetitive, you've got to be nagging sometimes, but end of the day it's easier to mould mud than a solid structure".

Coach 16 argued that interventions are fundamentally different between elite fast bowlers and novice fast bowlers due to the experiential knowledge of the elite bowler:

"Look I think you can be more directional with a complete novice. I think the thing about an expert fast bowler is the very best will understand the mechanics, they'll understand what worked for them, and they'll almost be able to, they're just looking for some advice. They'll be going when I move like this, I do this, and it just doesn't quite feel right, are you seeing anything? And I've found that with my coaches. I was very aware of how I worked when I was at the very peak of my powers, and I would do some, I'd bowl a couple of balls and think ah, my shoulder dropped there. And I'd walk that passed him and he'd say to me I think your shoulder just dropped there, like we were attuned like that. So, he could see the things that I could feel, and then it's very reassuring. The novice bowler has no idea what they're doing. They don't know where the body's going, they don't know how to work".

Coach 7 wanted to prioritise the delivery stride, for novice/young bowlers:

"…with the nippers we tend to go with alignment being a really key thing".

Coach 13 had a clear set of systematised outcome descriptors that he was looking for, from his bowlers, which was charted and colour-coded accordingly, depending on the age of the bowler. This system was governed by outcome measures and not technique measures. Technique interventions were used only to enhance outcome measures if required:

"So, as a young, say for example 12 to 14s that are in yellow, we want them all the way up to there, we want them into that. But by the time they get to 13 and 15 in green here, as you can see, we want it to be repeatable. And then obviously you'll notice then by the time we get to 15s and 17s, this is not a linear line, you might get a 13-year-old that gets all the way to this point and you can kick them even further, but we can't move them on into demonstrate the ability to swing the ball or seam the ball, they might naturally do it, but we can't really coach that element of craft until they've got those elements beforehand".

Coaches didn't want to make large technical changes to a bowler's technique, which reflected the earlier beliefs that 'natural is best'

"So, I don't really like changing actions as much, I like tinkering with them, but I would never, ever change someone drastically" (Coach 12).

Coach 16 suggested that it was better to make technical interventions with the arms and upper body than the feet, as this was easier for the bowler:

"…there's parts of the body that are very difficult. I think changing your arm and your shoulder is very different to changing your feet position. So, you almost work your way through what's easiest, and the last resort might be the really difficult thing that might take a long period of time".

Coach 15 pointed out that quite often it's the bowler who decides when a coaching intervention is required, and usually only when things are not going so well:

"I almost think that the coaches are mechanics in that sense. You tend to go to a coach when you're doing badly, like your car's broken down. If your car's running smoothly, you don't drive it to the garage and go what's wrong with it?"

Coach 15 progressed this by suggesting that the player's interpretation of what bowling coaching specifically was, may play a part in a player's choice to seek guidance:

"…fast bowling coaching is viewed as change and batting is viewed as coaching. It's the same letter C but one's coaching and one's changing. And bowlers don't want to change".

The time of the year (in-season vs out-of-season) and the nature of the contracted time together between player and coach had an impact on the coaches' decision making around coaching interventions.

For Coach 4, the nature of his role limited the time available with the players, and thus impacted upon the choices surrounding coaching interventions:

"Where I am coaching is on a performance basis... So, I'm coaching the Indian A team …which is, you know, sometimes I see the lads four days before the test match. And that defines their careers, you know, because they're playing for India, or the Under 19 World Cup…we have a little bit more time with the Under 19's so, sometimes we, you know, we work a little bit here with the under 19s… maybe the run up so for example, someone may have the angled run up and so the coaches feel they need to try to straighten it or not, that's something we can work on and say…and it's something that you can work on with an under 19 boy, if we have them for four or five weeks, and just, you know, I think that that's challenges I think coaching is…at least at the level I coach at is… which is two things. One is that it's very much about

performance at that point of time for some of these... And also, the amount of time that we have in contact with them".

Coach 14 also suggested that the time of the season had an impact on the choices of intervention, especially technical/technique interventions:

"There's lots of other things that you take into consideration and share that… especially the time of the season as well, can't do the middle of the season. Well, it's very hard to do in the middle of a season".

Some coaches were concerned however, that other coaches provided coaching interventions either for the sake of it, to justify their position as coach:

"…there's a perception of necessity for coaches to change something and that's not always the case.…You don't necessarily have to change technique, but you just have to look at where they can be more effective… And I'm always really suspicious of coaches that want to make lots of change, because I'd like to know what the agenda is, but that's just my I guess cynical side, yeah" (Coach 17).

Other coaches may not, however make a 'technical' intervention as they do not seem themselves to be a coach who focuses on technique or a coach without the technical knowledge:

"But most coaches now tend to be appointed because they're very popular with the players and they're probably ex-cricketers who are mates with the team and they're not really technicians. I don't think they're technicians at all; a lot of them are not. And that's not because they don't know how to coach, it's just because I don't think that's where they are as coaches. If you speak to quite a lot of ex-big fast bowlers who have got many, many more wickets than I will ever get, they will say 'well I'm not a technical coach'. I don't think I've ever heard an interview where a coach says, 'yes I'm a technical fast bowling coach', I've never heard that in my life. I've never heard it, just don't hear it".

4.1.5 Analogy

Coaches used analogies and metaphors to explain their internal models of the technique and its elements, as well as to give a representative explanation of their coaching practices.

Coaches used analogy to explain their approaches to coaching, in particular the need to individualise approaches. Coach 15 used a gardening analogy to describe his approach:

"It's a bit like having a lump in your garden but you cut the grass around it, the lump still stays there, well you could have taken the lump out when you bought the house, I didn't, but what I've done is, I've still got a lovely garden, I've just built around it. And I think that's how you need to operate as a coach, especially international level and just underneath that".

Coach 5, used the analogy of handwriting to explain his approach to individualisation:

"I would probably use the analogy of one's handwriting. You know, each one's handwriting is different, but the way you write an A, B or a C does not change. But if one wants to improve his handwriting, he doesn't change his style of writing; he's got to use his own style but get closer to the basics, the way you write an A, B or a C. So, I would say fast bowling is very similar to that".

Coach 6 used the analogy from making ceramics to explain why technical coaching interventions were easier to use with novice fast-bowlers:

"I would say it is comparatively easier to coach a novice. Because he is going to, if he has not done it, there is no muscle memory, it is easier to work with. He's going to forget things, you've got to be repetitive, you've got to be nagging sometimes, but end of the day it's easier to mould mud than a solid structure".

In terms of technical analysis, Coach 19 used an analogy of a ladder to explain the order of the technique that he analysed first:

"…always go to the bottom of the ladder. That's your starting point. So that's where I've always gone. Let's look at the run up".

While making technical interventions, coaches used analogy to explain different aspects of the bowling technique.

Coach 15 likened the sequential accumulative nature of the fast-bowling technique, to that of a bicycle gearing system, and uses this analogy to explain the process to bowlers:

"So, you've got intra-muscle and inter-muscle linking going on, you've got the elastic band effect through all the ligaments and joints working together, all of that works in my mind more

like a bicycle going through the gears. And it isn't literally that, but when I speak to young kids this is what I say to them. When you're on a 21-speed racing bike and you put it in first gear, and you pedal how fast do your legs go? And they say oh they go like crazy. So, I said so you pedal really, really, really, really fast and you're doing five miles an hour and there's an old granny with a trolley walking past you looking at you thinking what the hell's that kid doing? You then put it up and go through the gears, once you get into 21st gear your legs are not moving anything like as fast but now you're doing 35 miles an hour and not five miles an hour, how is that possible? And they say oh well the gearing system. And I said in a similar way, but not the same way, your body uses an internal gearing system to transfer that ball from the ground to the top. That isn't actually what is happening, but as an ideal and a thought people then realise there's a sequence that goes through the body, and it's the connective chain as you and how it all links together".

Coach 20 also used a bicycle analogy, but in this instance to help bowlers understand the co-ordination of arms and legs:

"…I ask the boys why in the cycle one pedal is one, one pedal is down, why they cannot be both the pedals in the same level? So, you cannot pedal, not that time, so you can pedal only until maybe a quarter of that cycle, after that you will not be able. So, this is the reason when your one pedal goes up, one pedal goes down, the same concept you keep in bowling, if one hand is going up, the other hand has to be done, and other hand comes up, this hand has to come down. So, the same thing, when this hand comes up, this hand has to go. So, you are creating momentum in your upper body, and you're creating a momentum with your legs running, so that is has to synchronise. See bowling is nothing but coordination of the hand and legs. Running is nothing but the coordination with the hands and legs".

Coach 10 used analogy in his explanations of what he defined as a poor bowling technique. His analogy was that of 'leaking' energy:

"All right, leaking energy, well, let's say, you hear it a lot you want all your momentum and energy going towards the batter. So, one example of that would be if you, let's say you collapse on your front leg, for me that's leaking energy. If you drop your left side too early rather than pulling your chest through the action, for me that's leaking energy. So, the energy that you get from your momentum you want that to, yeah, leaking energy, it's just a loose term, isn't

it? Let me explain it. I think biomechanically it's got to be efficient, but we're able as athletes to generate power in certain ways, whether that's rotational power or whether that's straight linear power or speed. That power that's generated, it can just leak at some point in the action. Maybe if you drop this too early, maybe if you lose your wrist so the energy going into the ball, you're just dropping it rather than having the force behind the ball. So, without getting too scientific that's how I'd explain it".

Coach 13, likened the whole bowling technique to water and wanted it to flow, and also linked to Coach 10's ideas of 'leaking energy':

"But ultimately the big thing that is important is that you've got to keep it moving and keep it fluid, because the more it stops the more, you're going to sink into that back leg and you're going to lose energy".

Regarding the specific phases of the fast-bowling technique, coaches also used analogies. The most common analogy was of a 'train on a track', to represent how the bowler should move in a straight line through the run-up phase, into the delivery stride and release:

"Basically, if I think of a train on a train track, if I start the train at the top of this track and it gets a nudge, it keeps going in a straight line for as long as possible; if part of that train comes off the track, something will go wrong, and it stops" (Coach 9).

Coach 8 used the analogies of other coaches to help inform his own coaching practices. The analogy of 'not disrupting air space' was used for the bound and delivery phase in particular:

"He talked a lot about not disturbing air space. That was his big thing. You know, he'd be massive in terms of everything towards your contact but keep it within your air space. He didn't like things going out and I quite like that as an analogy. So that's basically my basic structure based on little things I've picked off from the coaches that I've learnt off".

Coach 19 used the analogy of a puppet on a string to describe to bowlers the change in coordination of arms and legs from the Run-up phase to the Bound/Gather phase:

"…one of my descriptions for people that I'm coaching is that you turn into a puppet. So, once you take off, you go from using opposite arms to opposite knees. Then once you jump in the air there's a period of hang time where basically the levers change over to basically there's a piece of string that's attached to your right elbow. If you're a right arm bowler there's a piece

of string between your right knee and your right elbow, and a piece of string between your left knee and your left elbow, and that's the changeover of that".

Coach 19 used the analogy of a ship's rudder to articulate the impact that the frontside (left side in a right arm bowler) in terms of guiding the direction of the bowling technique:

"…this front side which is your rudder".

Finally, Coach 10 used an analogy of a jockey being dismounted from their horse when discussing the Front-foot Contact phase, using a braced front-leg:

"OK, well, if you imagine a jockey on a horse and all of a sudden, the horse jams its front legs into the ground the jockey's going to go flying. So that energy going up from the ground into the jockey. That's the concept that I like to visualise when I think of transferring the energy from the ground into the ball".

4.2 Physical and mental preparation and development

The second of the first-order themes involved both physical and mental preparation as well as development of both areas. This area was seen as very important to all coaches in this study. This factor was subdivided into six second-order themes: *Anthropometric/individual differences, Mental, S&C/Physical preparation, Injury prevention/rehabilitation, Inter-/multi-disciplinary approaches,* and *Individualised workload management.*

4.2.1 Anthropometric/individual differences

The size of the bowler played an important role for the coaches in this study, with Coaches 3 and 13 both ideally looking for a tall fast bowler:

"…tall would be good… …they have to be tall, so their height and their release creates their maximum bounce" (Coach 13).

Although both recognised that there were exceptions to this rule:

"…you've had Michael Holding and Malcolm Marshall. You know two opposite ends of the spectrum one's not quite so tall: one's quite tall and athletic" (Coach 3).

Coach 17 recognised that taller bowlers may sometimes struggle because of their size, particularly in the delivery stride:

"So, when your back foot hits in an ideal world you want as fast a leg transfer as possible, because the longer you spend on that back leg the more force tends to go slightly up the side the left, rather than over the front. And not everyone can do that, taller bowlers struggle with the faster feet".

Coach 15 however, suggested that size was not important for speed:

"And even the smallest guy who has no real muscular definition or you wouldn't say he's a big lad can bowl quickly. And sometimes a big lad you think he's going to bowl fast, and he lumbers up and he comes out like confetti in a wedding into a gale force wind. And you think how is that possible? Well, it's possible because their sequencing and timing is completely different".

4.2.2 Mental

This theme covered all psychological and attitudinal factors that coaches thought important.

Coach 4 saw that the desire to be a fast bowler as an essential part of being a fast bowler:

"I think you've got to be able… to be someone who loves bowling fast, those who are wanting to bowl fast I think, I think bowling fast is an attitude…you know, you see when the guys who want to bowl fast, they love bowling fast so it's just… you can just imagine these guys running in and wanting to bowl fast, in front of their house on the street in India or on the garage or, you know, in the park wanting to run in and bowl fast and I think they're less concerned about taking wickets".

Coach 12 also saw the need for an appropriate attitude as well as further psychological attributes, and sort to develop these:

"…it's hard work bowling fast, it's really hard work, so there's a lot of things, it comes down to character, whether they're robust, whether they're resilient, whether they like the hard work, do you know what I mean, whether they get a sense of reward after a hard day instead of being a hard day. I look at how they come back the next day after the ball. I look at, like I said, I look at the character, I look at how resilient they are, I look at how robust they are, I look at the individual, what the individual needs".

Coach 13 recognised the mental challenges of fast bowling also, but believed that a love for the game and fast bowling was the answer:

"… they've got to love it, because bowling fast or bowling hurts and fundamentally if they don't love the bloody game, they're not going very far".

He also wanted bowlers to develop confidence and self-awareness:

"… And they've got to have a very good understanding and awareness and confidence in their own bowling action".

While Coach 12 saw aggression as a valuable psychological attribute:

"…being aggressive, I like aggression, I like a fast bowler that's in your face that knows like you're there, like you know he can hit you on the head, but yeah I like aggression".

Coach 8 believed that focussing on the mental aspects of the game and of fast bowling was the best way to approach coaching in this area:

"…a lot of my philosophies around fast bowling is the mental side of the game…. just your general mental approach to bowling, how that can affect your action and ultimately your results".

4.2.3 Physical Preparation/ S&C

Physical preparation and the use of strength & conditioning was seen as an essential part in the coaching of fast bowling; specifically, being discussed by Coaches 2,3,4,5,6,7,9,10,11,13,15,17,18 and 19.

"…in my experience when you look at so many fast bowlers, yes, one thing that is common is that physically you are extremely strong, you prepare your body to take the rigours of fast bowling… …I think a coach should ensure that you are working really hard on your fitness part of it and this is work that doesn't happen overnight, overall fitness you understand, and power, your strength, and fast bowling is an explosive arm activity" (Coach 5).

Some of these physical components, included, athleticism/movement skills, endurance, strength (overall and core), speed, and power:

"…the basics of a bowling action are run, jump, push, pull, lunge, squat. That's the basic movement pattern of that bowling action. So therefore, that person itself has got to be able to do that with its own body weight. If they can't then there's no point trying to put technique into place because they just won't be able to accept it." (Coach 9).

"…I think if you are athletic able to run…well …be fairly… have a lot of agility, and a lot of flexibility in your body you certainly can develop fast bowling…athleticism is certainly important, and obviously core strength is very much…you know something that you require to bowl quick" (Coach 3).

". You need to do a lot of plyometrics. You need to obviously have a strong core and all of that. You need to be a good sprinter. The mechanics of sprinting are really beneficial for the mechanics of fast bowling. So, there's a lot of athletic components which are really important in fast bowlingI would make sure that they are regularly improving their athletic competency and if it's specific to fast bowling then I would make sure that the relevant boxes are ticked in terms of the athletic quality that I want to have in the fast bowler. So that's where the S&C comes in" (Coach 10).

The need to build upon these physical qualities, in alignment with the work of a strength & conditioning coach was seen as crucial:

"…speed is also dependent on a lot of S&C fitness" (Coach 4).

"In terms of the body, things like mobility, strength, ability to contract quickly, these kinds of things, you'd have gym sessions, but you'd have fitness sessions where you're working on specifically those things" (Coach 10).

Coach 19 also agreed that fitness and conditioning were an essential part of fast bowling success:

"…if you're a fast bowler that wants to go to the next level, the fitness side of things goes hand in hand. You've got to be fit… obviously the gym, their strengths work. The ability to control their levers".

Coach 19 also noted that the converse was true:

"…that's why, for me that's the other side of the fence. Because what will happen is if the guy's not fit, he can do all the technical stuff you want, but you need to be able to do (the workload)*".*

Coach 13 also noted a lack of functional strength was an issue, and that this loss often occurred with young bowlers going through a growth spurt:

"…when a bowler goes through these growth spurts, now they lose what I call their functional strength in their body. So, it's something we have to keep on top of".

Coaches 2,5,7,13, and 20 and explicitly stated that they felt the need to combine the physical preparation/S&C work with the technical bowling work to maximise benefits:

"I think there's a lot to be done now where the gym work that the S&Cs work on is fine, you can get the lads to a certain level of strength and conditioning, but I believe you've got to be

able to bring the gym to the dance floor. And that's what I'm doing now with our S&C… he's excellent, is once we've got them to a certain level of basis strength and conditioning, how do we then marry up bowling technique and the basics of the bowling technique to the stuff they're doing in the gym" (Coach 13).

Coach 7 believed that aligning strength work with technical development/skill acquisition in young bowlers was particularly important:

"It's more providing an awareness for those guys, because the reality is that takes a lot physically to achieve that position. If you're rocking your centre of mass back you need to be pretty strong on your back foot, which a lot of nine-year-olds are going to struggle to do. So, it's more of an awareness at that stage. I'd say then our development bracket between 13 to 16, or 13 to 15, then it's an opportunity for them to really do that stuff alongside their physical work. So, it becomes more about developing those skills, and then performing them more when you go 16 to 18 and into the pro game".

4.2.4 Injury prevention/Rehabilitation

Injury prevention was seen as an essential part of the Physical and mental preparation and development of the fast bowler.

One of the key risk factors in fast bowling is spinal stress fractures (Bartlett et al., 1996). Coach 13 believes that these maybe caused by a multitude of factors:

"…Is there one particular reason why stress fractures happen? and the answer to that question is, there isn't one specific component of why it happens, I think it's an accumulation of a few things".

Although there were numerous factors relevant, he looked to focus on technique:

"We can look at diet, strength and conditioning to make sure they're strong and fit. But ultimately if we can keep to the technique side of things, if we can align them better at the crease, so that's coming from all the way from run-up, so they've got good running style, they've got good arms, they've not got these curves in their run-ups and we can keep arms from running style, running for longer as they're coming to jump gather, then that'll allow them to set in a more balanced position at the crease and more effective place to be able to go through their bowling action".

Coach 14 believed that it was important to tie in injury prevention work with performance and technical work:

"Injury prevention is something that should be high on fast bowling coaches list because safety first all the time. But you want to, if you're going to tie in injury prevention, you should also tie in improvements in it as well. If you could marry both where you're working with young fast bowlers it will be very good, while educating them as well, because the more educated they are in what they need to do, your job becomes a little bit easier

Coach 12 suggested that investigating where the causes of injury come from was an important part of his role as a coach:

"I would do a lot of research into their background, see where they are, see what injuries they've had… But we're actually in a situation here with (An England Player), because (An

England Player) had two stress fractures, has played for England, so we're trying to get to the bottom of that and I've looked at his action, I've looked at where I think he may be getting these from and speaking to a lot of people I just think that comes down to strength, strength and stability at the crease".

Coach 17 saw the rehabilitation period of injury to be an ideal time to include work on the bowler's technique:

"So, when I look at an action, the only time I try to have an influence on that action is when they are in rehab" (Coach 17).

Coach 15 believed that work to reduce the risk of injury and to increase speed through technical interventions was in fact the same approach:

"I believe you said is it about speed or is it about injury prevention? It's actually the same thing".

4.2.5 Inter-/Multi-disciplinary approaches

The need to work with individuals and teams from other disciplines was recognised by the coaches. This was closely connected to the work done for physical preparation and injury prevention:

"I always feel a coach has to work with a trainer and a physio as a team, so he'll be able to bring out the best out of the boy, and then he'll be able to get him out of the injury much quicker…

…I'm not an expert on strength and conditioning, so I use the experts for that" (Coach 20)

Coach 12 also looked to use multi-disciplinary collaborations when working with bowlers, particularly if the bowler had been injured:

"…speaking to physios in conjunction with S&Cs, just trying to get their take on it. And if something does need changing, for instance, we work together in the gym specifically to put to work things to be correct".

Specific examples of joined-up work with specialists in other disciplines were given:

"And that's what I'm doing now with our S&C… is once we've got them to a certain level of basis strength and conditioning, how do we then marry up bowling technique and the basics of the bowling technique to the stuff they're doing in the gym" (Coach 13).

While coaches recognised the value of using knowledge from other disciplines, he also noted that some disciplines, for example, may have different priorities and may lack technical cricket knowledge:

"A lot of these S&C coaches then came from rugby and football because there weren't any in cricket but coming from other sports. And I think there was a steep learning curve for the S&C coaches as well and I think there's still a lot of stuff out there that is misinformation on strength and conditioning as well. Like you have to be big and strong, that's not necessarily true. Someone breaks their back, the first thing you do is just send them back in the gym to get stronger. I don't think that's necessarily true" (Coach 15).

4.2.6 Individualised work-load management

Workload management was seen as a critical factor in the coaches' approach to coaching and the decisions that they made in terms of coaching content.

As discussed previously, workload was seen as a factor closely correlated to injury, and so the need to monitor it was explicitly discussed by coaches 1,2,3, 10, 13, 16, 18 and 19.

"Yeah, well, there's a lot of work done now on workload management" (Coach 13).

Coach 16 was keen to point out that workload should measure all physical loads that the bowler experiences:

"That's around all sorts of load, running, training, training load on and off the field, and then bowling load in particular".

Coaches were keen to express that this workload management was to be done on very much an individualised basis as different bowlers can tolerate different workloads:

"…the cricket we play…at this level is …keeping them on the park, and as a bowling coach to try and get the workload right as well… that's just as important as you know, thinking about the technique all the time and something that we've put a lot of lot of emphasis on this last year. And we've got this new program set up, workloads… and it's the first when it was coming back from preseason with every bowler fit." (Coach 2).

Coach 16 added:

"Yeah, I mean there's heaps of research around bowler workloads, around… back-to-back days, all that sort of stuff. So, I'm aware of all that. So, what I do know is everyone's different on that front as well. Bowling workloads are often talked about stopping bowlers from bowling… I'm of the massive belief that it's about understanding how much a bowler can take before they get an injury. So, if I know, so for example (Country 1) *just played* (Country 2)*, I know that when I was preparing* (Bowler 1) *in first class games, I could let him bowl 50 to 55 overs because he could handle it.* (Bowler 2) *I'd probably keep them to 40/45.* (Bowler 3)*, I'd keep him to 30 to 35, because he just wouldn't tolerate. I knew* (Bowler 3)*, if he was playing a one day international, wouldn't bowl the day before a game if he was going to go and bowl 150 the next day, because he had a history of side strains, and we had to limit that".*

Coach 19 also noted the importance of workload management, particularly when working with international level players:

"…the transition of a coach at this level, (to) *international level, is as well as having all those different technical things, you've got the next step which is around load management…So, I mean it's really plain and clear that when guys get injured, their bowling load management goes out the window. And so yeah, so that's a really important aspect. My job is, it's more of a monitor".*

Coach 19 also did not want to see rapid increases in workload:

"… the chronic load… a lot of people focus on chronic load. I don't focus heavily on it, I like to be aware of it, but for me chronic load will just happen because you're doing bowling. For me

the bowling load management stuff (is about) *making sure the guys* (rapidly increase bowling) *from nowhere"*

Coach 2 also noted that the age of the bowler also impacts on the workload that they can tolerate.

Coach 18 also recognised the need for workload management in relation to the ages and stages of development for bowlers, and felt that workload can be used to help develop the bowler:

"…some fundamental research that highlights there are some key things that happen at particular ages and background, so if you go through, you've got a body that will, if you take the straw that breaks the camel's back, you know, you can't just keep bowling, so your body will have a limit to it and that will take time to adapt and develop to be able to take more, so periodised loading would be an effective way to build your body up".

Coach 2 noted the relationship between game volume and its impact on speed:

"Trying to get them to gain extra yard of pace…It's…. quite difficult one at county level because of how much cricket we play".

Because of this, Coach 2 and his team had collected data for all bowlers across games and training over several years to help formulate a workload plan for each bowler with some success:

This is come from four years of research really, we've… we've collated all this all this data of workloads, in doing technique and skill base work in the winter, high intensity bowling and building up to a summer, of getting the balance right and…erm…it's the first time with you know we've got…five, six years of data in our…what we've done and try to build it up in the right way to go to a summer so it's the second time but we've got the numbers now and we've also hopefully we've got the right balance with it".

Coach 16 also used workload records to work back from when injuries occurred, so that he could better judge individual workload tolerance:

"And when you have an injury, because an injury can happen, you can go back and review that. But what I did know is if you got that preparation right, the injury rate was very much diminished, because I knew how to prepare those bowlers, and how much they could take, and they're pretty resilient".

As well as looking to measure and monitor maximal workloads, Coach 1 also suggested that there are minimal threshold workloads that bowlers need to meet to be conditioned to the rigors of fast bowling:

"…early monitoring workloads but getting them to bowl a good amount often the thing that people don't ball enough these days. The bowling restrictions that they initially called them came in a long time ago have been a bane of people's lives. I think we're actually seeing the downside of those now in that people aren't equipped to actually fulfil what the game requires".

4.3 Coaching Environments and Interventions

The third first-order theme involved the coaching environments that the coaches created and the interventions that they aimed to deliver. Coaches had clear strategies for the environments that they wished to coach in and for the interventions that they favoured using. This was further subdivided into six second-order themes: *Individualisation, Context, Pedagogy & content, Homework, Coaching aids,* and *Self-awareness.*

4.3.1 Individualisation

A reoccurring theme throughout this study was the desire for coaches to individualise their work with bowlers, and this included the environments that they created and the interventions that they created for each bowler.

"I think when you're coaching fast bowling just understanding that actually you know nothing until you know the athlete. That's the most important thing" (Coach 17).

Coach 13 looked for factors that stood out with a particular bowler, and looked to take a 'super-strengths' approach (Ludlam et al., 2016):

"… get to know that player, whoever they may be, get to know them as an individual, how do they learn and then really find out what their unique X factor is and look to enhance that. Whatever they do very well, get them to do it more often…. *…these natural raw abilities that they have, you know, the X factor that they may have, they may be tall and get bounce, so I think it's really important, in my personal opinion as a coach, is when they've got an X factor element we look at what's that wow moment when you see a bowler, you know, I call it like a snapshot, and you try and accelerate that really"*

One of the reasons for this individualised approach was that it was seen as being a way to better understand the bowler's strengths and weaknesses, and hopefully a way to improve the individual bowler:

"…you have someone that works through those movements, in their way and you will discover as they go along, what they can and cannot do…. But if someone does the work and they actually do the drills correctly they end up becoming the best version of themselves. And that's all we can every do as a coach" (Coach 15).

Coach 16 saw this as an ongoing process as small changes of an individual bowler's technique could lead to larger impacts on game performance:

"So little things around training practice you've got to keep an eye on because it's little things like that can start to drift and impact on a technique".

Coach 11 looked to assess each bowler against four criteria and then individualise training interventions from there:

"…the four things that I'd look at in no particular order, but to make them into a good quick bowler would be pace, bounce, control and movement, and do they tick those boxes. The best in the world potentially will tick all four, the majority, not all of them will tick three. And so, do they have those? And if they have three of those four, we're onto a bit of a winner,

how do we make them a little bit better? If they have less than that, what can I potentially do to help them get one of them?"

Coach 15 found that bowlers tended to want to work with a coach when things weren't going to well and used the analogy of a car mechanic, with the nature of the issue then leading to the individualised intervention:

"And this is why I almost think that the coaches are mechanics in that sense. You tend to go to a coach when you're doing badly, like your car's broken down. If your car's running smoothly, you don't drive it to the garage and go what's wrong with it? And he goes nothing it's fine. And I think that's where we are as coaches, we should be seen more as mechanics than what's happening at the moment is you become a mate, you put your arm around them, well there a value to that, that's mentor coaching".

4.3.2 Context

The context in which coaches interacted with the fast bowlers had a powerful impact on how coaches worked with bowlers, including the decisions they made about the interventions they used (or not).

For Coach 4, his context meant that he only got to work with squads of players for short periods of time:

So, you know, they could they be in touch with us for some time and they go on their state coaches, or they go to their under 19 coach, they go to… India being such a big country we don't get to see these boys. So, it's not like we see them for 18 months so for example if football academy of Arsenal or Manchester United, as a young kid, you're at that Academy for nine months a year or 10 months of the year. I think in cricket you don't get that kind of…maybe at county it's better … I'm only coaching at this sort of level…and at this level I don't get enough time with them to actually do something very meaningful important…".

This lack of time with the bowlers was less of an issue with some of the other coaches, who had access to their bowlers all year around. This allowed these coaches to choose at what point in the year they could or should make any technical changes:

"There's lots of other things that you take into consideration and share that… especially the time of the season as well, can't do the middle of the season. Well, it's very hard to do in the middle of a season".

As well as the professional structure and organisation that a coach works, the country that the coach works in also has an impact; not least in the way that bowlers develop outside of the coaching context, which in turn impacts how they are coached within it:

"… one major aspect is the environment they learn the bowling in, so what I've seen with kids over here in Pakistan the passion is incredible, and they want to bowl faster because their heroes are fast bowlers and they bowl with tape balls, tennis balls wrapped with insulation tape. They've been doing it for years – this is why Pakistan produce so many quick bowlers with no structure, because they develop the mechanics of a fast bowler at a really young age. Why they develop the mechanics: (a) they've got the intent to bowl quick; (b) the ball is light. Soy, at the age of 12, 13, 14 where kids in England are using a cricket ball, which is heavy, so their firing pattern becomes more like they muscle the ball to get it to 22 yards; whereas in Pakistan you've got kids who have got a really light tennis ball and they're able to fling it as fast as possible. So, the whole action speeds up. Now, I think if you have something heavy at a young age your body is naturally going to protect your shoulder joints, so it's going to slow you down, it's going to switch off the gas" (Coach 10).

Coach 17 also observed similarly that the environment that a bowler learns to bowl in has an impact in how they bowl:

"But with bowling people learn to bowl, on the streets of Colombo they learn to bowl in their backyard, they learn to bowl in many different places. And they may grow up seeing Malinga bowl, they may grow up seeing Bumrah bowl, they may grow up seeing Shaun Tait or Dale Steyn. So, their ideals are different and there's no perfect scenario. So, once you build those movement patterns and they are set from a certain point of view, breaking them can be dangerous, because you can create too much stress for different parts of the body".

4.3.3 Pedagogy and Content

This was the most complex second-order theme, which was sub-divided into six further sub-order themes: *Age appropriate, Gender appropriate, Experience appropriate, Sessional focus, Individualised,* and *Psychological*. Coaches had to make several choices regarding the content they delivered and the pedagogies they used to deliver it depending upon these sub-divisional themes.

4.3.3.1 Age appropriate

The age (and often experience level of the bowler dictated the both the content and pedagogical choices of the coaches.

"… it depends what age they are. Like if you're saying a novice adult versus novice junior and when I say junior, I mean there's so many issues with fast bowling as a junior, because they have these growth plates and growth patterns" (Coach 17).

Coaches, in general, looked to make coaching environments less complex and more fun:

"… for children, very young children you don't really need to coach, they play the sport for fun, so if you start coaching them too early then it ceases to be fun anymore. it's a case-to-case basis where I would develop drills which help them to get closer to the basics while they are performing the drills and the drills should be fun. It should be a lot of fun, like you take a young kid, and you imitate the bowling action from a very short distance and just give them the stumps as a target and say let me see how far you hit the stumps and bowl as straight as possible. From a very short distance, not necessarily you need to keep 22 yards, even if it's going to be 10 or 15 yards you just give a kid the chance to bowl, they develop the action. I think it's very important for each one to develop their own style; you, as a coach, can create an atmosphere where they can develop their own styles" (Coach 5).

Coach 4 believed that one of the crucial elements of the coaching environment was one that encouraged children to bowl fast:

"…you want them to bowl fast. Yeah, you want them with a correct attitude, and you want them to just bowl fast…. Don't worry about no-balls… Don't worry about wides…, let your body learn how to bowl fast so that's what you enjoy doing, you know".

Other than the nature of the coaching environment changing when coaching younger players compared to their adult counter parts, coaches altered their content and pedagogies depending on the age and development stage of the bowlers:

"I think for me I just explain, I just go through what I've just said. Just go back to this is how I think you need to look at these steps. But it depends on the age group. So, if you're really concerned about their safety, I'll approach the safety, or an injury, possible injury standpoint. And the other one is basically someone not very accurate. I'll try and work with them on trying to smooth out the rough edges of the first step being run up, that's a really good starting point" (Coach 19).

Coach 6 suggested that repetition of tasks was appropriate for children to learn:

"I would make things easier for him, and whatever I feel needs to be changed I'll be repetitive because the kids tend to forget. But it is easier to, without the muscle memory it's easier".

Coach 10 also looked for elements of repetition when working with children:

"I might take that approach and slow it down for them and just give them no target, just bowl at a wall and just get some repetition. So, get some muscle memory going, get some repetition, allow them to familiarise themselves with bowling with a straight arm because that's what kids struggle with and then just see where it goes from there".

This change in content and pedagogy was also reflected when coaches worked with older adults:

"But somebody like… (experienced county bowler) *75 mile an hour, we're never going to get….at his age when I've never going to touch him technically to try and get them an extra yard of pace. So, it is understanding your individuals and what they do for the team as well"* (Coach 2).

4.3.3.2 Gender appropriate

Only two of the coaches in the cohort regularly worked with female fast bowlers, but both coaches believed that the gender of the bowler made an impact on the way they delivered their coaching:

"I don't think it would be unfair for me to say that a lot of female cricketers are still trying to understand what bowling's all about and understanding the action and things like that. So again, there's an element of that in my coaching with the women as well is that you certainly don't want to overload them with information in risk of confusing them. That's the last thing you want, you don't want to confuse them; you want them to try and be as relaxed as possible when they bowl. And it's my job to try to drip feed that information in where necessary" (Coach 8).

Coach 10 explained that there are many issues for female cricketers to address before they can even play the game:

"So, for the last year and a half I've been in Pakistan, which again is an even more incredible experience than the kids in Nottingham, because here you've just got the rawest raw form of talent, enthusiasm, passion and then these young women that I'm working with they've had to overcome social and cultural boundaries, which you probably would expect in Pakistan. In the whole country there's only about 40, well, just 45 women cricketers in our pool in a country of 220 million. So that in itself has been an even steeper learning curve, but an amazing experience, and I've learnt so much about myself and also about the game and the struggles that these girls go through".

As well as female bowlers having cultural differences due to their gender in Pakistan, female bowlers in general have different physical make-up and therefore technical interventions are different for female fast bowlers:

"… there's less rotational power for females. They're not able to generate as much pace through that torque mechanism that I spoke about. And it's the same reason why they don't hit as many big shots, they tend to open up early, so obviously women are different. I think for fast bowling women, I would say they need to use the momentum more, so I think they should have a good approach speed and I think they should be front-on. I wouldn't change someone who's bowling side-on, I've got a couple, but I would encourage them to bowl front-on and to generate the pace through the approach speed rather than trying to generate it from rotation at the crease, because biologically females have got less rotational power, so everything is done slower. But in the female game if you're bowling at, I think the quickest bowler is around about 76, 77, but if you're at about 72, 73, 74, that kind of pace, 75, you're in the game with females… But in terms of coaching the action, one thing is a lack of rotational power: another one, obviously things, the strength levels, the muscle mass, the speed. Actually, the speed, the running speed is not that far off…. that's why I think that female fast bowlers need to use the run-up more, because in sprinting you don't really have that rotational energy, you're not generating rotational force, it's all linear" (Coach 10).

Coach 10 also noted that female cricketers are motivated differently to their male counterparts:

"So, women are also… they play cricket for different reasons as well what I've found and I think you have to understand that when you're coaching the fast bowlers, women tend to play to

be part of something, part of that team unit. Whereas men it could be individual performance, individual accolades, whatever, but with women, I've asked a lot of female cricketers, they play because they enjoy it and they enjoy the company of their friends and they enjoy being in a team, which I think is very different to guys. So, there's certain characteristics of females, because they're females, that you need to consider when coaching them, especially in fast bowling as well"

4.3.3.3 Experience appropriate

Coaches also varied their approach to coaching the more experienced and expert fast bowlers were:

"…expert players it tends to be easier because they know what you're talking about. They get it, they know what and they have a better understanding of their action, so they know what you're referring to, whereas younger players… are still trying to understand what bowling's all about and understanding the action and things like that" (Coach 8).

While more experienced and expert bowlers were expected to know more about their own techniques and what they were trying to achieve, Coach 20 was quick to point out that elite fast bowlers may still have technical errors:

"People can play for the country, and then still they can be successful, but still, they can do mistakes. It is not that the guy who is playing for the country is free from all mistakes. It's true there are international bowlers you can see, and then they do mistakes".

4.3.3.4 Sessional Focus

Another set of decisions coaches made in relation to pedagogy and content was in the use of drills vs. game-based approaches, technique vs. tactical focus and whether the coaches wanted the learning to be implicit or explicit.

In general, coaches favoured drills for novice and young bowlers (see above), and when making adjustments to the bowler's technique:

"So that is where I use a lot of drills to correct their flaws in their bowling action, so they do 100, they see the videos, I make them bowl in front of a mirror. And then even without a ball

I'll make them bowl, and then with the ball I make them come back. Without a ball when they bowl their action is almost correct. When they bowl with the ball, then a lot of things come into place, but bowling, trying to bowl right length, right line, and then depending on the batsman, what's the rate the batsman going to hit him, what he's going to do. So, try to get closer from there without a ball or with the ball, and then try to get them close, and then try to get them to bowl the same length without a ball and with a ball" (Coach 20).

However, once a bowler had reached a good level of competency, Coach 17 wanted to use more problem-solving approaches which allowed for more game-based activity:

"But then once they are proficient with the technique, then you remove the technical aspect, and you say I just want you to solve this problem" (Coach 17).

Coach 3 believed that both competitive match competition and games in training were the key to skill development:

"… that's developing your skill in game situation, so I mean, performing under pressure in games is probably the ultimate to where you want to be. And then to be able to replicate that consistently week in, week out and also through each session and each spell that you bowl is important".

Coach 13 looked for implicit learning through games:

"I believe the art of a coach is to design a game so that the kid or the player never, ever realises they've ever been coached. So, I'd set games up where they couldn't achieve the game, like for example they wouldn't be able to get the points if they don't stay in the train track, if they don't hit, you know what I mean. So, I would set my session up accordingly to the ability that they've got at the time, but again I wouldn't lose my principles of what we're trying to achieve and that is stay in the train track, get from A to B in the most efficient way possible".

Coach 10 also used implicit learning approaches, but within drilled activities rather than games:

"So, I think it's really important at a young age just to manipulate the environment, so bowlers develop that technique. I'm not a fan of telling bowlers that, you need to do this this

way; I'm a fan of coming up with drills that become the coach, so I'm not giving them, if you do this, do this, but I'm setting up a drill where in order for them to be good at it they have to adapt and get through that drill, so for example, I mean let me give you an example. Let's just say if I was to resist the bowler from behind with a bat so they've got some resistance. So, they're working, they're bowling with that resistance. What that will do is it will prevent them from spending too much time on the back foot because they're always pushing off it. So, something like that rather than trying to physically tell them that's how you should bowl".

This need to reduce or even avoid explicitly telling a bowler what to do was further repeated by Coach 17:

"…you allow them to use the other aspects of their skill, which is their judgement and their ability to adjust… We almost remove the trust aspect and make it so explicit and so technical and so definite and so narrow, that their ability to learn about themselves just goes out the window".

Coach 16 wanted to ensure that all activities, including the warm-up were done in the same way as they would be in games:

"…a bowler often bowls in warm-ups off a short run up; sometimes their angle of approach can be different than the long run up. So, all of a sudden, a much greater movement pattern that become natural that then comes, so their approach angle, how would I explain this to you? Imagine a bowler who runs pretty straight to the crease and bowls through but off a short run comes on more of an angle. All of a sudden that movement can start to feel natural, so you create that sort of line … because that's what they've been doing. So little things around training practice you've got to keep an eye on because it's little things like that can start to drift and impact on a technique".

Other than when coaching novices, Coach 17 used the opportunity of a bowler in rehabilitation from an injury as an ideal opportunity to focus on interventions to alter the bowler's technique:

"…the only time I try to have an influence on that action is when they are in rehab. So, there's a significant time period where you can break the last segment of the action down and teach

feel, and then drag it back. You don't do it halfway through a season, you don't do it in game, you don't do it when, you're trying to make people more effective because that's the last thing they want to be worrying about".

Coach 17 used step by step refined drills on those occasions of technical intervention:

"… when I'm coaching technique, I break it right down. So, we start at a standing position, and we're talking about delivery stride, very last part of its delivery stride. And so, from there we try to influence the way the head moves from that very last position and then work back from there. So, each time we set back and increase more intensity or momentum, because momentum automatically makes the body adjust, it makes you move backwards because the body will use itself as a brake if it feels like it's moving too fast, it will lean back to slow down. You start at the very end and then work backwards, and you add momentum in slowly and then understand how you can influence the position that you want to be in based on the last exercise you did.

However, Coach 17 warned of using drills and having a technical focus when coaching rather than an outcome focus of the bowler:

"…the problem is the coaching is so generic and everything is always a technical issue…. It's amazing, you can make stuff so complicated, but it's not for the benefit of the players, it's just for the box ticking benefit of the coach, so that then they can say oh I've done this, I've done all I can. There's not enough practical element to the theoretical stuff".

Coach 17 suggested that outcome focus for a bowler was superior to a technique focus:

"I'm a massive fan of outcome-based stuff. So, for example we were dealing with the bowling, in the winter we were only allowed to do a certain level with the guys indoors. So, I've got one of those, you know those foam poles they use in rugby league…. It's about five feet high. It's only four inches across. So, I taped an area and that was probably half a foot above the stumps and that was the target, not a cone on the ground. But the target was I want the bowlers, bowlers, I want you to put that agility pole somewhere. You put it wherever you like, whether it's a left hand or right hand or wherever and I want you to hit, I want the ball to hit between the taped area. I'm not interested in where it lands on the wicket; I'm only interested in can you get the ball to hit that. And so, they, and you know from a technical aspect there's only

certain things they can do. They have to be in front, their head has to be in front. They have to drive over their front knee. They have to get the ball to climb. It's not about hitting a cone which doesn't teach them anything other than to land the ball in an area, which will then disappear back over their heads. It's about can I make the ball do this, can I get this ball performance, which teaches you technique".

Coach 16 noted that playing periods of time in distinct formats, impacts on the bowler's technique and the type of deliveries that they are then able to bowl; therefore, he wanted to break down training to focus on all types of delivery that the bowler uses across all formats:

"So, if you're playing T20 cricket for example, I think guys like Bumrah angle the ball in, try to reduce some of the ball, they drop their arm down. So, their arm angle changes. And so, when you're doing that, then move back to four-day cricket you see bowlers who, the position on crease is different. They're not swinging the ball because it's been adjusted from a different format. So, I think a lot when I've got time about do you break your training down to enable players to keep refining those skills that work best for them; because if you just simply focus on bowling a type of delivery for a type of format, you can have a knock-on effect to another format when you transition over".

4.3.3.5 Individualised

Not surprisingly, coaches wanted the coaching environments that they used to be individually focussed, as it went hand in hand with their conceptions of the technique and their intervention beliefs; both of which, as previously discussed, they wanted to be individualised:

"How do you coach? well, again, depending on what you've got in front of you it partly depends on how they learn, so obviously looking at their preferences and what they've done to get to where they are, so if you're looking at different ages, some have never bowled before, so again you've got options there in your teaching categories to look and show and demonstrate and then being able to then monitor as they go through, obviously again you're looking at the fundamentals of bowling which is to get the ball down the green and take the wicket apart".

The one notable exception to this was Coach 12, who in addition to a lot of individualised work, also wanted his bowlers to work together as a 'bowling unit' and have greater task

cohesion (Smith et al. 2013), which was part of their identity and development as a team member:

"And my theory is it's not just coaching fast bowlers, its coaching people, you're trying to make them become the best person they can be… And part of my theory here is getting people to try and bowl in a unit, try and bowl together, not just bowling for themselves, being selfish, actually bowling for the other lad down the other end".

4.3.3.6 Psychological

The psychological environment that a coach created through their delivery was also considered by the coaches. They wanted to create environment that was psychologically appropriate for performance:

"… you want them to try and be as relaxed as possible when they bowl" (Coach 8).

"…you're looking at what's inspiring them, what's motivating them" (Coach 18).

Coach 8 also believed that the psychological elements of coaching had an impact on the techniques then used by the bowlers:

"… a lot of my philosophies around fast bowling is the mental side of the game…just your general mental approach to bowling, how that can affect your action and ultimately your results…. but you want good results. And sometimes your mental approach to that is as important as the technical approach".

Coach 6 liked to use questioning in his coaching, as he felt it led to the bowler using visualisation, a psychological technique used to advance motor learning (Silmani et al,. 2016):

"I try to get an answer out of him only, rather than giving him a straight answer. And I think in that process he'll start thinking more, and he will also visualise and understand what I am telling him".

4.3.4 Homework

There was an expectation from coaches that bowlers would work on improving their abilities away from formal coaching activities with the coach. While many coaches recognised the learning opportunities on the streets, beaches, and car parks around the

world (Coach 10 & Coach 16 in particular), on coach looked to give drills to bowlers as 'homework' and championed the long-term use of them:

When working with children Coach 15 said:

"If you're doing drills, they can be dull. So, we have to make those drills interesting and relevant, and those kids then come back, and I can see that improvement, it's better. And the dads, oh my son just won't stop doing the drills, he's in the garden every night, they become almost obsessed with them. One of the kids, this is true, this Christmas, has drawn his dad a Christmas Card and his dad has sent an email to say he's drawn me a Christmas Card of the four tent pegs".

Coach 15 also used this approach with experienced bowlers and detailed how one of the world's leading bowlers was still using this 'homework':

"We did a bit of work on his control and action just through the tent pegs and he went back to (A Country) *he worked with, did a bit of work with* (A Coach) *and then within two years he'd gone from 300 in the world to number one. It was that dramatic. And he stayed there for a decade. And I hadn't seen Dale for years and I saw him… at the 2011 World Cup… and he came up to me, he gave me a little man hug on the outfield and stuff and said how are you? The first thing he said to me, he said 'do you remember those drills you gave me?' He said, 'I still do them'. I said 'really?' He said 'yes'".*

4.3.5 Coaching Aids

Coaches used several different teaching aids throughout their coaching practices.

As noted previously in the discussion of context, many young fast bowlers have role models/heroes that they look to emulate:

"…they may grow up seeing Malinga bowl, they may grow up seeing Bumrah bowl, they may grow up seeing Shaun Tait or Dale Steyn. So, their ideals are different" (Coach 17).

An obvious extension of this then was the use of expert role models, by coaches, as useful role models or archetypes, particular for young and developing fast bowlers:

"… what I try to do is that I try to see the similarity of that particular bowler with somebody great. Somebody is a skinny kid, bowling with a skiddy action, I try to relate him to say Lasith Malinga. I try to find out how do I adjust him, so if I want to make him… I won't be able to do that. So, I need to find out somebody who's been successful international or in first class standard who's close to him, and try to get out in that way, which will probably suit him more. So, if I try to make somebody like Allan Donald who had a fantastic running technique and a fantastic loading which goes by the book and me not helping the way he would want me to do. So, I try to find out the similarity of that particular person to somebody who has achieved, and who's probably very good in international cricket".

Coach 12 suggested that role models maybe a good framework for coaches to use as a comparison or model to work towards:

"But I think if you were to probably ask a bowling coach 'what would you really like to see?' it would be somewhere along the lines of a Brett Lee or a Dennis Lillee type".

However, Coach 1 and Coach 20 warned against this approach:

"I think it's a very dangerous way to say to pick somebody, a Brett Lee or whoever it might be and say that's the way to bowl fast" (Coach 1).

"… the idol modelling is something which is very detrimental to the game. Because trying to do idol modelling, they're totally forgetting their own style, and then either their own style or more on the idol side they get mixed and that. So, idol modelling is not really good…

…You take the case of Mohammed Shami. He doesn't have a front foot facing bracing at all, both legs are bent. But still, he's able to get it on 140, 145 out balls. But Bumrah, everybody thinks he has got a freak action, but if you see his delivery stride, I think his technique is superb. His body position and his front foot bracing, and then the way in which, don't see his run up or his load up or whatever it is, but in spite of it, but I don't want the boys to copy Bumrah, but there can be only one Bumrah, or there can be only one Malinga. So, try to copy, then you will lose your originality" (Coach 20).

Coach 18 and 16 both used video footage of bowlers as a way of demonstrating the technique and outcome that the coaches were looking for. This included video footage of

the bowler's themselves, with Coach 16 particularly focussing the use of a bowler at their performance peak to be used as the 'role-model approach' mentioned earlier:

"… trying to then picture and put some vision in front of them or at least a demonstration to get them into a position where they can actually look, and most of the stuff now as you can see on YouTube, plenty of demonstrations, plenty of things to look at. I think it's the skill of a coach, depending on where they position themselves in the crease, different actions that you could probably visually put in front of them that would be very similar to what they're doing to give them some guidelines and some guard rails about what to do" (Coach 18).

"I think video's a massive tool, because people visually can see exactly what they're doing. I think if you can see, if they can see themselves, and then see what they're doing and how that looks differently, I think that's a massively powerful tool…

… So, if you can stay on that approach that works absolute best for you, and you're aware of what that is, at least you've got a reference point back to when you were at the absolute peak of your powers" (Coach 16).

Additional tools were used by coaches within their coaching practices. As alluded to earlier, Coach 17 used a target he had made, to stand behind the wickets, to get the bowlers to focus on their outcome.

Coach 16 looked to use weights, and kinaesthetic tape to increase self-awareness of body parts for the bowler:

"I think you can create awareness around stuff by, say if you're looking for a risk position or a body part by taping something, or putting something on the body that creates awareness around it on a part of the body, so they can feel where that's going. So, it stands out and you can do that in whole different ways. Tape, weights, different stuff that you go I just want you to feel this one part, and what it's doing".

Coach 13 liked to use weighted cricket balls, to increase stability, increase arm speed and to increase kinaesthetic awareness (see also the discussion of 'Self-awareness' later):

"I'm now starting to work with heavy ball training. So, I put a heavier, so a cricket ball is about 165 grams I think, I'm actually working to 200 grams, 300 grams, 400, 600, even to 800-gram

cricket balls, so they're able then to control heavier weighted balls at back foot contact and still be able to create the same speed through the crease and velocity. So that's in their bowling hand. I've also then got a weighted ball in their non-bowling hand. So, what we've worked on now is, there's a bit of study to show that if you over-train the body in the bowling action, when you then take the weighted ball away, they've got a better understanding of what their body's doing and plus they're in a more stronger position to control their momentum…. …the crucial bit coming through delivery drive phase, how do they generate from that point on. So, again, the weighted ball stuff, how do they use the weighted ball. I've got a lot of them using weighted balls to flick the ball out or maybe drive it back".

However, Coach 17 warned of using too many coaching aids that were not part of the actual game:

"You can introduce hurdles and so on and so forth, but I try to remove as many devices or cones, or things that wouldn't be there in a game, so they can learn to do it without the use of anything other than what they're used to thinking, if that makes sense".

4.3.6 Self-awareness

Coaches wanted to increase the bowler's self-awareness while bowling. The primary reason for this was to enable bowlers to self-regulate during match conditions (as well as training):

"So, whoever the best bowlers in the world have ever been… they've fundamentally got their understanding and awareness of what they're doing within their own actions. So, when it goes wrong for whatever reason they're able then to put it right themselves" (Coach 13).

Coach 14 wanted his bowlers to not only know themselves, but to know more about bowling itself:

"… educating them as well, because the more educated they are in what they need to do, your job becomes a little bit easier" (Coach 14).

'Feel' or kinaesthetic awareness was very important:

"So, for (International bowler 1) *and* (International bowler 2) *and* (International bowler 3) *we had a significant period with them to have a conversation about what they wanted, what they*

were feeling and how we could influence that feel, rather than that technique… hundred percent yeah, it's all on feel" (Coach 17).

Coach 17 then expanded this further with an example:

"So for example if you're doing a three step exercise where you're walking and bowling, can you maintain that position when you add more momentum; what position do you need to be in when you enter that last position and how do you, what does your run up look like; what is the last part of your jump going to feel like, how long are you going to be in the air? All of those things are dependent on the bowler… The bowler dictates them and the way that they enter. So ultimately if you are, if you look at (International fast bowler A)*, if you can, he likes to be quite close to the stumps, he's quite interesting. He's quite side on, but then when he hits, he has a very open shoulder pattern, but his back shoulder's set really nicely. So, if you're working with him, you'd work on maintaining that feel of the timing difference between when he takes off and when he lands. You've got to simulate that scenario. For someone like* (International fast bowler B) *who spends a long time on their back leg, you have to simulate that when they're, but if you're trying to, if they're saying no, I'd like to spend more time in the air, then you have to try and introduce that feel aspect. And so, there's many things you can do".*

This concept of feel was also used when focussing on ball outcome rather than technique:

"When you're bowling a half volley you know it feels different. When you're bowling a bouncer, it feels different. So, when you're asking people to tune into their feeling, their technique changes because technique is not finite. It doesn't, it's not the same every single time, it can't be. There's always a subtle difference. And so, when you're asking, when I want to get someone to drive the ball, it feels different to when I'm bowling a bouncer. So, if you can get them to connect to the feeling, rather than the technical aspect, they'll be able to deliver it. Because you can only have a feeling you've had. You can't generate a feeling you've never had. So, there's an automatic trust in that, you can trust the fact that you can feel it. And that's the big difference between I want the ball to full rather than what does a half volley feel like, what does a bouncer feel like?" (Coach 17).

Coach 16 wanted his bowlers to increase their self-awareness:

"I think you can create awareness around stuff by, say if you're looking for a risk position or a body part by taping something, or putting something on the body that creates awareness around it on a part of the body, so they can feel where that's going. So, it stands out and you can do that in whole different ways".

Coach 16 wanted to marry up his bowlers' kinaesthetic awareness with what they saw in videos of themselves:

"… bowlers have to be able to understand or feel their way in space and time. So, if they don't understand exactly how their body's moving, how it works, that makes it very difficult. So, one of the big parts of coaching I think is trying to educate your players to understand, marry up the images in your own mind of the bowl with the image on the video screen. So, if they can feel it, and then they can picture in their head, and what they see on the video aligns, then I think it makes it easy to start to make adjustments, because they know who they are and space and time; but very difficult otherwise".

He felt that this was particularly important, as for many bowlers, what they felt and what they saw was often different:

"Often when you video something and do it, the change looks, can seem very small but it feels very big. And so that's the hardest thing with marrying up those two things".

Coach 6 believed in the power of using questions to help the bowler increase their self-awareness, particularly in relation to their bowling technique and bowling performance:

"… I should always encourage the bowler to solve his own problems. So rather than giving a straight answer probably I'll ask questions. I'll let him speak. So, if you're saying why am I bowling outside leg style, I'll ask him what do you think? What did I tell you to bowl the ball in the right area? So why would the ball go outside leg stump? So, he might come up saying my head is falling, or my non, he might come up with an answer, and try to encourage his answer, and try to get an answer out of him only, rather than giving him a straight answer. And I think in that process he'll start thinking more, and he will also visualise and understand what I am telling him. But if the answer is coming straight from me as the coach, it will not register the way it will register if it comes from his own mouth".

4.4 Analysis

Analysis played an important role in the coaching practices of these coaches. The coaches' approaches to analysis were focussed around the four questions of *Why? How? What?* And *When?*

4.4.1 Why?

Coaches had a clear idea of why they needed to analyse their bowlers.

Coach 10 believed that each bowler was unique, and each had their own limiting factors, therefore analysis was critical to working with each individual bowler:

"So, I think there'll be limiting factors in every bowler. So, I think identifying what's limiting him from either having an efficient action or generating pace, every bowler will have a different limiting factor and I'd work on that individually".

Coach 13 believed that fast bowlers can get injured at any time and that some may have a pre-disposition to be injured, however, through thorough analysis of the bowler there were ways to reduce the risks:

"Now, I'm not saying that they can, even with the bowlers with the best actions, they can be strong as oxen, they can also have the best techniques, but they can be just maybe predisposed to the fact that they haven't got as much flexibility in their lower spine, or they've not got as much bone density in their spine. There's lots and lots of issues, but all we can do is help a bowler be stronger, cleaner in their technique, understand their workload management, get them on the right strength and conditioning plan, get the right diets and give them the best support, so they get their own understanding and awareness of what they're doing. If we do all of those things we can reduce injury, but I don't think we can ever take it away, it's just one of the jobs".

Coach 15 believed that many stress fracture injuries can be predicted by analysis of the bowler's technique:

"Someone like (International Bowler X) *had three or four stress fractures;* (International Bowler Y) *had three or four stress fractures. You could go through their actions and say well it's happening there. That's the reason it's happening, it's happening in this position, you can*

see it. (International Bowler Z) *had a stress fracture. I'm not being a smart-arse, but I was predicting that two years before he'd even got it. You can see, you can show me 50 bowlers and I'll probably be 95% accurate on which ones are going to break down. Not because they're bowling overs but because of the way they bowl".*

Video analysis can also be used to help motivate bowlers and to increase self-awareness:

"I think if a player looks at himself getting better, even in a small way, if you can show with measurements, then that motivates them to work even harder and then you have the results. But most often what is lacking is most players what they think that they are doing and what they are actually doing are two different things. So, if you need to bridge that gap, I think video is an excellent tool, as long as you don't overuse it" (Coach 5).

Once technique had been analysed and assumed safe, Coach 4 then wanted to measure certain physical attributes of each bowler as he felt them important:

"I think there will be certain factors that will be quite important to all fast bowlers… basic levels of fitness strength and fitness, I think would be important, basic levels of flexibility. I think will be very, very important… Once you have an action that is not mixed so you have an action front on, side on or semi. Then I think a lot of it is down to your conditioning and I think that level of conditioning i think is quite important".

4.4.2 How?

Technical analysis was done primarily using video capture of each bowler, and while explicitly mentioned by Coaches 4,5,9,12,13,14,15.16 and 17, was implicitly implied and valued by all:

"It's hard to pick up everything with the naked eye, so videos in slow motion, modern technology on the phones can help today" (Coach 14).

Coaches 12 and 14 thought it was important to analyse a bowler's technique from several different angles to get a fuller understanding of the bowling technique:

"I'd video from behind, from side, from front-on, maybe a little bit from the top just to take as much information as I can get" (Coach 12).

Coach 14 not only saw it as important to capture video to analyse the bowler, but to work through the analysis *with* the bowler:

"You have to educate your young bowlers. You let them watch the videos with you, you don't watch the videos and then tell them they should be doing this. So, they have an understanding that this is what needs to be done, as opposed to the coach telling them all the time, reminding you this needs to be done, this needs to be done. The more educated they are, the easier your job is as fast bowling coach".

Coaches generally analysed the technique using a phase-by-phase approach, often starting with the run-up phase:

"First and foremost, I would look at taking as far back in their action as I possibly can and see, like I said, if I'm trying to change something, I would look at where it starts. For me there's always an action reaction along the way. So, I look right back at the start of the run up, look at angles of approach, look at pace of run up, look at crossovers of feet, look at take-off positions, look at early loads of arms, see whether things are going early, then look at the consequence of that" (Coach 9).

Coach 17 believed that when an error was seen in the bowling technique, that the phase before the error should be the one explored:

"…you don't look at the end of the action, you look at the, the end of the action tells you what's happening before that, rather than trying to fix the end. You think about how you can make some changes before that".

Coach 17 had bowlers bowl the ball with a drastically reduced 3 stride run-ups:

"Whenever I haven't seen anyone bowl, when I'm working with someone for the first time, I get them to do the three-step exercise, which is if they're right-handed to stand pretty close to the pop and crease, start with their left foot first and they've got three steps to bowl the ball. And then I see where that power comes from and straightaway you can see whether someone leans back, whether someone's all arms or all shoulders, on side, or mixed, and you do it without any impact".

Coaches had a conception of 'good' and 'poor' fast bowling techniques (as described earlier) for which to base their analysis of their bowler's against, particularly the English fast bowling coaches, who used the 'ECB Fast Bowling Matrix'. Coach 5 also discussed the use of software and computer-generated models:

"… we have software where I could check the arm positions, the leg positions; if they have gotten better, then with the software with drawings and lines I can easily make out how more efficient they are. Visually also it is visible. But then more than being visual even small things, if you can measure on lines and the software helps you to explain much better and more efficiently to show their improvements".

Finally, some coaches also used radar speed cameras to analyse the release speed of the ball from their bowlers. For Coach 15, this was a novel approach at the time:

"I bought a speed camera for £2,000, which I still have, it still works, although it's 30 years old. And as far as I know I was the first cricketer to have a speed gun. So, I measured them on day one, put it away and I measured them on week five and every one of them, 21 participants, had increased their speed. And the most increase in speed was 16 miles per hour, which is a lot".

Coach 17 also used speed cameras ('speed guns') but warned of the impact that this can have on bowlers striving to bowl quicker:

"… we have used the speed guns, which I hate using, because people just try and bowl faster. And so, then you, which is great for certain things, but not when you're trying to teach feel".

Coach 16 valued the use of biomechanics labs and the expertise of sport scientists to ensure that correct decisions are made in terms of technical change with a bowler:

"…the naked eye it looked really good, and yet he was just over. So, what that tells me is even with videos when you're changing technique, your naked eye is not good enough to pick up those very fine margins. So, when you're talking about hip and shoulder separation or counter rotation, the stuff that causes injury, your eyes just won't pick that up, it's not good enough to pick that up. Only the expert, the video analysis that's done in the lab is good enough. So, I'm very wary of changing techniques when I can't definitely say that that's going to be right".

4.4.3 What?

In terms of what coaches were looking for in their analysis, coaches had three primary categories, technical analysis, ball outcome and physical strength tests.

"When I first started, I would look at the technical aspects. I'd look at what they looked like. Now I look at the outcome. So, the first thing I'd look at is outcome and what is it. And then I'll try and break it down into the four, the four things that I'd look at in no particular order, but to make them into a good quick bowler would be pace, bounce, control, and movement, and do they tick those boxes. The best in the world potentially will tick all four, the majority, not all of them will tick three. And so do they have those?" (Coach 11).

Coach 16 took an opposing order:

"I always start with technique, the run up first. That's my first point, because everything out of the technique flows from the run up. So, a lot of the speed, direction, angle, do they move in and out, do they run straight? No. Are they consistent in their approach? Start there and then just basically work through to the end, and try and use the cause and effect, going what do I think the cause of any issue is and how can we fix that cause or how can we even make that cause better? Then hopefully you'll have the knock-on effect is that the action will be, or really the outcome will be that the bowl that was more consistent that what you're doing".

However, while Coach 16 started with the technique as the first thing to analyse, he saw the outcome as the more important measure:

"I focus more rather and say that actually it's got to look a certain way, is try to get the bowler into a position where they're at their most effective at the other end. So, it's less about the look for me, it's more about the performance down the far end, and making that as good as we can"

The model used for technical analysis varied between coaches but was in some way part of the models expanded in section 1 and 2 of this chapter. Coaches had their own systematic ways of then analysing what they saw against the representative model:

"Having done Level 4, and having been on the biomechanics module, and believing that the doctors and the professors they are, and I guess going along that scientific route, the biomechanical chain. So, I guess big things get them moving first, then move slower and then, so if you went up the body it's almost quads up through chest. The last thing you want to move is the wrist, the fingers, so getting that chain to work well will help them propel the ball quicker (Coach 11).

Other coaches looked for critical elements/body parts or phases within the bowling technique:

"For me the first thing I look at when I'm looking at a fast bowler is the head position. So, I look at what the head does because the body follows the head. And once you have an understanding of where the head is going, then you can understand what the body wants to do, or why the body is reacting the way it's reacting" (Coach 17).

Coach 17 also looked at the wrist and the knee:

"… if you look for, if you're looking at wrist position, if you're looking at knee drives, knee drives are really big. So right knee drive for a right-hand bowler. If you've got really good right knee drive, then you can remove a lot of the sharing force on the left side of the back. If you leave that right leg behind you create a big sharing force on the left-hand side of the back, it also stops your hip rotation and stops your shoulder rotation being able to come right round. It means you have to go into more of a side on position".

Coach 7 was particularly interested in the bowlers' centre of mass:

"… for me the more bowlers I've worked with and the guys that I've seen those things in, I'm big on centre of mass…. So, if I'm watching a bowler from behind, the two things that I'm watching for, as I said centre of mass is a big thing".

For Coach 13, the non-bowling arm was an important element to analyse specifically:

"I believe the non-bowling side gives you two major things: accuracy, it gives you pace and power, but it's how you use it. And also, once they've got pace and they've got power how they actually use this front arm can dictate the length they're going to bowl as well. So, the non-bowling side and the front arm is a huge part of the bowling action, a huge part".

Outcome measures were seen as important variables to analyse. An ability to bowl the ball at pace, with swing (air deviation), seam (ground deviation) and bounce were critical as was an ability to do those things repeatedly:

"… to repeat that, for that to become. I talk about it a little bit as your money shot is your, I like darts so your treble 20. So, the best players hit treble 20 more often than not. So, the best bowlers hit top of the bowl, the area that helps them. So being able to repeat that time and

time and again, and then also to give them the release point, or help them with the release point, give them the most amount of chance to move the ball, whether it be off the pitch or in the air. So, you want it, one, to be accurate and, two, to have some form of movement area as well" (Coach 11).

The other measure was bowling speed as mentioned above, using a speed gun.

Finally, coaches 3 and 19, looked to conduct general strength tests with the bowler:

"…had a series of strength tests that I used to do. So that was something that I did, particularly with teenage girls and boys. Because that's that period where they get stronger, or they get taller sorry, taller and they've got arms and legs everywhere. And yeah, I just do a couple of really simple tests where one is literally, I just had this on their, leaning on their back, laying down on their back. They'd lift up their knees and heels, and that's got to be at 90 degrees. And if they can hold that position with the back flat for one minute, then I would probably deem them safe to bowl. And then the next phase is they can actually control their legs up and down, and then that's probably when they can control their action, but they probably need to do a little bit more work if their back is arching. So that was one thing I used to do in that area" (Coach 19).

4.4.4 When?

Coaches wanted to have video of footage of bowlers when they were at the peak performances. This was then used as a reference point to compare against if the bowler lost form (performance reduction) or got injured:

"... I think is that when you got a bowler who's been playing for a while, especially on the A Team and stuff we try and take a video of him when he's bowling at his best and bowling really well, and try and compare that to when he feels he is struggling or is not improving and see if there are any real changes in that, that's you know and then if there are changes you could sort of show him that" (Coach 4).

4.5 Coach-Player Relationships & Communications

The next first-order theme focussed on coach-player relationships and the communicative encounters between them. The relationship between the coach and the bowlers was seen as

critical by the coaches. This first-order theme had three second-themes: Knowing the player, Principles of

4.5.1 Know the player

Getting to know the athlete as an individual was seen as very important:

"…my coaching philosophy is to really get to know that player, whoever they may be, get to know them as an individual, how do they learn and then really find out what their unique X factor is and look to enhance that… understanding how your player learns and understanding them is crucial before you start to intervene in any way" (Coach 13).

"I think when you're coaching fast bowling just understanding that actually you know nothing until you know the athlete. That's the most important thing" (Coach 17).

"… you've got to know the person as well. It's not as simple as just seeing what they deliver; I think you've got to know a bit more detail as you work up through the ranks" (Coach 9).

4.5.2 Principles of communication

The key principle of communication was to keep things as simple as they need to be for bowlers to understand:

"I try I try not to feed this information to them because you know the old biomechanics things could kind of blows our young lads out of the water and you lose them quite early" (Coach 2).

"You've got to be able to describe it and keep your language extremely simple, so they get it. Because if they don't get it, they're not going to get it, and they're not going to realise" (Coach 19).

Coach 19 suggested an ability to relate enabled communicational processes:

"Yeah, so I think that's for me is the, I have this weird knack of being able to relate to people in that type of stuff, and I think it's really important as a coach is you've got to be able to put it across to people. You've got to be able to describe it and keep your language extremely simple, so they get it. Because if they don't get it, they're not going to get it".

To understand players better, Coach 6 insisted on saying less and asking questions more of his players:

"Too much of talking is bad coaching…. Because you know what, when I talk much, I'm not letting the guy speak. He's going to have questions; he might have answers to his own questions. It is easier to ask him what, I should always encourage the bowler to solve his own problems. So rather than giving a straight answer probably I'll ask questions. I'll let him speak. So, if you're saying why am I bowling outside leg style, I'll ask him what do you think? What did I tell you to bowl the ball in the right area? So why would the ball go outside leg stump? So, he might come up saying my head is falling, or my non, he might come up with an answer, and try to encourage his answer, and try to get an answer out of him only, rather than giving him a straight answer. And I think in that process he'll start thinking more, and he will also visualise and understand what I am telling him. But if the answer is coming straight from me as the coach, it will not register the way it will register if it comes from his own mouth".

4.5.3 Coach-player relationship

The relationships that coaches build with their bowlers was seen as instrumental to their work:

"… my relationship with my player is absolutely paramount. So, I have to get to know my cricketer, my player, whoever I'm working with. I have to know them inside and out, they have to know me inside and out, they have to get that trust and then I have to know how they learn. I have to know how they, you know, some people like to do, some people like to see it, some people like to talk about it, so understanding how your player learns and understanding them is crucial before you start to intervene in any way. Then we try and work out from an end goal in mind, so what am I coaching and why am I coaching them, what are they wanting to achieve, what's their goals, what's their aspirations, you know, is it a performance gain, is it a physical gain, what are the reasons for why you would want to come in and help this player. And then put all that together, sit down and then come together with a really good plan that's in synergy with the player and make sure that they are very, very happy. It's their plan that you're helping them with, it's not your plan as a coach, you know, and then work on that and know that it's not going to be one linear line either, you're not going to just keep improving, you could regress somewhere down the line, but understand that whatever you're going to do with this particular player you're on the journey all the time with them, you're not just jumping in just for a little one-stop drop here and you're certainly not coaching for your own benefit, you're coaching for the player in itself" (Coach 13).

Coach 17 agreed with the essential aspect of a good coach-athlete relationship, particularly when it comes to giving coaching interventions:

"… they need to see evidence that there's a different way of doing it, or a better way of doing it or something will help them. And again, that comes down to relationship. So, if I don't have a relationship that's strong enough with the bowler, I can't say no that's wrong".

Coach 3 also saw that there was a need sometimes for the coach to understand a player's needs and to 'sell' the process of change:

"… it's also about selling the, the process and the understanding of what they need to do to the player, and once they actually see some improvement then you get a lot more gravity, as far as engaging in that program and really pushing the boundaries".

Coach 14 also discussed the need for player 'buy-in' to what the coach was suggesting:

"… first, you'll have to get the athlete buy into it. If you're going to work with someone, they have to know that I see something that I think doesn't look correct and they have to agree as well. If they don't not agree it's a waste of time trying to do the work. That's the first thing. You both agree and you come up with an action plan".

Coach 10 agreed, and used the building of the relationship, as a way of knowing what to work on as a priority with his bowlers:

"I always believe you need to have that strong relationship with a player first. What they want, do they want, are they just obsessed with pace, because you've got to know what you're working with first, because I think it's always mind over body. If they're hell-bent on bowling pace, then I think you've got to help them in that direction; otherwise, they're always going to resist bowling with what they think is line and length".

Coach 12 saw his role in the relationship as not just being about developing sports skills but also personal development of the players:

"…it's not just coaching fast bowlers, it's coaching people, you're trying to make them become the best person they can be… how they deal with adversity, whether they're coachable, whether they're up for the challenge, like I say, whether they're resilient, whether they're robust and just if they're a decent lad, if they're a team player".

4.5.3.1 Decision Making Power

A lower-order theme that came across clearly from the coaches was in relation to who had power in the decision making within the relationship.

All coaches reported being athlete-centred in their approach, and this looked at the who had decision making power.

Coach 16 looked to offer the bowler ownership of decisions that were made:

"I'm very much a believer of I don't know exactly what it might be, but I think we've got to be prepared to go and try some stuff and allow the athlete to make a decision. Hey, here's some options for you, why don't we work through some stuff, and you decide what's best for you. And if you're happy with that you can go with that, and if you're not then we'll find some other way to do it. so that's part of me as any coach, you've got to be prepared to go and make mistakes and try some stuff, and learn some stuff, and ultimately make a decision because it's easier if the player owns (it)… *So, all I do is, there's some things that I work on, but I'd never try to pigeonhole people into you must do this or that. I look at their action specific to them. Talk to them about what they do, how they train, and offer them stuff to make them be as good as they can be"* (Coach 16).

Coach 14 looked to work collaboratively when making decisions around action plans:

"As I said first, you'll have to let the athlete buy into it. If you're going to work with someone, they have to know that I see something that I think doesn't look correct and they have to agree as well. If they don't not agree it's a waste of time trying to do the work. That's the first thing. You both agree and you come up with an action plan. How long do you think you're going to take to do this? How many reps a day, how much time a day? And then we work from there".

Coach 16 expanded this point further by looking to give his players several options:

"I mean I'll always have an idea of what it might be, but I'll offer some options. I think it could be this. It could be this, which one do you want to try first? And you'll generally get a player who tries to have a go, I don't like that. And so, if I just, to me if I set my ways on this is it, and it doesn't work, I've got nowhere to go. And I can't push that agenda on a player because they'll get the shit. So, I try go well look, here's a range of stuff, why don't we try some things.

And I think if a player than picks up on something that they like you can run with it. Ultimately if it doesn't work, you can always come back to something else anyway".

Coach 17 also saw collaboration in the decision-making process as a key requirement in his coaching. However, he wanted the bowler to lead the process and then work from there:

"All of those things are dependent on the bowler… The bowler dictates them…But ultimately you need to, they need to see evidence that there's a different way of doing it, or a better way of doing it or something will help them. And again, that comes down to relationship".

Another area of the coach-athlete relationship that sat alongside decision-making was responsibility:

"You're not going to influence change; you're not going to have massive change over technique and you're not responsible for their performance. Not their good performance. You can be more responsible for their bad performance than you are on their good performance" (Coach 17).

Coach 17 also felt that there was an environment in some coaching relationships where coaching interventions, and in particular technical changes, were seen as a must-do by some coaches:

"And I'm always really suspicious of coaches that want to make lots of change, because I'd like to know what the agenda is, but that's just my I guess cynical side… There's an absolute necessity, or there's a perception of necessity for coaches to change something and that's not always the case… So, I think there's, if we do a lot less, we're doing a lot more from a coaching point of view. But some, there's just that necessity to change something, which is the bane of my existence".

Coach 13 also saw this as an issue:

"I think don't try and justify what you're doing as a bowling coach just because you feel like you've got to do something. If it ain't going to affect change to a positive and you ain't going to help that person positively then don't bother saying anything".

The age and experience of the fast bowlers being coached also had an impact on the power relationship of who made the decisions:

Coach 6 gave an example of how he would be making most of the decisions with a novice:

"So, if he can put the ball in the right area, I would see how many times he could do it out of 10, if he can put the ball in the right area say out of ten, four to five, I'll be happy as a novice. So, if I see how he's adjusting, so I just need to, I mean, three little things. I would probably work with his running technique, or probably a little bit with his loading, probably a little bit with his release, because if he wants to put the ball up towards the batsman, his fingers need to be up towards the sky, so little things. But I would make things easier for him, and whatever I feel needs to be changed".

Coach 16 agreed with the need to make most of the decision with novices, but that this these changes when working with expert bowlers:

"Look I think you can be more directional with a complete novice. I think the thing about an expert fast bowler is the very best will understand the mechanics, they'll understand what worked for them, and they'll almost be able to, they're just looking for some advice".

This linked to Coach 15's point earlier that expert fast bowlers only tended to use the coach when things were not working so well, as a motorist does with a mechanic regarding their car.

Finally, Coach 13 saw the power of an athlete-centred relationship, to be able to make the decision to refer his players out to other expert coaches:

I think the biggest learning I learnt was from Toni Minichiello, who was Jessica Ennis's coach, and he did a big conference on change and there were about 700 coaches in the room, and I always remember him saying do you coach for yourself, or do you coach for the player, he said, and I'll explain what I mean. Jessica couldn't hurdle, she needed to hurdle to win the gold medal and I'm not a good hurdling coach, he said but I've got a brilliant relationship with Jessica, so I got the very best hurdling coach in in the world to help her and I backed my relationship with Jessica to know that I would not lose her, because the only person important for me is my athlete and my player. And that really resonated with me that because I may not have all the answers and I may not have certain parts of bowling technique or certain parts of bowling I might not know, so I am very, very happy to bring other people in, because I'm (a)

very secure in my own skin and the only person that matters is my player and I work on that basis really".

4.6 Other factors

There were a series of other categories that impacted upon the coaches' approaches to coaching. These were split into two further second-order themes: *Scientific knowledge* and *research, and Other coaches (mentor/mentee).*

4.6.1 Scientific knowledge & Research

An understanding of the technique in fast bowling was seen as an essential part to how a coach coached fast bowling, and that this technical understanding came from understanding biomechanics:

"Yes, I think technique is extremely important, but then for a coach I would say understanding the whole concept of it and understanding the whole idea of fast bowling in different aspects is extremely important… I got a lot of knowledge from studying and I did have knowledge through a few books that I read. Books nothing to do with cricket but it was biomechanics for coaches, it was an American book, and in it there was a lot of examples of different sport, of force generation, of balance and stability and things like that. And over a period of time employing that knowledge into cricket, understanding the concepts of bowling and understanding how important balance and the stability during your run-up and your action status are important" (Coach 5).

Coach 16 also valued the use of scientific research to increase his knowledge, and the use of biomechanists conducting analysis to get greater details about his bowlers, particularly in relation to injuries:

"… I think it's reading, watching stuff. I've read a lot of studies on fast bowling…

… And then when you're having a look at certain injuries or continued injuries, I think you've got to take it a level up and go for that scientific analysis to make sure that what you think is absolutely right, and then you're in a position to make some changes… the eye or the video doesn't always tell the full story about what's going on with a bowler's body".

Coach 15 had a similar influence for biomechanics which impacted on the content he delivered in his coaching:

"So I started out trying to teach the staff, I met a professor from America called Ken West who was a professor of biomechanics and I met him and he worked across about 40 different sports and he didn't, know cricket at all, I met him, spent some time with him and he took me on a further journey and said listen, you know, if you get these guys into these kind of positions they will bowl faster".

One of Coach 15's worries regarding coaching fast bowling is a lack of connection with the sport science and biomechanics empirical literature in the education of coaches:

"… one of the biggest disappointments for me, and this includes the ECB to an extent, is our coach education system does not cover this subject at all. Good luck finding out about anything to how to bowl fast in any of the levels, it just doesn't exist…I do get slightly disappointed when we don't cover these subjects which other sports cover. And all other coaches know this stuff in their sport. We are in the dark arts of fast bowling. I have to say that. We are in an area where no one seems to know very much at all".

This lack of knowledge is further exacerbated by coaches being recruited into roles based on their credentials as a player rather than their coaching knowledge and abilities:

"But most coaches now tend to be appointed because they're very popular with the players and they're probably ex-cricketers who are mates with the team and they're not really technicians. I don't think they're technicians at all; a lot of them are not. And that's not because they don't know how to coach, it's just because I don't think that's where they are as coaches. If you speak to quite a lot of ex-big fast bowlers who have got many, many more wickets that I will ever get, they will say well I'm not a technical coach. I don't think I've ever heard an interview where a coach says yes, I'm a technical fast bowling coach, I've never heard that in my life. I've never heard it, just don't hear it" (Coach 15).

4.6.2 Other coaches (Mentor/ mentee relationship)

The coaches in this study both had mentors and were mentors to other coaches, coaching fast bowling.

Coach 20 talked at length about having a former fast bowling great and a coach as his mentor:

"So, then it happened, associated with Dennis Lillee…. We start a very good rapport, and then he shared all his experience with me, and then he allowed me to go to Australia and learn from the other experts. And then I learned a few things, and then by working with Dennis Lillee I learned a lot of things. Then I really enjoyed this fast-bowling coaching, because when I was young there was no coaching available, at least it should be available to everyone, aspiring cricketers in India… He was a role model for so many fast bowlers.".

The evidence-based approaches used by his mentor, then became the coaching approach that he followed:

"So basically, in India there was no manual available for us, because first time it came when Dennis Lillee came. He brought the manuals to us. This is what is, because getting it from Dennis Lillee from the horse's mouth… So that is how this fast-bowling coaching has evolved in India and all over the world."

Coach 8 also used the approaches of a mentor as a framework for his own coaching:

"… a lot of my philosophies around fast bowling is the mental side of the game. My other mentor through (A County) *is* (A Coach)*, and he's massive on that, he's very old school in that response, so I hope he wouldn't take offence to that if I call him old school, but every type of coaching possibly has its place in fast bowling. And I've certainly learnt a lot from him in terms of what, just your general mental approach to bowling, how that can affect your action and ultimately your results".*

Coach 13 acted as a mentor for other coaches, and in doing so set out how he wanted fast bowlers to be coached by other coaches:

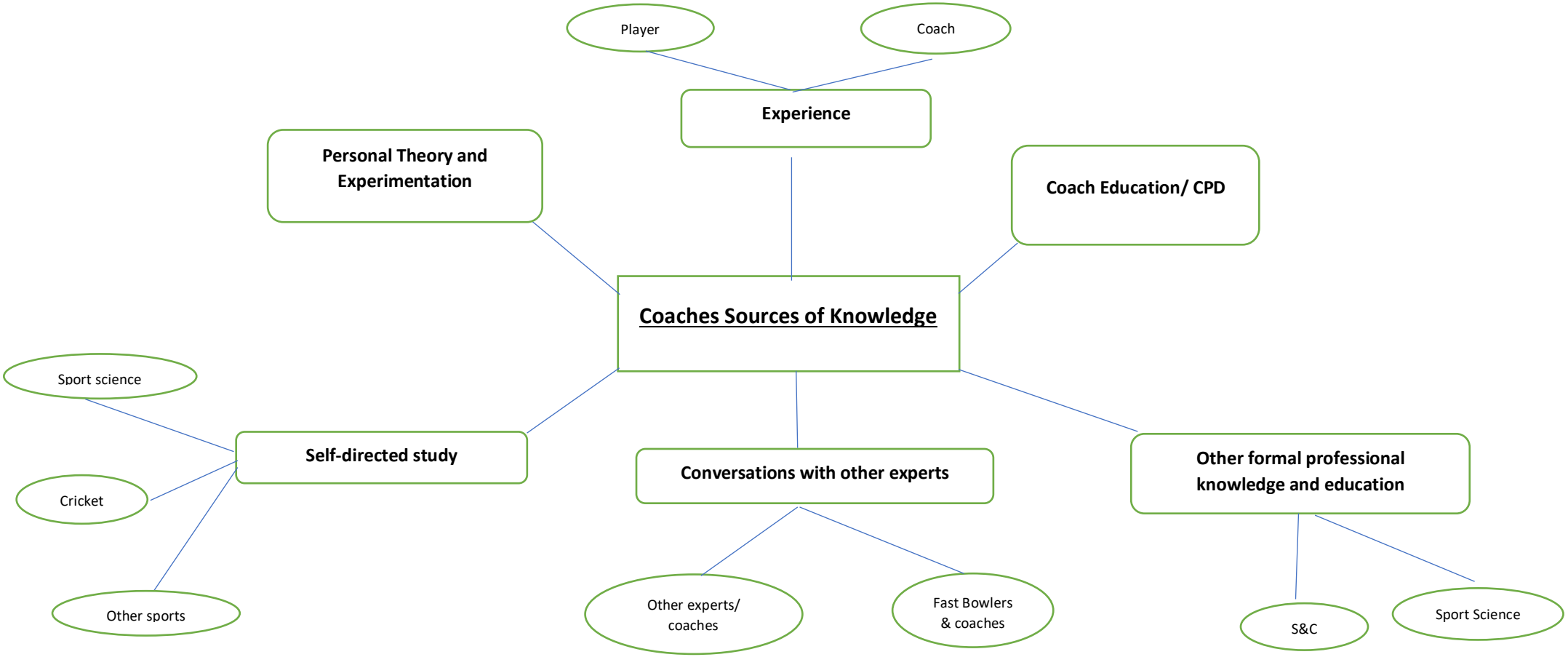
"So, I'm having to now not just coach, I've got 16, 17 bowlers across from 12 through to 17, so that's not including the academy, and with the best will in the world I can't look after 16, 17 players properly, so I need to be able to help my coaches come through too. And so, it's educating them well and making sure they've got the right information and supporting them".

Summary:

There were many factors that impacted upon how coaches approached the complex task of coaching the fast-bowling technique. Coaches had to consider their own philosophies and

beliefs about coaching, and about fast-bowling; they had to consider the development of the player mentally and physically as well as technically to bowl fast. Coaches had to consider the coaching environments that they wished to create and the interventions that they were going to use. They needed to undertake in-depth analysis of the bowlers, using the key questions of '*why?', 'how?', 'what?',* and '*when?'.* Coaches had to negotiate and consider their relationships with the bowlers and the factors that impacted upon them, and finally coaches looked to use current knowledge as well as studying further, whilst also using other coaches as mentors and sometimes being mentors to other coaches themselves.

Figure.9 Thematic network of the coaches' sources of knowledge



5. Results 3 - Coaches sources of knowledge

The third area of this study was to de-construct the coaches' sources of knowledge, that is, how did they know about the fast-bowling technique and how did they know how to coach it?

Six sources of knowledge (first-order themes) were identified by this cohort of coaches: *Experience, Coach education/CPD, Other formal professional knowledge and education, Conversations with other experts, Self-directed study,* and *Personal theory and experimentation.*

5.1 Experience

By the far the most identified area of knowledge gain for these coaches was through their experience. Two second-order themes were identified in experience; namely experience as a player and experience as a coach.

5.1.1 Experience as a player

Within this cohort, eighteen of the twenty coaches had played cricket at a minimum of First-Class Professional Level or International Level, and all but one of these coaches had done so as a fast bowler.

That lived experience as a fast bowler was seen as a key factor in their knowledgebase:

"…how do I know this to be true? Well, personal experience!" (Coach 13).

Coach 19 noted a lack of high-quality fast bowling coaches around, so he was forced to learn through trial and error himself as a bowler:

I think I've just got a real passion for fast bowling and technique. And I think through my own career when I actually got to (first class team) *there wasn't really a lot of good bowling coaches around. So, I think that just drove me from, just mainly it's just trial and error".*

Coach 3 reported similar:

"(Knowledge gained) *From personal experience myself. Yeah, having the ability to run 100 meters in 11 seconds flat and being able to bowl at a reasonable pace where guys were playing in the yard and bowled against indoor… … I think it was just a case of what I've*

experienced and also learning from what other people have done. I think it's just… you've got a natural eye to actually identify how people move and what you can do to make them better. And then also, the skill that you had as a bowler, what…what worked for you and what worked for others".

Coaches 6, 16 and 19 both acknowledged a similar learning experience as a player (fast bowler), but in addition also noted that the coaching that they received and the conversations that they had with other players, also impacted upon this learning:

"I think it's your own experience…. Talking (to) *other fast bowling coaches. Just picking up tips and things that they do. And then I think it's coming to your own, I suppose your own philosophy of how you want to coach or see the best way to coach someone. So, ultimately, I had my own experiences having gone through a heap of injuries, and rebuilding, and so there's things that worked and didn't work. And I'm a massive believer going through that and trial and error"* (Coach 16).

Coach 19 noted the importance of receiving good coaching as a player (fast bowler):

"…when I first started, I got coached so well, and I was very lucky, and I was fully aware of those different parts of those techniques in terms of being coached".

5.1.2 Experience as a coach

Experience as a coach, was a significant factor for many of the coaches. Coaches 1,3,4,7,9,10,11,12,15 and 19 all acknowledged the role of learning through the experience of coaching itself.

"I think it's just from years and years of coaching people" (Coach 19).

Coach 15 talked at length about his "journey of self-discovery" in the 1980's as there were no fast-bowling coaches in the professional game in the UK. He then used this approach to teach other, learning how to create drills as he went along:

"…how do you then do the drills that go with those things, like how do you keep your front leg straight, how do you drag your back foot, how do you delay your back arm, how do you have shoulder, hip separation. And I had to work that out. Because if I'm coaching a young lad I can't just say to him, you're lifting your back foot off the ground too soon like a spinner,

and he'll say well how do I change it? I go I don't know. Because if a dad's paying me £50, £100, £75 an hour he's going to say well you better know the answer because I'm paying you… my coaching journey has been driven by necessity. And I'm not saying that I am correct or right on all of these things, but under challenge and scrutiny a lot of it appears to make common sense, and when you're coaching you need to have common sense and have a set of tools that actually work for your client. So that's where I've got to where I am today".

While there have been many great strides in improving coach education in cricket, it appears that some of the coaches are gaining knowledge through the experience of coaching, as they have very limited knowledge on gaining their position:

"I went to (First Class Team) as a bowling coach, didn't really have a clue what I was doing, so the first year was basically tactical, realised there was probably a little bit more to it than that, second year worked a bit more on the technique" (Coach 12).

"I'm only six years in, so I'm a novice coach still. Very lucky to be in the situation I am. It can feel and it can look really scary at times. I think fast bowling is definitely one of those, because you're looking at people and out of all of the cricketers that you get, a high percentage of the long-term injuries you get are fast bowlers" (Coach 11).

Coach 9 also identified that how, through his experience as a coach, his knowledge increased, and his coaching practices and approaches changed and developed:

"*As a novice I would very much be along the 'is it safe, is it straight, can they, from that action can they actually deliver the basics that they need to progress?' Whereas as you progress through the ranks, I think you accept certain idiosyncrasies which appear in actions. So, I've got 10 bowlers in a pack here, every one of them is very different. I've got guys who are very technically correct, but I've got guys who,* (player)*'s a perfect example… Very low, falls away, was one of the best death-bowlers that I've got. I know he can accept that force. So therefore, I'd be happy… again you've got to know the person as well. It's not as simple as just; that he was only equipped to coach the players at an elite level: seeing what they deliver; I think you've got to know a bit more detail as you work up through the ranks".*

While the coaches valued that knowledge that they gained through the experience of coaching, Coach 2 noted that this knowledge was context specific. When asked how he would coach a novice, he replied:

"Honestly, I wouldn't know... Because……I've never really coached a level below where I've been at because I've played cricket at this level and gone straight into the……the lowest I've been with is starting with lads who have just come on the Academy 16-year-old, so….to be honest I've never really even thought about where I would start with somebody who's never bowled before".

5.2 Coach Education/CPD

Coach education was an important factor in the Coaches' acquisition of knowledge, particularly for the English coaches.

Coach education provided a framework for technical analysis, a model to base coaching interventions and a framework for talent identification. Coach Education gave coaches specific knowledge of biomechanics and provided some of these coaches with access to research that they otherwise would not have been exposed. Finally, Coach Education provided the qualifications that gave them licence to practice.

In terms of coach knowledge in relation to the technical aspects of fast bowling, Coach 1 referred to *the model that had been used as part of his Coach Education:*

"…there's a lot of it from the ECB with the fast-bowling matrix…if your level four qualified coach there will be a pace bowling module where they'd run through some of those areas as well. And fairly constant CPDs. So, I'd say the… the fast-bowling group would turn up to Academy directors meets or you know, certain coaching CPDs and they would run and that's predominantly how they get the message down".

Similarly, other coaches had gained knowledge through their formal coach education:

"Having done level 4, and having been on the biomechanics module, and believing that the doctors and the professors they are, and I guess going along that scientific route, the biomechanical chain" (Coach 12).

Coach 8 saw the value of formal coach education for future increases in his knowledge and skill base:

"I'm fairly new to it all, the biomechanics is something that I'm still a little bit off, but I'm about to start my level 4, which I'm hoping will be a big learning curve for me in that department".

In particular, the information gained on Coach Education courses was seen as a central aspect of technique analysis and a framework for coaching interventions to be designed around:

"So, if you look at some of the stuff that the ECB look at and in terms of a lot of pace attributes, or pace factors they will look for, they talk about bowling arm delay, they talk about heel strike. They talk about delivery stride, they talk about shoulder angle, release trunk flection, releasing knee angle…

For me it's a simplified version of the points that the ECB and this is slightly outdated to be fair, but I think it's still very relevant for the things that they will look for in their fast bowlers in particular (Coach 7).

When Coach 1 was asked how he would go about coaching a novice, replied:

"I probably go through that fast-bowling matrix".

This information also formed the basis for Talent Identification for some of these coaches:

"So, there are quite a few things… quite a whistle-stop-tour of that matrix. But what that does do is it does allow you to do is talent ID within the fast-bowling area, probably more than a lot of the other areas in cricket. Because you can look for these attributes, you can almost predict speed. But what it doesn't do is tell you if these bowlers are going to be necessarily world class bowlers with the result that they're going to get." (Coach 1).

Formal coach education also allowed coaches access to research that they may otherwise not have seen:

"If you look at the some of the research that has been done by the ECB, you can have a look at some of the fast-bowling matrix. Now the fast-bowling matrix is very good. And most of the guys that bowl fast if you like, have a good amount of those traits, if not all of those

traits… It (The ECB Fast-Bowling Matrix) was essentially designed looking at the most successful fast bowlers in history and looking at things that they all did. And that gave us an indication as to where the speed came from….

…And the researchers say 'get their head going over the front knee', they're less likely to get injured" (Coach1).

Finally, formal coach education qualifications provided coaches with 'licence to practice' i.e., made them a qualified coach, that otherwise they would not have had:

"I think one's experience as a player could help them to be a good coach, but does not qualify you to be one, so I have to, in order to coach it's important to study science to understand coaching. And so that set the journey and I completed my level 1, 2 and 3 in India. Level 2 was taken by the Australians and even level 3" (Coach 5).

5.3 Other formal professional knowledge and education

Four of the coaches in this study had expertise and formal professional knowledge, that they used in their coaching practices and to understand the fast-bowling technique.

Coaches 7 and 14 had a formal qualification of a Sport Science Degree. Coaches 9 and 10 had professional qualifications in Strength & Conditioning, which they used to structure S&C as a supportive element to the technical work that they did with their bowlers.

5.4 Conversations with other experts

Expert coaches used conversation with other experts to further enhance their knowledge of both the technical aspects of fast bowling as well as approaches to coaching practice. They used expert others as a sounding board which aligned closely to what Culver & Trudel (2008) calls a 'Community of Practice'. The experts fell into two second-order themes (categories), cricket experts (the fast bowlers themselves and other fast bowling coaches, and experts from other fields.

5.4.1 Other cricket experts/coaches

Expert coaches looked to others to share information, ideas, and knowledge. For Coach 6, this was a continuation from a process adopted in his playing career:

"…you're discussing, and while you're playing with your experience, you're discussing with other good cricketers around, you try to filter out those traditions and take those good ones, and which did work for me, I try to pass that on. And I think playing cricket and working with certain people, certain coaches, you have that knowledge. I'm not saying that I have the best knowledge, but it's still entirely relevant, which works for me, it may work for somebody else, but that is where I see the coach needs to be open about it".

The idea of an open and sharing environment for expert coaches was also suggested by Coach 1:

"… cricket is a pretty open game. So other counties have a pretty good at sharing information. The majority of them have the goal to produce cricketers for England. So, sharing information and chatting about all sorts of areas of bowling is also a good resource" (Coach 1)

However, for Coach 1, this did not mean that coaches accepted or used all the information provided:

"…but the best way to do it is to gather all the information whether you agree or disagree with people".

Coach 4 saw the value in conversations with both expert fast bowlers as well as expert coaches:

"…a lot of it is conversation with coaches, and conversation with people who've been in the field, conversations with fast bowlers. You know, you find your conversations with fast bowlers who understand their craft quite well. You know, they've gone through the journey, and they try to make changes and adjustments in their bowling actions. Some have done it successfully some of them have failed and then it's very interesting to talk to them about why they think they were successful, why they think they failed. You know…What were they trying to change did it work did it not work. So yes, I think one of our conversations with these guys is quite…with fast bowlers… especially the experienced ones…".

Coach 20 worked with a specific former expert fast bowler and expert fast bowling coach:

"We start a very good rapport, and then he shared all his experience with me, and then he allowed me to go to Australia and learn from the other experts. And then I learned a few things, and then by working with Dennis Lillee I learned a lot of things. Then I really enjoyed this fast-bowling coaching, because when I was young there was no coaching available, at least it should be available to everyone, aspiring cricketers in India".

Coach 13 saw those conversations with other experts as an essential part of his learning as an expert coach:

"I want to learn from every other fast bowling coach that's out there. And the batting coaches as well, what do they see? …I've also spoke to a lot of fast bowlers myself. I've spoke to a lot of fast bowling coaches, and I believe I'm a student in bowling and I'm always a student and I always want to be learning."

5.4.2 Other experts/Coaches

As well as experts within the field of cricket, the coaches in this study sort to speak to other experts such as sport science and medical staff:

"…being able to keep talking to good people who work in these areas around all of that, so definitely talking to doctors, physios…" (Coach 18).

Coach 12 saw a particular value in talking to physiotherapists and S&C coaches when working with fast bowlers who were injured:

"…basically, speaking to physios in conjunction with S&Cs, just trying to get their take on it. And if something does need changing, for instance, we work together in the gym specifically to put… to work things to be correct".

Coach 15 sort out expertise from the sport sciences in his quest to understand more about the technique of fast bowling and how to bowl quicker:

"I met a professor from America called Ken West who was a professor of biomechanics and I met him and he worked across about 40 different sports and he didn't, no cricket at all, I met him, spent some time with him…and he took me on a further journey and said listen, you know, if you get these guys into these kind of positions they will bowl faster".

5.5 Self-directed study

Expert coaches looked to enhance their knowledge and practice through self-directed study, which fell under three categories: *sport science, other sports,* and *cricket.*

5.5.1 Sport Science

The knowledge base situated within sport science was seen as important to several the coaches. While a few coaches looked to Coach Education and their National Governing Body for access and interpretation of the empirical literature (see later), Coaches 5 and 18 looked to examine this literature directly to further their knowledge as an expert fast-bowling coach:

"If you really look at coaching fast-bowlers I think what biomechanics has of knowledge for a coach is extremely important. Because I think the basics of the game haven't changed, over a period of time it's been the same. And knowledge of science is extremely important to understand the styles of bowlers… And biomechanics helps you to get that style closer to the basics without compromising on their style…"

This understanding of the importance led to further self-directed study in the area:

"Well, I got a lot of knowledge from studying and I did have knowledge through a few books that I read. Books nothing to do with cricket but it was biomechanics for coaches, it was an American book, and in it there was a lot of examples of different sport, of force generation, of balance and stability and things like that. And over a period of time employing that knowledge into cricket, understanding the concepts of bowling, and understanding how important balance and the stability during your run-up and your action status are important".

Coach 18 saw this search within the empirical literature as an ongoing process so keep his knowledge up to date:

"Basically, through research, so obviously delving into research and it's basically looking at and keeping your eyes open and reading, so there's some good literature available. It's not as widely, it doesn't go as deep as running and all the other things, but definitely you've got some good people at the moment around the world doing some good research, giving you a good understanding of what needs to be looked at, at what time, so at this point in time, so at the

moment that literature research is a good way to check in and make sure that you keep yourself up to date".

5.5.2 Other sports

The coaches in this study looked to other sports for both increase in knowledge and for confirmation that the ideas in one sport were confirmed in another.

As has been mentioned earlier, Coach 15 gained experience in the USA in Baseball (pitching) and track & field (javelin throwing). From here he took several ideas from that context and applied it into his cricket coaching:

"I do remember the pitching coach at one of the teams, which was the Philadelphia Phillies, I ended up spending a couple of weeks with them, and he said you've got a very powerful throwing arm, but you don't just throw with your arm, and I said well what else do you throw with? He said you throw with your legs. And I remember thinking how on earth do you throw with your legs? And I had this crazy image in my mind, and he said well no, it starts from the base like a rocket taking off, it starts in the ground and then you have the ground force reaction that goes through the body, through the hips, through the upper body, thoracic spine, into the top and then release the ball. And this was being taught, we're going back 40 years nearly, and I'd never heard of these phrases or words before, but it was very matter of fact. And when I spoke to other pitchers and they said yes but that's how you throw, you have to learn the technique of throwing. And I thought no one teaches you how to throw and no one teaches you how to bowl".

While Coach 15 used concepts from other sports, Coach 17 looked to other sports to see if there was any confirmation of the principles that he was coaching in cricket:

"If you look at all the martial arts, if you look at anything, if you grab the head you have control of the body. So, if you can and the thing is as well is your feet and your body can go in a different, if your head's not going in a certain direction like if your head stays neutral, your arms and legs can go in a certain place. But if you lead with the head, if the head leads the movement, the rest of the body has to follow".

"I think that's something that sort of comes over a period of time with the experience of playing games and also watching other sports and what the best players and the best people

in those sports how they do things and what they need to do… so…it's not one… one cap fits… everyone" (Coach 3).

5.5.3 Cricket

By far the strongest area of self-directed study for the coaches, was of cricket itself. This self-directed study was generally focussed upon observing and analysing the current and former greats of fast bowling at the highest performance levels:

"Just on having watched a lot of plays and how efficient they are, and what makes them… the bowler that they are…. So, you know, going back to the even back when Dennis Lillee was playing the way he approaches…you know Jeff Thompson yeah just studying a lot of… …. different bowlers and the way they did it" (Coach 3).

In addition to the academic/empirical literature referred to earlier by Coach 18, he also looked at observing expert bowlers:

"…watching the history of the game as it's unfolded…looking at the history of the game, looking at actions that have held together, so yeah, so your own internal research definitely would complement the research and development".

In addition to observing experts in action, and studying empirical literature, Coach 10 studied work published online by another expert fast-bowling coach:

"I've read quite a lot of work from Steffan Jones, who you will know. I'm really intrigued by his work. I think he's on the cutting edge of fast bowling. I think he's worked it out and I think his work needs to be followed and needs to be looked into. And I think it's only a matter of time before he starts churning out fast bowlers. So, he works quite closely with, he's got a webpage called Cricket Strength, I think Dewar from Worcester, they work together. So, I follow his work, I've read about his work. Before I was reading his work I was intrigued with fast bowlers, and I always had a curiosity for it, and I think I stumbled as I tried to learn about fast bowling, and I was applying the things to myself as well. So, it was a lot of trial and error, but the only work which actually makes sense to me and leaves me with no further questions is Steffan's work. And he also combines it with the S&C, which I think is basically the same skill. You can't have a fast bowler without having a very good athlete and vice versa".

5.6 Personal Theory and Experimentation

For the coaches in this study, personal experimentation and building their own theory of both the fast-bowling technique and coaching it were important factors in increasing coach knowledge:

"…just mainly it's just trial and error…

…So yeah, just been lucky that over the years I've had the trial-and-error experience of being a private coached" (Coach 19).

Coach 15's career in coaching was built upon in his own personal experimentation as a player and through the influences of other sports and biomechanics experts as discussed in the previous sections:

"But when I tried these other sports and they said listen there's a technique to this, I thought we should be teaching technique. So, in the '80s and '90s I went out on my own and said listen, I'm going to start teaching people to bowl faster…

… And then as you know since then Loughborough's turned into a fantastic university and centre of excellence for developing and looking at the scientific side of stuff. So, we are now getting more scientific information. The problem we have is what we do with it, because it's not very user friendly at the coalface to talk about eccentric load-ups or clear pathways to a nine-year-old. And when I started my coaching journey, I thought how do I want to be coached if I was a student? And if I understand that terminology, I cannot use it with my students because they don't understand it, it makes no sense….

…So, I had to come up with a framework. And it's not a blueprint for success but it's a guideline, and the framework I called the four tent pegs, which were the four common positions that we all share, which is back foot contact, front foot contract, ball release, follow through. Now that's not new, it's been around a long time, but I did spend quite a bit of time looking at that stuff. And over the course of about 14 or 15 years I probably worked with more than 1,000 students, one-to-one, because that's what I set out to do, and I kept notes from everybody. And one thing I realised was I was looking at this stuff. They were making very similar mistakes all of them. They crossed their feet over, they'd bend their front leg, they'd lift the back foot too early, they were pulling their arms on the wrong foot or whatever it was, and there's a

common thread of about 13 things they were doing. And from that I then wrote my first book which was written in 2002".

Coach 7 also looked to build his own theories, but these were alongside his formal learning opportunities:

I'm starting to see trends in shapes. And this was before I even knew any of this stuff that the ECB speak about. And I was starting to note down well why is this person similar to this person, what are the trends? And you start to see really strong trends coming through. And then when I saw all this stuff it started to make even more sense. But I already had my own simplified version of that, which is what I'm still pretty true to be fair. So, whilst my theory has probably never been scientifically tested on my behalf, I think the fact that this is very data driven, and from bio-mechanists and that science side of things and it fits really well with what I look for, I think it kind of is proven in some respects, in my head".

Coach 2 and his staff looked to take this a stage further by collecting their own objective data to then build plans around coaching interventions and workload management:

"This is come from four years of research really, we've… we've collated all this all this data of workloads, in doing technique and skill base work in the winter, high intensity bowling and building up to a summer of getting the balance right and…erm…it's the first time with you know we've got…five, six years of data in our…what we've done and try to build it up in the right way to go to a summer so it's the second time, but we've got the numbers now and we've also hopefully we've got the right balance with it…"

One of the key messages to come from this question area was that coaches looked to pull all the different elements of learning together, in formulation of their theories and approaches to coaching fast-bowling:

"I don't have all the answers firstly, number one, I would never ever wish to say I do, I am always learning myself. I want to learn from every other fast bowling coach that's out there. And the batting coaches as well, what do they see? … (Learned from) *personal experience, I've done a lot of study, so I've watched a lot of fast bowlers. I've tried to find some common denominators between the very, very best that have ever been. I've also spoke to a lot of fast*

bowlers myself. I've spoke to a lot of fast bowling coaches, and I believe I'm a student in bowling and I'm always a student and I always want to be learning" (Coach 13).

"I think it's your own experience. I think it's reading, watching stuff. I've read a lot of studies on fast bowling, really books from other fast bowling coaches talking about other fast bowling coaches. Just picking up tips and things that they do. And then I think it's coming to your own, I suppose your own philosophy of how you want to coach or see the best way to coach someone. So ultimately, I had my own experiences having gone through a heap of injuries, and rebuilding, and so there's things that worked and didn't work. And I'm a massive believer going through that and trial and error. That's one of my coaching things. The ability to, I think that's what kids do best, I think adults want to see well this is the way. I'm very much a believer of I don't know exactly what it might be, but I think we've got to be prepared to go and try some stuff and allow the athlete to make a decision" (Coach 16).

Summary:

Coaches used several different sources to build their knowledge and skill base in regards of the fast-bowling technique and how they coached it. The source with the greatest influence appeared to be from their personal experiences, with a greater emphasis on playing experience. This was often necessitated as many of the coaches were fast-tracked from playing careers directly into high-performance coaching roles.

Formal coach education formed a strong basis for building coaching knowledge, especially for the English based coaches who referred positively and often to the education provided by the ECB. Some coaches used other formal sources of education such as sport science degrees and professional S&C qualifications, but for many, they looked to gain specialist sport science knowledge, through conversations with experts in those fields.

Self-directed study (non-formal learning) was also used to gain further insight, particularly looking at the techniques of fast bowlers of the past who had been successful. Some of the coaches, particularly those who had held National Lead roles quoted the use of the empirical data to gain further detailed understanding. Finally, the use of personal theory building, and experimentation was used by several coaches, particularly those with international team coaching and National Lead roles.

6. Discussion

The discussion chapter is separated into two parts; Part 1 discusses the answers obtained to the questions posed in the study namely:

- Is there an idea fast-bowling technique? If so, what is it?
- How do you coach fast-bowling?
- How do you know the technique and how to coach it?

The second part will focus on the key implications of these findings to the field of sport coaching. Firstly, the concepts of Epistemological Chain, Experiential Learning and Adaptive Expertise are discussed in relation to these coaches, and to cricket coaches working with elite fast-bowlers. The implications for coaching pedagogy are then explored. How coaches form 'Communities of Practice' that allow them to gain knowledge and develop their coaching practices, and how this process could be engaged with further, follows on. Townend & Cushion (2016) in a study of a similar cohort of cricket coaches, identified issues with coaches engaging with biomechanics knowledge, this is explored here. Finally, the implications of this study for multi-disciplinary teams and for those involved with coach education and coach deployment is explored.

6.1 Discussion of the Research Questions

The first question explored was whether there was an ideal fast-bowling technique and if so, what was it. The coaches concluded that there wasn't a generic ideal, but that fast-bowlers have an individualised ideal. The coaches also suggested that improving/optimising technique wasn't a priority unless the bowler had a technique that was likely to lead to injury.

The coaches in this study, had clear conceptions of what elements did and didn't make up a good bowling technique, and how was best to coach it. This is in line with findings from tennis (Fetisova et al 2021), sprinting (Waters et al 2020; Thomson, Bezodis & Jones, 2009), golf (Smith et al 2012; Smith et al 2015), ice hockey (Mell et al 2017) gymnastics (Cote et al 1984) swimming (Moreno et al 2006) volleyball (Bian, 2003) and climbing (Mitchell et al 2020). In these studies, expert coaches had clear internal models of the relevant sports technique, which was made up of the key kinematic variables identified in the respective

sport-related biomechanical literature. This was no different with the coaches in this study, with conceptions generally fitted closely with those factors found in the empirical literature (Anderson, 2019; Glazier & Wheat 2014). Waters et al. (2019) found similar matchups between the knowledge of high-performance sprint coaches and sports biomechanists in relation to sprinting mechanics.

Each of the coaches discussed the importance of a rhythmical and sequential phasic approach to execution of the fast-bowling technique. A stable rhythmical approach is a keystone of all mature motor patterns (techniques) and has been demonstrated in several tasks such as swimming, hurdling, juggling, and volleyball spiking (Wang, 2010). Interestingly, while coaches discussed the importance of rhythm, at no point did they describe any specific rhythm, suggest a rhythm that was 'good' or 'poor', or any coaching interventions that may improve a bowler's rhythm. Wang (2010) suggests that this is normal for coaches as rhythm is a difficult factor to analyse and to instil in others, even in gymnastic floor routines which have external musical cues to assist the performer and coach. Exploring the rhymical nature of the fast-bowling technique and ways in which coaches may look to use coaching intervention to assist them warrants further investigation.

Coaches had clear philosophies for their coaching practices, which were built around individualised approaches. Coaches also believed that game performance was a greater priority to them and the players than technical execution of the skills. Coaches also discussed the need for players to understand game requirements, and when different technical variations were best executed. However, coaching practices with the fast-bowlers appeared to centre around the use of drills. While some coaches did mention creating game-like scenarios for these drills, little discussion or explanation was given as to how the coaches hoped that development from these drills would transfer into games. Both Roberts (2011) and Renshaw & Chappell (2010) explored the issues that cricket coaches faced when trying to implement pedagogical approaches differing from the usual 'drill-based' approaches with cricket coaches, citing that those coaches often lacked a strong pedagogical understanding and found these approaches 'take longer' than traditional approaches.

The jury is still out in terms of *how* and *why* coaching practice has an influence on subsequent game performance (Nichol et al, 2019). However, it would be interesting to

explore if there are any noticeable technical differences for bowlers when coached using drill-based approaches verses constraints-led approaches, to see at least, if there is a more effective approach to coaching fast-bowlers.

The coaches also had quite varying paths to gaining knowledge within these areas, with coaches displaying knowledge across the broad spectrum described as the epistemological chain (Collins, Collins & Grecic, 2015). The coaches used several different approaches to source further knowledge but were spread between formal and non-formal learning opportunities It should be noted however, that it was the UK based coaches who referred mostly to coach education and formal education routes as knowledge, sources, which is in line with Ji et al. (2021) findings with Chinese sports coaches. This contrasts with non-UK coaches, who discussed more non-formal approaches used, similarly to previous studies in this area (e.g., Carter & Bloom, 2009; Gonzalez-Riviera et al., 2017).

6.2 Discussion of the implications

The results of this study have clear implications for the field of sport coaching and its academic study. The second part of this chapter will discuss the implications of these finds in relation to six key areas:

1. Epistemological Chain, Experiential Learning and Adaptive Expertise
2. Coaching Pedagogy
3. Communities of Practice
4. Biomechanics knowledge
5. Implications for multi-disciplinary teams
6. Implications for coach education and coach deployment.

6.2.1 Epistemological Chain, Experiential Learning and Adaptive Expertise

Coaches had to make decisions about their coaching practices that align with the professional judgement and decision-making literature in general (PJDM - Abrahams & Collins, 2011), regarding the structure and content of their coaching practices.

Coaches had to negotiate the tricky boundaries of their coaching context and professional environment, the relationship status with their athletes, the needs of their bowlers and their current understanding of coaching and biomechanics.

Crowther, Collins & Holder (2018) discuss the link between epistemology and PJDM in cricket, and in particular the Epistemological Chain (Grecic & Collins, 2013). Cricket offers coaches many unique challenges, not least their being three clearly distinct versions of the game itself (first class and test cricket that lasts 3-5 days; limited overs cricket or 50 overs a side which lasts around 6 hours, to T20 cricket which lasts around 3 hours). All versions have with them differing aims and objectives, offering different tactical and technical options, some being more widely used in some formats than others, for example the bowling of 'Yorkers' (a full delivery aimed to land near the crease and a batters' feet), is much more prevalent with T20 than the longer formats. As pointed out by coaches in this cohort, these differing deliveries, when repeatedly bowled can have an impact on the bowling technique. Coaches also had to have a grounding in the technical aspects of bowling and associated information from the empirical biomechanics' literature, adding yet further complexity to their decision-making processes.

Coaches also had to unpick the nature of their coaching environment and the working relationship with bowlers. For example, Coach 4 worked with bowlers for only a short period of time depending on which national team the player had been selected for. This was markedly different from the full-time coaches of the UK who would work with the same set of bowlers all year round.

These complexities of the sport and context within which these coaches worked, not only demonstrated the need for high quality PJDM, but it also demonstrated that there were clear differences in coaches' knowledge and experiences, and in their epistemology. Epistemological beliefs have an impact on the understanding a coach has how those coaches use their individual expertise in practice (Özturk, 2020). Epistemological beliefs are fundamental to a coach's Epistemological Chain (Grecic & Collins, 2013). Perry (1968) suggested the spectrum of knowledge from naïve to sophisticated lie in an understanding of the multiplicity and ever evolving nature of knowledge that becomes personalised:

1. Acknowledges absolute knowledge handed down by authority

2. Acknowledges differences of opinion that are the result of poorly qualified authority
3. Acknowledges uncertainty as temporary
4. Acknowledges relativistic knowledge as the exception to the rule
5. Acknowledges absolute knowledge as the exception to the rule
6. Apprehends the need for personal commitment in a relativistic world
7. Initial commitment is made
8. Exploring commitment
9. Acknowledges commitments as an ongoing, complex, and evolving process

Fig. 9 (Adapted from Perry (1968).

This commitment to a personal theory was seen in the work of Entwistle & Petersen (2004) when examining the conceptions of learning and learning preferences of university students. Here they noted the jump between a concept of learning related to relativism to that of a Committed relativism, where learners took a personal stance about a subject area (Crowther, Collins & Holder, 2018). A similar jump appeared to happen with coaches in this study. This was particularly observed with those coaches who were a National Lead Coach. These coaches had a clear, committed theory of practice, of both the fast-bowling techniques and how to coach them. These personal theories were based on extensive personal research (formal and informal) as well as personal observation and reflection. This was notably different from some of the less experienced coaches who looked to the governing body coach education and CPD opportunities to gain further knowledge and insight.

While we would expect coaches to lay on the spectrum somewhere between naïve and complex in general, when looking at the coaching of elite bowlers, who's potential earnings, as cited earlier, could compound into the millions of pounds, or conversely nothing (Wigmore & Wilde, 2019), the demands placed upon coaches to make appropriate decisions, based on the best possible evidence and practices becomes highly critical to those that they coach.

Coaches demonstrated the need to not only repeat good practices (routine expertise) but to also to adapt to novel situations and build the appropriate decision-making capabilities to deal with this. This is what Berry (2020) defines as *adaptive expertise* and aligns closely to

PJDM models (Collins & Collins 2012), which also call for problem-solving skills to cope with the complexity of the coaching environment. It is clear from this study, that while no measurements of adaptive expertise were estimated, the coaches in this cohort fit across a spectrum of adaptive expertise. It is also clear, that more robust and complete models of coach decision making are required, if we are to get to the heart of what it is and what differentiates the more expert coach (Lyle & Muir, 2020).

Many of the coaches in this study were fast tracked from a career as a player, straight into high-level coaching, a common practice across many sports (Chroni et al, 2020; McMahon et al., 2020; Mallet, 2010). It appears almost expected that coaches within the first-class and international structure will have been elite players themselves (Townsend & Cushion, 2017). While these coaches will hold much contextual experience and knowledge from their elite playing days, there will be much lacking in regard to coaching, as pointed out by Coach 12, who stated that, initially he worked on the tactical side of the game as it was all he knew; Coach 15 suggested that this was common practice for many coaches, to focus on the tactical aspects of bowling as they do not have the technical knowledge anyway. The impact of this could be serious for bowlers who would benefit from technical intervention, but who have a coach without the required knowledge and skill-base.

Other than a lack of knowledge in certain areas, another area of impact can be that coaches tend to coach the way that they were coached, with the potential to pass on inappropriate or even damaging coaching practices (McMahon et al., 2020). McMahon et al. (2020) noted that elite athletes are often fast tracked into high-performance coaching roles as it is believed that they will quickly gain player respect and understand the sub-cultures existing in these environments. However, it is the understanding of these sub-cultures and recycling of these culturally entrenched coaching ideologies that are problematic: *"The recycling or perpetuation of culturally entrenched ideologies is problematic given that many forms of harassment and abuse have come to be normalised in sporting contexts"* (p.265). While there was no discussion of practices that could be seen as harassment or abuse explicitly discussed by the coaches, that is not to say that there were no coaching practices that are less than optimal to the performance and health of fast-bowlers or even injurious. Further work needs to be done to ensure that coaches are choosing coaching interventions that are evidence-based rather than those copied and recycled from past experiences.

Experience was seen as an essential part of learning and development to these coaches. This has been mirrored by many coaches, across many other sports, who identify that experiential learning is often their primary source of knowledge (Mallet, 2010). This aligned with the views of pioneering educationalist John Dewey, who championed the essential elements of experience in learning (Day & Newton, 2016). Dewey believed that learning takes place from experiences and reflection of those experiences (Dewey, 1902), and that learners must be actively involved domain-related activities (Dewey, 1938). Dewey also saw the importance of reflection, as a rational and purposeful act to derive learning from this inquisitive thinking, and it is this reflection and inquiry that leads to further experimentation, formula building and testing of those theories (Day & Newton, 2016). It is clear from this study that some of the coaches were heavily involved in reflection of their experiences, to build personal theories of coaching, which they then tested and re-built, depending on their results and reflections. It is also clear that some of the coaches, while operating at a similar level within the professional field, were not yet operating in this manner, and more likely re-employing familiar approaches that they had done previously or experienced from coaches when they were players.

Clearly, players being coached by coaches at different ends of the above-described spectrum, will be receiving potentially very different coaching environments and content. If we consider that traditionally fast bowlers experience significantly more injuries than any other role in cricket (Anderson 2019; Arora et al 2014; Glazier & Wheat 2014), if we do not change the approaches taken to coaching fast-bowling that have traditionally occurred, we may never be able to change the number of injuries occurring in the fast-bowling population. There may be no relationship between the quality of fast-bowling coaching and fast bowler injury, but if we do not raise the level of learning and understanding in our coaches, we will never know how much impact this could have on the career longevity and performance levels of fast bowlers around the world.

Coaches used the idea of building experiences, reflecting on those experiences, and allowing their fast-bowlers to build and test their own theories within the areas of fast-bowling. While many referred to working with expert fast bowlers who had their own theories and approaches, coaches appeared to facilitate practices for these fast bowlers to experiment, providing feedback as an external pair of eyes'. There was little evidence given by the

coaches to suggest that they sought to engender this type of reflection and theory-building in their developing fast bowlers. For Dewey, this would mean the coach acting as a facilitator, developing problems for the fast bowlers to solve, and creating environments that develop curiosity (Day & Newton, 2016). That is not to say that these coaches did not do this, but that there was very limited discussion of this in their approaches to coaching fast-bowling.

The coaches in this study had a vast wealth of personal experiences, most of which as elite performers, especially in the domain of fast bowling. So, while many useful experiences were there within these coaches, scaffolding to support these coaches in their reflection and theory-generation from those experiences and reflections, especially those new to coaching role, was not always evident, but very much needed.

Cronin and Lowes (2016) are among several academics calling for the use of experiential learning within coach education. This learning should not only engage the learner but also affect future actions. This learning should also occur within the domain that the learning is to be used (e.g., coaching professional fast bowlers within a first-class UK County Club setting, or International Cricket Academy), and not in the often simplified and decontextualized surroundings of much coach education (Jones et al. 2012). Clearly there is room for the use of experiential learning theories to support coaches working in this area, especially those who have been fast-tracked into coaching roles with little or no experience as a coach prior to their employment, so that they may make better sense of their experiences within this change in roles.

While some coaches went from being elite players into elite coaching, others moved into grassroots coaching first. Coach 4 had a particularly interesting journey as he was an elite player as a batter and occasional wicketkeeper, never a fast bowler. Coach 7 started as a performance analyst and junior coach and moved into elite coaching. This non-linear route to their current position matched the findings of (Phillips et al., 2010) who showed that across several sporting domains, the road to expertise was not a linear one, but an equally individualised and non-linear journey, best explained from a dynamical systems perspective.

Knowledge gain, particularly of the supporting sciences such as biomechanics came about through differing sources. For some coaches (e.g., Coaches 7 & 14) they attended formal

sport science courses, whereas Coaches 5 and 15 undertook study of biomechanics under their own initiative. Many of the coaches talked about speaking to experts in other domains, while Coaches 16,17 and 18 spoke about the use of the empirical data in their work. Finally, the UK coaches, talked of the value of information being passed down from the England Cricket Board, both on formal courses and further CPD opportunities.

There are clearly differing levels of support with biomechanics, for these coaches, even though they are all working with players performing at some of the highest levels of the game. So, while it would appear from this cohort of coaches that at least one governing body (ECB) provided useful knowledge and guidance, this was clearly not the case across the board; and this is not to say that the situation in the UK answered all the learning needs of the coaches. It is clear to see that there was a large spread across the epistemological chain between naïve and sophisticated coaching knowledge.

There was a desire by some of the coaches to take an experimental 'trial and error' approach. This might be where formal coach education and University/academic (HEI) based coach education could offer much, in the way of research and investigative skills and knowledge. If coaches had further research and analytical skills, they would be better placed to ensure rigor within their own investigations. HEI based collaborative coach education could also be a gateway to allow coaches to better access the empirical literature pertinent to their needs. Alternatively, partnerships between national governing bodies of cricket and HEI's may allow greater dissemination of the empirical literature into professional coaching practice.

This study also further adds to Greenwood, Davids & Renshaw (2012) position of the value of expert coaches' experiential knowledge to inform the academic field. They point to the benefits that experiential knowledge may add to the empirical field by using the experiential knowledge of elite coaches to support and enhance empirical research processes, provide direction for future research, assist in the representative design of empirical research, and highlighting limitations of some empirical research protocols and findings (p.411). Nimkulrat, Niedderer & Evans (2012) concur further, and suggest that this experiential knowledge can help further understand studies of practice as well as in practice and for practice of coaching:

"Expertise and connoisseurship can support the production and communication of knowledge from research into, though, and for professional practice" (p.11).

Coaches in this study were keen to involve further study and identified areas of the technique that they would like to see further analysis of, as well as to test out some of their own personal theories. Collaborations of this kind would clearly be beneficial for and welcomed by all parties.

6.2.2 Coaching Pedagogy

The pedagogies reported by coaches in this study appeared to be heavily biased towards using drill-based practices. Drill-based practices are often criticised within the literature, for lacking an environment representative of competition (Pinder et al, 2011). It could be argued that as fast bowling is a closed and self-paced skill (McMorris & Hale 2006), drills can be appropriate in some environments. However, it was pointed out by coaches that often game formats and contexts change rapidly and in formats such as T20, bowlers must observe and react to the batter's pre-delivery movements; this making bowling a more 'open skill' than maybe previously considered. Open skills call for more consideration of representative design (Robertson et al, 2019; Renshaw et al., 2019; Chow et al., 2016).

However, some coaches did infer more sophisticated practices, including either game related practices or had implicit learning in their design. Overall, however, there was little discussion of a range of pedagogies, and there was no approach given that was then linked to skill acquisition, or at least the coaches model of skill acquisition. Coaches clearly prioritised individualisation of analysis and intervention and suggested that differentiated practices were a large part of their coaching pedagogy. However, without an understanding of pedagogy or skill acquisition, coaches prescribed further individualised drills. While this would clearly impact positively on coach-athlete behaviour, it may not be the optimal approach for technique enhancement or improved performance. The implications of this are clear, that coaches need further development of their pedagogy and skill acquisition knowledge and skillset, if they are to fully engender evidence-informed practice. If skill acquisition and pedagogical theory had a stronger position in coach education and CPD courses, coaches could enhance their coaching practices accordingly.

Jones et al. (2012) discussed the use of pedagogical theory and application with a Higher Education based coach education cohort. Coaches were given different pedagogical approaches and theory bases on a week-by-week basis for the coaches to apply in their own coaching practice. They reported that the coaches were positively engaged and *"were generally stimulated by and, hence, generally positive about the pedagogical approach experienced. This was specifically in terms of better ordering the knowledge they had as well as developing new insights about coaching practice"* (p. 313). This study further advocates the need to expand coaches' knowledge of pedagogy and skill acquisition to improve coaching practice. This maybe another area where NGB's and HEI's could collaborate for mutual benefit and development.

6.2.3 Communities of Practice

Creating communities of Practice and other forms of social networks proved to be a valued method of coaching learning and development in this area.

Coaches formed these different social networks in different ways, depending on the location and experience of the coach. For many of the coaches based in the UK, they had a ready-made network of CPD opportunities and coaching networks to gather and discuss ideas around coaching. Others, and particularly those coaches who worked in franchise cricket, where they may work with three or more teams in a year, had a network of other coaches that they worked with regularly and so used them as a sounding board for further ideas and development. This matched the summary of Stoszkowski & Collins (2014) who saw coaches use both formal and informal coach networks (including mentoring) to reflect upon and further develop coaching ideas. However, there was little critical reflection or analysis of the efficacy of such approaches. It would appear for those coaches operating in countries with more limited coach education resources, that they were forced to drive their own learning and development processes. One option for some of the coaches for (Coach 5, 15,16, 18 and 20), was to refer to external knowledge holders such biomechanical experts for further advice and clarity.

Some of the coaches in this study also acted as mentors to other coaches. This usually happened within the same team or franchise environments, but less likely outside of those, except for the UK coaches who appeared to have a more open and formalised network.

Mallet, Rynne & Trudel (2021) noted that this does not happen more in professional sport due to the emphasis on winning which may stifle cooperation (p.251).

Coaches also looked to the use of technology and specifically the global access to expertise via the internet to create what Mallet (2017) referred to as Informal Knowledge Networks (IKN) and Networks of Practice (NoP), which were loosely formed groups of people who interacted, usually on an asynchronous basis to discuss ideas and share information, for only brief periods of time. IKN's and NoP's are clearly of use to coaches, particularly those operating in countries with limited formal coach education, however, the need to critically understand such concepts as *validity and quality of the information* provided is quite crucial if coaches are to use appropriate sources of information and knowledge to build their internal models of the fast-bowling technique and their approaches to coaching it.

There were clear implications for the fields of biomechanics, coach education, multi-disciplinary performance teams, and coach deployment.

6.2.3 Coaches' knowledge and its implications for biomechanics

A knowledge of biomechanics is essential for coaches (Arora et al., 2014; Coleman, 2002; Hay, 1994). Without this sound knowledge, coaches do not understand the principles that underpin successful and unsuccessful techniques. As Arora et al. (2014) insist:

"With respect to bowling technique, a sound understanding of bowling biomechanics is necessary prior to the design and implementation of any intervention" (p.3).

This leaves coaches without that knowledge, with three options, 1. *'aping'* the technique of champions, 2. '*Educated guesswork'* using intuition and experience, and 3. Employing a specialist biomechanist (Coleman, 2002). None of which can be considered as effective as the coach having the pre-requisite knowledge and understanding. All three of these options were expressed by the coaches. The coaches varied in levels of confidence and competence in the application of biomechanics, from the coaches who openly admitted to having very little if any knowledge and understanding of biomechanics, through to those with both formal and informal study of biomechanics and regularly working alongside biomechanical experts.

If we consider that these coaches were working at some of the highest performance levels of the game of cricket, including fast bowlers whose career contracts could be worth millions of pounds (Wigmore and Wild, 2019), it is a concern that some coaches demonstrated a lack of consistent understanding, to ensure and enhance biomechanically appropriate techniques. In addition, this lack of consistent understanding impacts the work of coaches at lower levels of the game. If we want fast bowlers using techniques that are biomechanically appropriate to them, the coaching workforce *en masse* needs a far greater engagement with biomechanics and its application.

It was evident that coaches had more familiarity with some of the nine biomechanical principles that Knudson (2007) suggested, more than others. Table 6 gives an overview of the responses given by the coaches in relation to biomechanical principles. It is important here to note that the interviews did not look to un-pick the coaches' knowledge of biomechanical principles, and so this table may not be reflective of their knowledge but what was mentioned while discussing fast bowling technique.

Biomechanical principle	**Coach**	**Examples**
Balance	3, 5, 18	Coach 3 – *"is if he's got a good base, he can change his release point"* Coach 5 – *"I would look at a nice smooth run-up which generates pretty good speed into his run-up. But not too quick, because if you're too fast then you're not extremely balanced at the time of your action".*
Co-ordination continuum		
Force-motion	7,13, 18	Coach 7 – discussed CoM at BFC and its impact on motion going forward. Coach 11 – *"you need to be able to transfer your momentum from the run-up into the ball"*

		Coach 13 – *"If your movement is correct, your forces are going to go in the right direction"*
Force-time	11, 16, 19	Coach 11- *"They talk about I think with a heel strike and a braced front leg and a longer delivery stride, those peak forces don't last for quite as long. So, the peak force is going vertically through the body would still be quite high, but there won't be as long a period of time. So, I think if you look at that, there might be some factors in that."* Coach 20 – "*Follow through is very important actually, it's important because it absorbs the shock basically".*
Inertia		
Range of motion		
Segmental interaction	10, 15	Coach 10 – *"you've got your feet, they will rotate towards the batter, that will start your hip rotation, which is usually quite aggressive, and then working up the chain you get this torque effect which then translates into your shoulder, arm, wrist and back through the ball"* Coach 15 – *"So energy then gets transferred up through the system, through the hips, into the back, release, so the last thing you do is bowl a cricket ball".*

Optimal projection	11	Coach 11 – *"So being able to repeat that time and time and again, and then also to give them the release point, or help them with the release point, give them the most amount of chance to move the ball, whether it be off the pitch or in the air".*
Spin		

Table 6 – Coaches discussion of biomechanical principles in relation to Knudson (2007)

Force-motion, Force-time and *Balance* were the three most cited and clearly understood biomechanical principles. Other principles were hinted towards but not necessarily overtly stated. There was also mis-use of terminology (Winter & Knudson, 2011) with coaches using such terms as *power, force, energy,* and *momentum* when discussing alignment of forces and conservation of momentum.

The point here is not to be critical of these coaches, in fact quite the opposite. Most of these coaches did not have formal education in these areas and have sort to understand these principles through self-directed means. This then, offers the exciting prospect of what an increased understanding of these ten principles could offer to the coaching practices of all these coaches and the coaching workforce in general, and in turn impact the fast-bowling populations of the male and female game, to bring about safer and more effective techniques.

This understanding of the biomechanical principles also relates to performance analysis from a biomechanical perspective (Coleman, 2002; Lyle, 1996; Hay, 1994). The most common method used here was using video to perform qualitative analysis. However, as Coleman (2002) points out, it is often very difficult to pick out the biomechanical principles using this method compared to a quantitative approach and that a sound technical model is essential for use in analysis (p.139).

Coleman (2002) makes a critical point very pertinent to both this study and biomechanical research within the area of fast bowling, that to carry out any form of performance analysis:

"…no biomechanical study (whether quantitative or qualitative) should have been carried out without first identifying the model which is appropriate to the task" (p.139).

Glazier and Wheat (2014) performed a systematic literature review of the biomechanical literature of fast bowling technique to date and proposed a deterministic model for fast bowling that would fulfil some of the requirements of Coleman (2002). However, the deterministic model used by Glazier and Wheat (2014) was built from a proximal to distal perspective, building back from the point of release. The issues with this are two-fold: 1. This proximal-to-distal approach does not fulfil the criteria of a deterministic model set out by Hay (1994), which calls for a clear hierarchical approach of the biomechanical factors most critical for influencing performance and the factors that then impact of each of those in turn of significance. 2. There is no account for the follow-through phase of the bowling technique, which, while not affecting ball release speed, does impact upon bowling performance and is part of the fast-bowling technique. As there is little empirical data and analysis of the run-up, gather and follow-through phases (Anderson, 2019), there is little surprise that they are seemingly absent within the model. Without a complete model of fast bowling, considering **all** phases of the technique, it becomes an almost impossible task for coaches to analyse fast bowling technique and draw any meaningful or evidence-based conclusions with which to base their coaching interventions.

Glazier and Wheat's (2016) deterministic model also only considers factors critical within the delivery stride and does not consider how differing factors involved in the run-up can impact upon these. Previous findings suggest that the key technical elements associated with increases in fast bowling performance (release velocity), are increased run-up speeds, reduced back foot contact time durations, the use of a more extended knee angle during front foot contact and greater hip-shoulder separation angles (Kiely, 2020; Worthington, King & Ransom, 2013). As these are the key factors that predict up to 73% of release speed (Worthington, King & Ransom, 2013), these should form the primary elements of a deterministic model. A final issue relating to the deterministic model proposed by Glazier & Wheat (2014) is that this model relates to ball release velocity only. Fast bowling coaches need a model of the technique that provides skilled output while also minimising the risk of injuries, something that is a long way from being readily available to coaches.

While the coaches had limited understanding of many of the biomechanical principles relevant to technique, they did have some knowledge of the findings of the current empirical literature on fast bowling technique, and their experiential coaching knowledge

and observations have clear implications for biomechanics research in return. For example, although (Burnett et al, 1995; Portus et al, 2000) found no noticeable changes in the fast-bowling technique across a bowling spell or a season, the coaches in this cohort suggested that this was not the case from their experiences. Tactical requirements were seen as the main drivers to alterations in fast bowling technique both acutely and chronically and therefore should be considered. Due to the technical difficulties currently in 3D motion capture, there are no studies recording kinematic changes in game situations. While this is likely to be the case for some time to come, more could be done in research settings to replicate match situations more closely.

Greenwood, Davids & Renshaw (2016) found that bowlers modulated their run-up approach based on the positioning of an umpire before the bowling crease. As umpires are clearly part of a game, and sometimes involved in players (net) practice, there is an implication for having an umpire standing, in lab conditions, to increase the representative design (Araújo, Davids, & Passos, 2007) of any future studies.

The presence of a batter may also impact on the mechanics of the bowler. Coaches saw the batsman as a target area for bowlers to align to, especially when bowling 'yorkers' in limited overs cricket. There are clearly issues around protecting expensive biomechanical testing equipment that also need considering, but by having a batter receiving deliveries from the fast bowler, once again, representative design would be increased.

Furthering the idea of having batters to bowl at when measuring the kinematics and kinetics of the fast-bowling technique, there may be differences for bowlers when bowling at left-handed and right-handed batters. The three wickets (target) have a width of 9 in/22.86 cm, with bowlers usually aiming for the off (outside wicket) relative to the batters, and so left-handed and right-handed batters create different targets, which in turn may impact upon bowlers' mechanics.

Coaches noted that tactical decisions such as bowlers bowling 'over' and 'around' (either side) of the wicket, as well as different delivery types and lengths, all altered bowling mechanics, acutely and chronically, so these should also be considered in experimental design. For example, there has yet to be a recorded study comparing the same bowlers bowling over and around the wicket at the same target; we do not know how the change in

angle may in turn impact upon the bowler, particularly bearing in mind the protected areas that bowlers are not allowed to run into. So, for a right-handed bowler bowling over the wicket, the follow-through will naturally rotate them away to the left and away from the protected area. When the right-handed bowler goes around the wicket, the natural rotation to the left will take the bowler into the protected area.

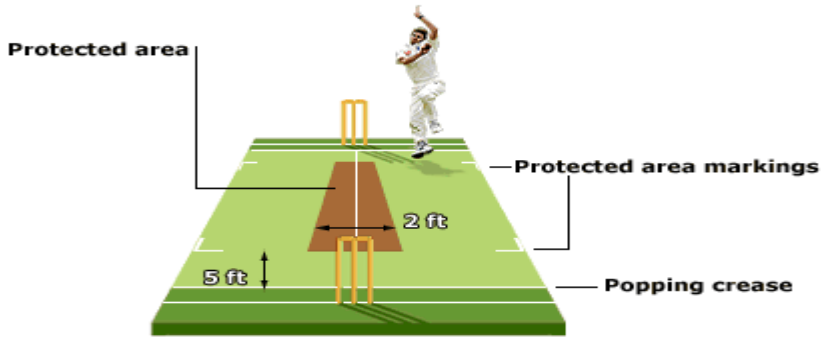


Figure 10 The Protected Area (taken from: https://www.quora.com/What-is-a-protected-area-in-cricket).

Related to this, coaches also noted that different bowlers had different angles in respect to the line that they ran in and the wickets. Again, angle of run-up has yet to be measured in empirical studies, so it is not known if differing angles have significant impacts on the kinematics of the bowler or not.

Finally, the follow-through phase is an important phase according to the coaches, however none were able to give many details as to what they thought this phase should look like mechanically. Anderson (2019) pointed out the lack of coverage of this phase within the empirical literature but provided argument for possible links between this phase and the incidence of spinal injuries within fast bowlers.

Felton, Shine & King (2017) used computer modelling to assess and potentially alter the biomechanics of fast bowlers. The data set used for this has been taken from the research carried out from elite populations. However, as Coach 15 pointed out, these bowlers are elite based on their cricket skills and the outcomes that they achieve and not because their biomechanical technique is either optimal or the fastest possible. This could mean that the 'elite' bowlers used to form these models could potentially have techniques with less-than-

optimal mechanics. The self-organisational elements of sports technique performance are also limited in the construction of these models (McErlain-Naylor, King & Felton, 2021).

In addition to this, all the coaches in this study went to great lengths to point out the highly individualistic nature of the fast-bowling technique. Different bowlers have different heights, limb lengths, mass, muscular strength, muscular endurance, joint stiffness and so on; all which impact upon the technique any individual fast bowler can use optimally. A model, combining data averaged across large samples does not take all these individual differences into account. Studies into the concept of an 'average pilot' when designing the cockpits for fighter pilots in World War 2, draw interesting comparison here. Cockpits had initially been designed using average height and limb length data, only to discover that no single pilot out of the thousands of US air force pilots, fitted these 'average' dimensions (Rose, 2016). Biomechanical research of the fast-bowling technique could be in danger of repeating a similar mistake here. Sports techniques can be considered as idiosyncratic performance solutions (Hristovski et al., 2012). If there is no 'average' and if all techniques are contextually adapted to the specific environment a fast bowler finds themselves in, it becomes difficult to promote a solution ('*technique'*) using models created using other bowlers, averaged out and applied to any other given individual. It must also be recognised that these forward-dynamics simulation models are relatively new to both biomechanics and cricket coaching, and so at best may form *"indicative rather than prescriptive tools within a coaching framework to aid applied practice and understanding"* (McErlain-Naylor, King & Felton, 2021).

It should be noted that while coaches noted findings from the empirical literature, not all their views were supported by this literature. Similarly, to Waters et al. (2019) when discussing the coach-biomechanist relationship, "*these differences revealed areas where the biomechanist can best assist coaches and where coaches can suggest avenues for future research. Working together through the coach-biomechanist relationship that exists in high performance sport can benefit all involved and gaps in knowledge can be overcome to ensure that athletes* (bowlers) *receive the very best support to improve their performance"* (p. 172). This also echoes the call from Woods et al. (2021) who called for a greater voice to be given to practitioner experience, to be considered alongside more quantitative performance analysis methods, to gain better understandings of performance behaviour.

While no attempt was made in this study to elucidate differences in the coaches' conceptions (internal models) of the fast-bowling technique, between coaches, there appeared to be differences in the understanding of the different phases and particularly the *'functionality'* of different phases and body movements. Fetisova et al. (2021) study the difference between expert and novice coaches' internal models of a flat serve in tennis. They found that while there was little difference in the elements that made up the serve, it was the understanding of 'functionality' that separated the expert and novice coaches, i.e., an understanding of the purpose or function that each element of the technique has on the overall performance. Further exploration of this in cricket coaches is warranted.

There are also important implications for Coach Education and continuing professional development (CPD). Biomechanics as both a theoretical base and an empirical source, is clearly potentially very important to the coaches of fast bowlers. There would appear to be differing levels of support from National Governing Bodies (NGB's), to develop coaches in this area and disseminate the empirical findings in a way that is accessible to the coaches. This leaves a challenge for coaches in less well-resourced countries to stay up to date in this area, or for the ICC, as international lead organisation for cricket to look to ways to help develop coaches; possibly through global partnerships with HEI's across the cricket-playing world.

6.2.4 Implications for multi-disciplinary teams

Coaches pointed to individualised technique analysis and interventions, individualised workloads, and individualised S&C support. They also discussed their interactions, with other specialist coaches, physiotherapists, doctors, analysts, biomechanists and S&C coaches. An issue for integration, is often the different philosophies, theory bases and language that is used by each specialism. The scientific and medical disciplines often follow reductionist approaches, which is often not congruent with sport coaching. Without a common language and joined-up approach, there is danger of narrow-sight, eagerness of individual specialists to quantify progress in isolated component, and siloed working (Rothwell et al 2020, p. 55). For these high-performance multi-disciplinary teams to function effectively, they need to coherently integrated (Otte et al 2020). A *Department of Methodology* is suggested as a framework to bring about the required functional integration (Rothwell et al, 2020; Otte et al, 2020). The aim of a Department of Methodology is for the

multi-disciplinary team to work within a unified conceptual framework to (1) coordinate activity through shared principles and language, (2) communicate coherent ideas, and (3) collaboratively design practice landscapes rich in information (i.e., visual, acoustic, proprioceptive, and haptic) and guide emergence of multi-dimensional behaviours in cricket performance (Rothwell et al 2020; p.55).

An ecological dynamics approach is argued to be an appropriate framework to operate a Department of Methodology in. An ecological dynamics approach sees the learner as a wayfinder, interacting with their environments and the tasks, often guided by a knowledgeable other (coach) to greater enskilment (Woods & Davids 2021; Otte et al, 2020). By viewing the bowler this way, coaches look to set tasks that allow the player to find the most appropriate solutions in their environments. It also gives a common language and ideology for members of the support team to work towards. For example, physiotherapists and sport psychologists can work together to create rehab tasks that replicate real match conditions/environments, such as integrating visualisation with rehabilitation exercises, another example could be integrating the work of the S&C coach with the specialist bowling coach using strength training exercises as pre-activation exercise before maximal speed bowling session, or by using variability in bowling-specific resistance exercises and then the same degrees of variability in a technical bowling session. A final example could be the integration of analysts and specialist coaching staff (head coach, batting coach, fielding coach and fast-bowling coach) to create scenarios that challenge the player(s) to come up with innovative solutions.

6.6 Implications for coach education and coach deployment

All but two of the coaches in this study had been fast-tracked from an elite playing environment into coaching with little, if any experience and limited coach education. It is believed that this fast-tracking of coaches from high-performance playing roles affords the individual with social capital, practical sense, and elite sport habitus, leading to greater respect from the players to be coached (Blackett, Evans & Piggott, 2017). Coach 15 suggested that coaches often get the role as Coach as they are popular with the squad of players that they are transitioning from.

However, coaches in this study noted that there initial coaching work was focussed on tactical advice as they did not have sufficient technical knowledge. These coaches worked with players from high-performance junior academies, junior international squads, first-class cricket players and with international players from the initial parts of their coaching careers. As coaching expertise takes many of years to develop and learn (Phillips et al 2014; Abraham 2011) these players could be missing out on technical intervention when they need it most.

Ewing (2019) suggested that one of the reasons for inexperienced coaches getting high-performance coaching roles as key stakeholders may be *"falling prey to the 'halo effect', i.e., overvaluing certain attributes while undervaluing others"* that is, over-valuing playing reputation over technical knowledge. Blackett, Evans & Piggott (2017) in their study of key stake holders in high-performance association football, rugby and cricket clubs found that a coach's ability to gain respect from the playing squad, and an ability to embrace the embodied philosophies of the club, carried far more value than formal knowledge. Blackett (2021) suggests that the *myth* of an elite playing career being an essential part of being a high-performance is growing, creating a *glass ceiling* for aspiring coaches. It also maintains current levels of knowledge and practices embedded within past-held sub-subcultures, without critical introspection. This, in part is why dangerous and abusive practices can continue unchallenged (McMahon et al 2020).

While employing former players may be more appropriate in some sports than others, the biomechanical empirical literature and the internal models of the fast-bowling technique collaboratively constructed in this study, suggests that there are many technical factors involved in the analysis and coaching of the fast-bowling technique, and that knowledge of such is critical to the role of fast-bowling coach.

To understand the complexity of these technical elements Knudson and Morrison (1997) hold that it is essential for any coach to have a grounding in the previously mentioned ten principles of biomechanics, before undertaking any intervention on a player's technique. Employment of coaches without this technical knowledge may be a contributory factor to the high number of fast bowling injuries (Always et al 2021) within the game.

Ewing (2019) found that fast-tracking former elite players into head coaching positions was commonplace in the UK and Australia, especially in sports such as cricket and rugby, however, this was not the case for their counterparts in the USA, where coaches were considerably older (50+ years of age) and had considerably longer periods of *'apprenticeship'* (20+ years) in assistant roles before gaining head coach positions. This was believed to occur as sports team owners wanted to hire coaches with a proven track record of coaching success, and experience to deal with highly paid players (p. 245). Ewing (2019) also noted that most of the Head Coaches in professional sports in the USA had Degree level tertiary educations as their sports systems are based around Colleges and Universities. Head Coach and Fast-bowling coaches have different tasks, with the former looking at overall team performance, selection and team culture, and the latter focussing on player performance and injury reduction (Wigmore& Wilde, 2019). It could therefore be argued that fast-bowling coaches should spend appropriate apprenticeships, building their technical and biomechanical knowledge as well as developing their coaching craft before they deployed in specialist roles.

It is important to note here that we should be aware not to ask too much from coach education. Coach education is expected to cover the technical and tactical elements of sport as well as provide aspiring coaches with an understanding of skill acquisition and sport pedagogy. There are clearly demands to also add a grounding in leadership skills and the sport science disciplines as noted above, while authors like Cushion (Cushion 2011) and Jones (Jones et al 201) rightly point for the need of coach education to understand the sociological and political aspects of coaching, so that coaches may navigate the tricky sociological and political factors involved. If we then also add a demand to understand ecological dynamics so that coaches may lead a *Department of Methodology*, it is difficult to see coach education in its current format being able to cope with such demands, while providing a cost-effective qualification system.

It is noted that to this point, formal coach education has had little impact on coaches' knowledge and coaching practice (Townsend & Cushion 2017). It was also noted earlier in Townsend and Cushion's (2017) study of cricket coaches on a Level 4 course, that many coaches were resistant to new forms of knowledge if it did not fit with their '*self-referenced*'

approaches to practice (p.538). Much of the material mentioned above is likely not to fit with the current coaches many coaches are accustomed to.

The distinction of 'Professional Coach' maybe where national governing bodies can provide a two-tier system that allows for higher demands to be placed on full-time 'professional' coaches (Duffy at el., 2011). Duffy and colleagues argued that the coaching workforce is made up of many unpaid, part-time volunteers and a core of full-time 'professional' coaches. It is these 'professional coaches'. If the licence to practice for 'professional coaches' requires them to undergo ongoing CPD, demonstrating their learning and development over time, with coaches having to demonstrate how they have integrated this new knowledge into their coaching practices, it would be hoped that coaches are more likely to engage with this new 'knowledge'.

7. Conclusion

The purpose of this was to investigate expert coaches' conceptions (internal models) of the fast-bowling technique, how they coached it and how they acquired the knowledge for both.

Coaches have clear conceptions (internal models) of what a fast-bowling technique should look like, and this closely resembled the empirical literature. Fetisova et al (2020) and Thompson, Bezodis and Jones (2009) both suggested that this should be expected from expert coaches, with Fetisova et al (2020) noting that the ability to understand the technique as a whole and the biomechanical principles that underpin it, are the factors that differentiate the more expert coaches. Within this study, it was seen that the explicit discussion of biomechanical principles was varied across the cohort. This should not come as a surprise. There is limited biomechanical content within most NGB coach education, with specifically coaches in the UK getting their first introduction to the topic when they reach their Level 3 coaching award (ecb.co.uk 2021). As stated by Knudson (2007), we must also not confuse attendance on a course covering biomechanical principles, as engagement with and application of biomechanical principles in coaching practice.

A model of a poor technique was proposed, which we believe is that first time this has been done. Having a model of what could be potentially dangerous in a technique allows coaches to cross-reference what they see from their bowlers, and make interventions when issues are identified.

Coaches differentiate their coaching analyses and practices to meet the needs of individual players, with many reporting humanistic models of holistic development (Cassidy, 2010). This individualisation process has implications for coach education and the field of biomechanics. For coach education, they must ensure that coaches are facilitated with skills to be able to differentiate their coaching practices. For the field of biomechanics, comparative studies across bowlers are not appropriate if we are to follow the belief of this cohort of coaches. Each bowler has their own unique bowling technique, and it changes suitably, depending on the game context, match environment and individual contexts of the bowler; biomechanically studies should reflect this. This means more representative design

in experimentation, which ideally, should contain an umpire and a batter as well as a game-like scenario.

The coaches in this cohort followed a non-linear acquisition of coaching knowledge and skills, similarly to those seen in others such as Philips et al (2011) who charted the development of expert fast bowlers. This has implication for coach education, where a 'one size fits all' approach cannot be followed. Some coaches come to the coaching arena with many relevant life skills and additional qualifications (e.g., sport science degree), while others are fast-tracked from playing straight into high-performance coaching roles. It would make sense to have some form of auditing and accreditation for prior learning and experience (APEL) before and during coach education so that a coach's needs can be identified.

There were further implications for coach education and CPD. Many coaches were fast-tracked from their playing careers straight into high-performance coaching roles, while they had, in their own words 'no idea about the technical elements of fast bowling'. Coaches like Coach 12 were forced to focus on tactical factors initially in their coaching to make up for their lack of knowledge elsewhere. This position is further exacerbated if we consider the lack of impact that formal coach education has on the coaching practices of high-performance coaches (Townsend and Cushion 2017). To be put in this position is both unfair to the coach and to the players under their guidance. The complexity of sport coaching was demonstrated within this study, showing that coaches have many different knowledge and skill-bases called upon in their day-to-day job. Coaches require a suitable and expansive epistemology to be able to cope with this.

This then has implications for coach deployment. Key stakeholders are employing coaches based on their records as players and not based upon their knowledge-base, skills, or experience as a coach. By not valuing knowledge-base, skills, or experience as a coach, by making them requirements of employment, it becomes very difficult for those in charge of coach education to demonstrate the need and value for coach education.

One possible solution to this could be formalised 'apprenticeships', where players who are approaching retirement and have identified coaching as a potential future career, could serve an apprenticeship under the current coaching staff. If these experiences are reflected

upon and recorded, they could build towards a portfolio of evidence of learning and development. The use of apprenticeships has been demonstrated to work well in the medical professions across the UK and Europe (Snaden and Thomas 1998). Additionally, aspiring coaches with extensive knowledge and skill-bases, but who do not have an extensive high-performance playing career could be given more opportunities. As noted earlier, there are several high-profile cases of this happening in football with great success.

Finally, we are asking a lot of coach education in its current format, regarding effectively 'educate'/*enskill* high-performance cricket coaches. A greater understanding of the principles of biomechanics is clearly needed for coaches of fast-bowling. A potential solution is to create a new category of 'professional coach' (Duffy et al, 2011), where on-going professional development is a pre-requisite part of maintaining a licence to practice. This then allows coaches, much as in the same way as doctors and nurses, to obtain appropriate CPD as a matter of course. It would also allow coaches many more formal learning opportunities that are not present outside of their initial coaching awards. This approach may also allow HEI's greater opportunities to provide CPD and learning materials that not only enhance knowledge, but also gain criticality and more complexity to their coaching epistemology.

8. **Personal Reflection Chapter – *'From and for the field'***

I am a cricket coach, coach educator and consultant, as well as a former fast bowler myself. This reflective chapter will look upon the first three, and how this research project has and will continue to shape them going forward.

8.1 Coach

I am currently about to complete my ECB Level Specialist Coach Award and become one of only two CIMPSPA Chartered High Performance Coaches in Cricket in the UK. Alongside this doctorate, and other qualifications, this makes me, at least on paper, one of the most formerly qualified cricket coaches in the UK and possibly the world!

This study has made me reflect upon the very different academic and experiential path that I have taken to be where I am now, in comparison to the coaches who participated within my study. The coaches in this study have been exposed to much less in terms of theory and empirical findings, and just generally much less of an understanding of what there is to know, and what at least would be helpful to know.

So, I can put together, considered coaching practices that are far more evidence-informed than much of what is going on at the highest level of the game.

I did, however, learn a few things from the interviews, that I wouldn't have known otherwise. One of the main ones being the idea of periodised technical interventions based on the time of year and franchises/formats of cricket each player is playing in.

The concept of epistemological chain (EC), and the ideas about the complexity of understanding about the 'reality' of coaching, and all the possible things that coaches need to know became quite evident. In particular, the reflection that I have been lucky in my development as a coach, in terms of my academic background, giving me a more complex EC, than the 'expert' participants in this study. This gives me confidence as a coach, and as a coach-educator, that I am on the right track.

8.2 Coach Educator

I have been a coach educator for the last fifteen years, for both the ECB and in Higher Education (HE), working with both cricket coaches and coaches from other sports. The key themes that came from the results, relevant to this was where the coaches gained their knowledge of the fast-bowling technique, and how they went about coaching it.

Sources of knowledge varied across coaches in the group, with UK based coaches relying heavily on information gained on their coaching awards. This was less of the case was coaches from other countries. Only the National Leads looked to the academic literature and to working with experts in other areas such as biomechanics.

There appeared, however, to be a lack of understanding and confidence of biomechanics and its usage. This was seen outside of the cohort, while on the ECB Level 4, and has been discussed by Townsend and Cushion (2017), who pointed to elite coaches' issues with what they classify as 'non-cricket knowledge'. Sport science and in particular biomechanics are considered 'non-cricket knowledge' and therefore less valid in the communities of practice of elite cricket coaches.

By far the biggest sources of knowledge were through speaking to other coaches and using the practices they received as players from other coaches.

The take home message then is that, as a coach educator, I must ensure that coaches feel comfortable to explore how academic theory and empirical findings can improve their coaching practices, and in turn increase player performance. This would normally mean ensuring my delivery of learning material is as good as it can be. However, this has also led me to consider how I can create CPD and other learning opportunities for coaches, so that they feel comfortable to access more difficult learning material. This lies in helping coaches understand biomechanics, as it is such an essential part of fast-bowling coaching, yet these elite coaches are avoiding technical interventions with bowlers, because they don't understand the biomechanics that underpin the technique, and they don't understand the consequences of coaching interventions on the bowlers.

8.3 Consultant

Following on from the observation that coaches don't understand or necessarily value sport science and empirical evidence, I reported my findings of this study back to the ECB's

leadership team in Coach Development. They were very receptive to what I had to say and are keen to pursue how we get better buy-in from the coaches. I then agreed to take part in some videoing for the ECB CA in relation to coaching fast-bowling from a biomechanics perspective. It will be interesting to see how much impact this has – or even what the end-product looks like.

Linking this to my 'day job', I am looking at creating CPD for coaches in general – there is clearly a need for accessible sport science and sport pedagogy for coaches at all levels and across all sports. This is something I believe could become one of my missions of my professional career. I also think that there could be a book in this somewhere – something along the lines of *"How to coach fast-bowling from an evidence base and not myths!"*

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