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Preliminary stages in the validation of a talent identification model in cricket

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Preliminary stages in the validation of a talent identification model in cricket

Ph.D. Thesis

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Thesis Summary

Talent identification is an integral component of the ever-professionalised sporting landscape. However, to date, there is a dearth of high quality evidence upon which to conduct talent identification practice. This thesis represents the preliminary stages in the validation of a talent identification model for cricket. The thesis contains six chapters (four empirical), which examine varying methodological approaches to talent identification, and present initial evidence (cross sectional and longitudinal) of those attributes that may be related to elite success.

Chapter 2 presents two pilot studies examining the reliability and discriminant validity of batting and pace bowling assessments. Varying levels of validity and reliability are found. Some evidence suggests that skill-based differences (between high and low ability groups) become more pronounced after familiarisation / practice.

Chapter 3 presents two studies examining the discriminant validity of scouting, and the most appropriate methodologies through which scouting can be conducted. The analysis documents significant discriminant value in scouting data. Skill-based scouting parameters consistently discriminate between low and high ability groups. Psychological scouting variables are the only data that discriminate between high and very high ability groups.

Chapter 4 presents a longitudinal analysis of performance statistics. Findings suggest that performance statistics may be a valuable talent identification tool. Performance statistics that represent non-traditional metrics (e.g., ability to adapt on entering a new environment) consistently correlated with subsequent performance and are worthy of further examination.

Chapter 5 presents evidence examining relative age effect and maturation across the male and female England Cricket Pathway. The findings suggest that RAEs may be advantageous from a development perspective, with relatively young athletes who remain in the system, becoming overrepresented at later stages.

Contents

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A marriage, a baby, a job, two house moves, other slightly less significant moments, a life or death skiing accident for my supervisor, and the departure of one supervisor to Canada – an eventful PhD – before even addressing academia. Writing this sentence leads me to question the predictability of life, a particularly pertinent question, bearing in mind the talent identification context of the PhD…I digress (a challenge with my writing!).

I can honestly say that I had no idea of the exceptional environments that I was being exposed to on starting this Ph.D. Bangor University had featured on the undergraduate radar, but quickly disappeared with the lure of sports science on the south coast at Exeter. It was 6 years later that an England and Wales Cricket Board (ECB) and Bangor University collaboration drew me to North Wales. Four years on, I can reflect on the most welcoming, positive and supportive environment. Unquestionably, driven by the relaxed, yet focused Sport Health and Exercise Science (SHES) culture, which should be the envy of every other sports science department. Some will reflect on the rather grey, dark and torrential north-Wales days; I will look back on my days at Bangor University with great fondness: memories of social antics with friends and enjoyable hours ruminating with views over the Menai Straits. The SHES Ph.D. cohort cannot go unmentioned, particularly Alex, Caoihme, Rosie, Samantha and Jenny with whom I have shared nights out, dinners in, road-trips and lunch socials. Particular thanks must go to Bell for making my time at Bangor and the ECB enjoyable and entertaining (if a little more expensive on the phone bill, with a foreign departure).

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A quick note for the 'rents'; without a shadow of doubt there is no way on earth that they would have predicted me, their rather 'slow' and highly dyslexic child (who always read 'saw' as 'was' and vice versa) would take on a PhD, particularly over the two brainiac sisters. Still, perhaps it shows what personal interest and persistence can drive (umm…another pertinent thought for the thesis). So, I must thank my parents for their continued support, encouragement and pedantic emphasis on my progression in school.

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Chapter 1

General Introduction

With a growing number of nations pursuing and striving for intentional sporting success, British sport, both Olympic and Professional, has never seen higher levels of investment (De Bosscher, De Knop, van Bottenburg, Shibli, & Bingham, 2009). During this research, the annual cost of one player progressing through the England and Wales Cricket Boards (ECB's) development programme was approximately £25,000. As such, a 4-year programme (U16 – U19), cost the ECB £100,000 per player. With such investment, National Governing Bodies, such as the ECB, strive for an evidence-based approach (Vaeyens, Güllich, Warr, & Philippaerts, 2009) to the identification, selection, confirmation and development of talent. For this reason, talent identification forms a central component of the ECB's strategy.

Whilst coherent talent identification practices in cricket are a relatively new concept, there are a number of applied examples, providing evidence of the value in rigorous, systematic and informed talent identification practices. In 2007, UK Sport initiated a talent identification campaign, Sporting Giants. Through systematic identification, selection and development, this campaign generated multiple World Championship medals and an Olympic Gold medal in 2012 (UK Sport, n.d.). With appropriately informed talent identification practices in cricket, investment in the highest potential players may be possible. This research is an initial step in exploring the utility of talent identification practices in cricket.

Definitions

The field of talent has developed its own terminology that is poorly demarcated and often used interchangeably. For example, Gagné (2000) refers to talent as "the superior mastery of systematically developed abilities" (p. 67), whilst Tannenbaum (1986) provides a diametrically opposed definition, with talent being the potential to become critically acclaimed in whatever field it may be. Gagné is referring to talent as the *achievement* of expertise, whereas Tannenbaum is suggesting that talent is the *potential* to achieve expertise, a fundamental and crucial distinction. It is a semantic argument, however a lack of consensus drives confusion in an already a complex concept.

Definitions of talent have also been embroiled in the perennial, and often polemic debate, of the relative contributions of nature and nurture, only adding to a murky conceptualisation. There is neither the space nor desire to be distracted by such debate, and Kimble (1993) surmises aptly: “asking whether individual differences in behaviour are determined by heredity or environment is like asking whether the areas of rectangles are determined by their height or width” (pp. 13-14). Regardless, academics persist with polemic and extreme hereditarian (Benbow & Lubinski, 1993; Thorndike, 1908) and environmentalist positions (Ericsson, Krampe & Tesch-Römer, 1993). A practical and common sense approach, combined with high quality prospective empirical research will progress current conceptualisations of talent.

Whilst bearing the current limitations in mind, it remains necessary to provide a definition or premise that shapes the direction of this research. Ackerman (2014) suggests “talent is not properly thought of as innate endowment, but rather as a developed set of traits that are integral to the further development of expert/elite performance” (p. 16). In accordance, Williams and Reilly (2000) suggest that talent identification is “the process of recognising current participants with the potential to become elite players” (p. 658). Crucially, both definitions draw on the concept of potential, which is important for a number of reasons. Firstly, research has repeatedly evidenced the absence or, on occasions, negative relationship between junior and senior success (Bloom, 1982; Güllich & Emrich, 2014). Therefore, it should clear that talent is not denoted by current performance, but rather, other variables that relate to senior elite performance. It is only through longitudinal research that a better understanding of what these variables are, might be established. In a related fashion, research on expertise (Gould, Diffenback & Moffett, 2002; Orlick & Partington, 1998) has focused on the distinguishing characteristics of elite performers. Whilst certain factors may discriminate between elite performance, there is little to suggest that these variables are the antecedents of elite performance, something that has continually been misconstrued.

In this way, talent identification concerns the examination of attributes, characteristics and traits, which are *predictive* of future performance, not the assessment of current performance on the basis that it will reflect future success. The only mechanism, by which an evidence-based definition can be provided, is by conducting longitudinal research. However, the difficulty in conducting such work has hindered the development of the extant literature. In time, and with the progression of this, and other similar research, it will be possible to provide an empirically-based definition of talent. To reiterate, the definition proposed here, suggests that talent refers to variables that are predictive of future success, and talent identification, is the methodology by which these variables (if any exist) are elicited.

Existing Models

There is a burgeoning body of research devoted to the topic of talent identification and expertise, with a number of models well documented academically and in mainstream literature (Psychological Characteristics of Developing Excellence: Abbott & Collins, 2004; Long-Term Athlete Development: Balyi & Hamilton, 2000; Development Model of Sport Participation: Côté, 1999; Côté & Fraser-Thomas, 2007; Theory of Deliberate Practice: Ericsson, Krampe & Tesch-Römer, 1993; Differentiated Model of Giftedness and Talent: Gagné, 1991; An Emergenic and Epigenetic Model: Simonton, 1999). However, in general, one or more of three factors limits these models. The models tend to be overly simplistic, overly complex and or, fail to have any empirical basis. As Kokko (2005) suggests, model generation should be akin to generating a map. The map should be designed to help understand the essential features of the landscape and in this way may detail contour lines, rivers etc. However, the map should not detail every undulation, tuft of grass or feature of the landscape. If it did, it would be unwieldy and akin to carrying a full-scale paper model. In this way, models of talent should provide enough detail of essential features, without documenting every possible contributing variable. Talent models should demonstrate an acceptance of key interacting factors (rather than only documenting main effects) and should have some empirical and theoretical basis. Unfortunately, there are no models that fit this simple brief. A critique of two ‘models’, Deliberate Practice (Ericsson, Krampe & Tesch-Römer, 1993) and the Differentiated Model of Giftedness and Talent (Gagné, 1991) will demonstrate the strengths and challenges of such models, whilst demonstrate the rationale for not ‘testing’ such a model in this thesis.

Differentiated Model of Giftedness and Talent (DMGT)

Gagné’s DMGT (1991; 2009; 2013) proposed that the terms giftedness and talent were diametrically opposed, representing two distinct constructs. It was suggested that gifts are biological constructs, “the possession and use of untrained and spontaneously expressed natural abilities (called aptitudes or gifts), in at least one ability domain” (Gagné, 2000, p. 67). Whereas, talent represents the fully developed construct of giftedness: “the superior mastery of systematically developed abilities (called competencies or talent) and knowledge in at least one field of human activity” (Gagné, 2000, p. 67). Gagné suggested that gifts are comprised of six natural abilities, four categorised within the mental domain (intellectual, creative, social and perceptual) and two within the physical domain (muscular and motor control). Within the model, these natural abilities are depicted in their raw form, yet to commence development. Whereas, talents, are categorised more broadly in nine subcomponents (academic, technical, science & technology, arts, social service, administration/sales, business operations, games, sports & athletics) and come about through the systematic pursuit of excellence over a significant period of time (Gagné, 2013). Influencing the development process, are two forms of catalysts, intrapersonal (such as personality traits) and environmental (for example, location, or the influence of significant others), both of which can act in a negative or positive fashion. The final component, chance, is suggested to operate throughout the model. Conceptually, it is a broad model and has met with some approval (Tranckle & Cushion, 2006; Vaeyens, Lenoir, Williams & Philippaerts, 2008).

However, there are two significant limitations. Firstly, there is no empirical evidence that underpins the model. At minimum, some qualitative research underpinning the constituent gifts would be worthwhile. At present, the model offers little beyond Gagné’s personal reflection of gifts and talents. The lack of evidence is clearly reflected in the numerous and significant revisions to the DMGT (Gagné, 1991, 2000, 2013). Secondly, the model is so broad and all encompassing, suggesting that everything affects everything, that, it offers little more than an observation of the real world. A model should offer some way of simplifying, boiling down the essential features, so that one can understand the essential causal factors and differentiate between them and the unimportant ones (Kokko, 2005). At best, the DMGT may provide a 'shopping list' of factors worth considering in talent identification research.

Deliberate Practice

A model, which has received far greater levels of empirical support, is deliberate practice (Ericsson, Krampe & Tesch-Römer, 1993). There is extensive empirical evidence in support of deliberate practice as a key determinant of expertise in chess and music (Ericsson, Krampe & Tesch-Römer, 1993). Whilst well researched, it is worthwhile revisiting because: (i) deliberate practice offers the largest empirically documented body of evidence regarding the development of expertise; and (ii) the central tenets of deliberate practice have been recounted inaccurately on multiple occasions (e.g., Gagné, 2013; Gladwell, 2008).

The deliberate practice framework rejects the notion of talent (or giftedness), suggesting "a monotonic relation between the current level of performance and the accumulated amount of deliberate practice for individuals attaining expert performance" (Ericsson, Krampe & Tesch-Römer, 1993, p. 387). Further, deliberate practice must be optimised within three constraints. The first constraint (resource constraint) dictates "deliberate practice requires available time and energy for the individual as well as access to teachers, training material, and training facilities" (p. 368). Second, deliberate practice is not inherently motivating, depicted by a lack of reward or enjoyment when undertaking practice (motivation constraint). Ericsson suggests that this is regularly seen through a lack of desire to initiate practice spontaneously. Finally, "deliberate practice is an effortful activity that can be sustained only for a limited time each day during extended periods without leading to exhaustion (effort constraint)" (p. 369). It is proposed that individuals must practice to the extent that they can completely recover on a daily or weekly basis.

Deliberate practice itself, is depicted by four characteristics: (i) practice is explicitly directed at performance improvement (rather than developed through play as purported by Baker & Côté, 2006 and Webb & Pearson, 2008); (ii) practice tasks should account for the pre-existing knowledge of the learner and therefore be of adequate difficulty; (iii) participants should receive immediate informative feedback and knowledge of their results; and (iv) subjects should repeatedly perform the same, or similar tasks (Ericsson, Krampe & Tesch-Römer, 1993).

Clearly, deliberate practice has gained significant following, however, this may, in part, be attributable to the meritocratic appeal – the idea that anyone can become an expert – which may have captured peoples imagination (Hambrick, Oswald, Altmann, Meinz, Gobet & Campitelli, 2014). The criticisms of deliberate practice being the sole determinant of expertise are more substantial. In the first instance, there is little empirical evidence that the theory is applicable in sport. In fact, evidence is to the contrary. Bullock et al., (2009) detail how Australian bob skeleton athletes have progressed from novice to world podium level in less than two years, clearly not engaging in extensive hours of deliberate practice. Secondly, when considering the motivation constraint (practice is not inherently motivating), significant and extensive bodies of sport literature suggest the contrary. For example, Helsen, Starkes and Hodges, (1998) found that practice activities of National and International athletes were judged to be highly enjoyable. Hodges and Starkes (1996) have documented similar findings with wrestlers.

Finally, and perhaps most significantly, Ericsson's work fails to document any measure of variance. In the seminal paper (Ericsson, Krampe & Tesch-Romer, 1993) no standard deviation or ranges of deliberate practice for elite players are provided. Therefore, it is not possible to ascertain whether this supposed monotonic relationship exists across all individuals, or, as one would suspect, whether there may be significant variance within groups. Interestingly, Gobet and Campitelli (2007) present similar cumulative average practice hours for master chess players

(11,053 h), however the standard deviation across the group was 5,538 h providing irrefutable evidence that the concept of a monotonic relationship is overly simplistic. Research in chess and darts has documented that deliberate practice only accounts for between 28 and 34 percent of variance in performance (Duffy & Baluch, 2004; Gobet & Campitelli, 2007). It should be clear that the theory of deliberate practice presents a tangible, yet overly reductionist model of expertise. Quite simply, deliberate practice is necessary, but not sufficient (Campitelli & Gobet, 2011).

Empirical studies – limitations

In general, talent identification literature has been plagued by poor quality research. The intricacy of the challenge, combined with the methodological rigour required to appropriately investigate an individual's potential, has hindered progression of the extant literature, leaving a number of enduring and fundamental limitations. Firstly, there has been a primary focus on physiological and anthropometric variables. Whilst there is some rationale for these measures in sports such as rowing (Bourgois et al., 2001; Bourgois et al., 2000) where biomechanical advantage is dictated by stature and arm length, the justification in skill and team-based sports is much weaker. Regardless, talent identification research has continued to assess these factors with non-existent hypotheses. Unsurprisingly, research has found physiological and anthropometric factors to be the weakest predictors of future success in sports such as field hockey, rugby and volleyball (Elferink-Gemser, Visscher, Lemmink & Mulder, 2004; 2007; Gabbett, Georgieff & Domrow, 2007; Nieuwenhuis, Spamer & van Rossum 2002; Pienaar & Spammer, 1998). Meaningful talent identification research should take an informed and broad approach (including psychological-, skill- and tactical-based variables) when examining predictive factors of future success.

Secondly, the majority of research has adopted a cross-sectional approach, examining factors that *discriminate* between ability levels. However, given the definition of talent, "a developed set of traits that are integral to the further development of expert/elite performance" (Ackerman, 2014, p. 16) cross-sectional research offers little in developing understanding of those factors that are *predictive* of future success. It is imperative that talent identification research acknowledges that the characteristics of adolescent performance may not be the same as the antecedents of elite performance (Morris, 2000). Clearly, some cross-sectional research may be informative as initial, or pilot work that precedes longitudinal research, however on its own, it offers little. In fact, standalone cross-sectional research reinforces the concept of current performance over future potential, which has repeatedly been shown to be a poor, even negative marker of future performance (see, for example, Güllich & Emrich, 2014).

Thirdly, talent identification methodologies often draw on polemic and a priori sample groups that fail to address the differentiating factors of elite and sub-elite. For example, in examining tactical skills of football players, Kannekens, Elferink-Gemser and Visscher (2009) compared youth soccer players from Dutch and Indonesian teams, with respective world-rankings of 3rd and 110th. It would be unsurprising to the most lay reader that significant differences were revealed. Other similar limitations can be found in the work of Koon, Wang and Clifford (2011) who compared basketball statistics of the top 10 and lowest 10 ranked teams at the Youth Olympics, with a discriminant function analysis correctly classified 95 percent of teams. Meaningful cross-sectional research should examine the differences between elite and sub-elite, or, those that ‘make it’ and those that just fail to make it.

Fourthly, research in football, gymnastics and ice hockey (Carling, Le Gall & Malina, 2012; Malina et al., 2005; Mirwald et al., 2002; Sherar et al., 2007) suggests that talent identification and selection practices are confounded by maturation status. Typically, adolescent players are grouped by chronological age, which has been seen as an efficacious mechanism for development. However, given that children differ considerably in the rate at which they mature – some children have a rapid tempo of growth and attain adult stature at a relatively early age, whereas others have a slow tempo and finish growing relatively late – categorising individuals in this fashion is erroneous. Between individuals of the same age group, skeletal age (maturation) can vary by as much as four years (Malina et al., 2000). As talent identification practices in most sports occur at given chronological ages, athletes with advanced biological maturity are more likely to be perceived as talented and hence receive a greater level of support, training and opportunities. This can lead to the exclusion of later maturing individuals who may possess, but are yet to express, the requisite skills and abilities (Malina et al., 2000).

On a micro-scale, research has documented how annual age categorisation of players (e.g., a school or competition year) generates systematic biases, with an over-representation of chronologically older players, regardless of gender, sport and sport type (Raschner, Müller & Hildebrandt, 2012). This phenomenon is referred to as the relative age effect (RAE) and, whilst to date, there is little research linking physical maturity and the relative age effect, it is clear that talent identification research cannot continue to ignore the role of maturation.

Given the weighty and extensive limitations in the majority of traditional talent identification research, it would be relatively protracted to provide an in-depth review of the literature, only to conclude with the aforementioned limitations. Instead, the following section details a number of current and alternate approaches (testing, scouting and performance statistics) that may be more productive in the quest to understand an individual's potential. Each section draws on empirical examples (where available) and discusses the relative strengths and limitations of such approaches.

Approaches to Talent Identification

Traditional methodologies

Traditionally, talent identification research has included test and assessment based processes. However, the majority of this research has focused on physiological and anthropometric variables (e.g., Chaouachi et al., 2009; Gonaus & Müller, 2012; Vescovi, Brown & Murray, 2007) or, utilised technique-based assessments, which are unrepresentative of the performance environment (e.g., Ali et al., 2007; Figueiredo, Conçalves, Coelho e Silva & Malina, 2009; Pienaar, Spamer & Steyn Jr, 1998). Some argue "there is a need to re-evaluate the design of performance evaluation tests in talent programmes to ensure that they faithfully simulate the continuous interactions of athletes with their performance environments" (Pinder et al., 2013, p. 805). However, there is also evidence to the contrary, suggesting that relatively static, technique-based assessments do have predictive validity. Huijgen et al. (2009) conducted a six-year longitudinal study assessing adolescent soccer players who progressed to professional and amateur playing status. Those players who went on to become professional soccer players, had executed simple technique-based assessments to a significantly higher standard than those that went on to reach only amateur status.

Quite simply, this debate reverts to definitions of talent and talent identification. Talent denotes the potential of future expertise, and, at this stage, it would be remiss to suggest that more focus in talent identification should be orientated towards the assessment of technique over skill, or vice versa. Rather, more longitudinal work focussing on the predictive validity of both is required. This would mark a substantial progression in the field of talent identification research.

From an assessment perspective, psychological variables have largely been ignored in a talent identification context. In part, this may be attributable to social desirability and self-presentation confounds that are inherent with self-report and interview data collection methods. Regardless, a burgeoning body of research suggests that psychological characteristics of elite athletes may be a key determinant of the senior success (Collins & MacNamara, 2012; Durrand-Bush & Salmela, 2002; Gould, Dieffenbach & Moffett, 2002; Fletcher & Sarkar, 2012; MacNamara & Collins, 2013). Although none of this expertise work was conducted in a longitudinal fashion, Van Yperen (2009) addresses a number of significant limitations with a longitudinal design, post hoc grouping of players, and a broad assessment inventory. Van Yperen demonstrated that psychological factors (goal commitment, engagement in problem-focused coping behaviors, and social support seeking) differentiated between academy players who progressed into Premier League football and those that did not, with a discriminant function analysis correctly classifing 72 percent of players as successful or unsuccessful. (The discriminant function analysis correctly classified 85 percent when including a number of other non-psychological variables).

Scouting

Scouting is the process whereby players are observed in the competitive environment and concomitantly evaluated against a number of pre-defined sport-specific, psychological and physiological criteria. The process is commonplace in American sport (e.g., NHL, NFL, MLB) and widely adopted in football throughout the United Kingdom (Williams & Reilly, 2000). However, relatively little is known about the practices that operate in these environments. Presumably, the lack of published evidence is a product of clubs and franchises wishing to maintain a competitive advantage. However, Williams and Reilly (2000) draw attention to this, calling for greater academic access, such that scientists can examine the subjective and implicit criteria against which players are identified. Given the lack of research in this area, exploratory analysis would be highly innovative.

A likely strength of scouting assessment is the ecologically valid (or ecologically dynamic, see Pinder, Davids, Renshaw & Araújo, 2011) context in which assessment occurs. Recent research (Davids, Araújo, Vilar, Renshaw & Pinder, 2013; Pinder et al., 2013; Vilar, Araújo, Davids & Renshaw, 2012) has called for representative design in talent related assessments: "there is a need to re-evaluate the design of performance evaluation tests in talent programmes to ensure that they faithfully simulate the continuous interactions of athletes with their performance environments" (Pinder et al., 2013, p. 805). Whilst one could argue that performance statistics (e.g., batting or bowling average in cricket) provide the most objective representation of performance, there are limitations to this data. Not least, it is difficult to make comparisons between players because the performance environment is so varied, with players competing in different leagues, age groups, disciplines, and environmental conditions. Arguably, observation of players in the competitive environment (scouting) is the only method through which true representativeness and holistic assessment can be achieved.

In conjunction with this ecological perspective, there is growing consensus that elite athletic performance is dependent, amongst other things, on an individual's motivation (Bush & Salmela, 2002), how individuals cope with adversity (Connaughton, Hanton & Jones, 2010), optimise learning (Gould, Dieffenbach & Moffett, 2002), and persist in pursuit of their goals (Orlick & Partington, 1988). Scouting provides a mechanism through which these psychological variables can be observed, without the limitation of unrepresentative design or self-report bias. Through observation of performance and sourcing of information through informants (e.g., umpires, coaches, sport psychologist and parents) a reliable and valid psychological profile may be established.

Potential limitations of a scouting methodology include an increased orientation towards current performance. As the majority of scouting occurs in a performance context, it would be easy for scouts to be overly orientated towards current performance, rather than potential. A second challenge is in the qualitative nature of appraisal, with scouts possibly biased by their values and individual conceptualisations of talent. Csikszentmihalyi et al. (1993) argue that talent is socially constructed: "it is a label of approval we place on traits that have a positive value in the particular context in which we live" (p. 23). In this way, scouts may be imparting certain socially or culturally valued attributes on the appraisal of players. Whilst this is a valid argument, the use of pre-defined (informed by senior coaches), and theoretically based criteria for scouting, may circumvent or at least reduce bias. It is only through implementing and researching this talent identification methodology that more informed conclusions might be drawn regarding its utility.

Performance statistics

Whilst the majority of talent identification research in Europe has examined test, assessment, or questionnaire based data (Vaeyens, Lenoir, Williams & Philippaerts, 2008), a significant body of research in American sport offers a different approach – the analysis of performance statistics (Carling, Williams & Reilly, 2005; Hughes & Franks, 2004). In talent identification terms, performance statistics provide a particularly novel approach because of the longitudinal data sets that exist. This is especially pertinent in cricket, where statistics have been collected since the 1930's. However, to the author's knowledge no longitudinal examination of this data has been conducted.

In an American context, Berri, Brook, and Fenn (2011) examined the relationship between

College basketball player's performance statistics and NBA draft position, and subsequently, the relationship between NBA draft position and NBA performance. In considering the value of various performance statistics, scoring totals were the primary factor related to draft position, with shooting efficiency weakly related. With game outcome related to possession, rebounds, turnover and steals it would seem that draft selections are somewhat naïve and closely related to the most tangible measure of performance, with disregard for other factors that may be of greater value (e.g., efficiency). In conducting the second stage of analysis (relationship between NBA draft position and NBA performance), Berri, Brook, and Fenn found that points, rebounds, steals, shooting efficiency from two-point range, and playing for a National Collegiate Athletic Association (NCAA) champion were significantly related to an overall player metric, Wins Produced (Berri, 2008). In contrast to the previous stage of analysis, both points and playing for a NCAA champion had a negative relationship, suggesting that scorers in college offered less productivity in the NBA. In addition, rebounds did not relate to draft position, but was related to NBA performance. The authors conclude, "much of what NBA decision-makers consider on draft day is unrelated - or has the opposite relationship - to a player's career performance…less than 5% of a player's career WP48 is explained by where a player is drafted" (p. 33). The problem here is not that the data is unavailable, or that prediction is difficult to make, but rather, it appears that decision-makers are biased by outcome variables that are unrelated to future performance. Conducting similar analysis in cricket, examining the relationship between performance statistics at various stages of development, would be enlightening.

Particular strengths of this approach lie in the availability of longitudinal data sets, something largely lacking in talent identification research. In addition, performance statistics are objective data sets that are impervious to criticisms of representative test design (testing) and subjectivity (scouting). Furthermore, given the extensive and detailed data set, it may be possible to construct new, non-traditional metrics that tap broader underlying psychological or skill-based traits. For example, in a golf context, Finley and Halsey (2004) demonstrated the manner in which a psychological variable, ‘bounce back’ (the percentage of times players followed a bogey or worse, with a birdie or better), accounted for significant variance in predicting scoring average. The finding being suggestive, that better golfers display more short-term resilience. Applying a ‘talent’ orientated approach, e.g., examining factors such as the ability to learn, or the ability to perform exceptionally, if only on infrequent occasions, would be worthwhile, given the narrow manner in which statistics are currently used.

One possible limitation to performance statistics is the lack of comparability of performances across environments. At a structural level, players compete in different leagues, age groups, and disciplines; whilst from an environmental perspective, no two pitches are the same, and players compete against other players varying levels of ability. Researchers in golf (Quinn, 2006), baseball (Acharya et al., 2008) and soccer (Lago, 2009) have demonstrated how performance statistics can be adjusted, or weighted, to account for differences in match location, match status, opposition, and weather conditions. This approach could be adopted in cricket.

Thesis context

Given the breadth and complexity of the thesis, it is meaningful to detail the context in which the research was initiated and has subsequently evolved. In the first instance, research was driven by the ECB’s desire to progress the scientific rigour underpinning their talent identification processes. In this way, the ECB sought academic input from Bangor University in the form of senior academic consultancy and a doctoral student. This thesis represents the first stage of an academically driven 10-year ECB research programme aimed at developing a talent prediction model.

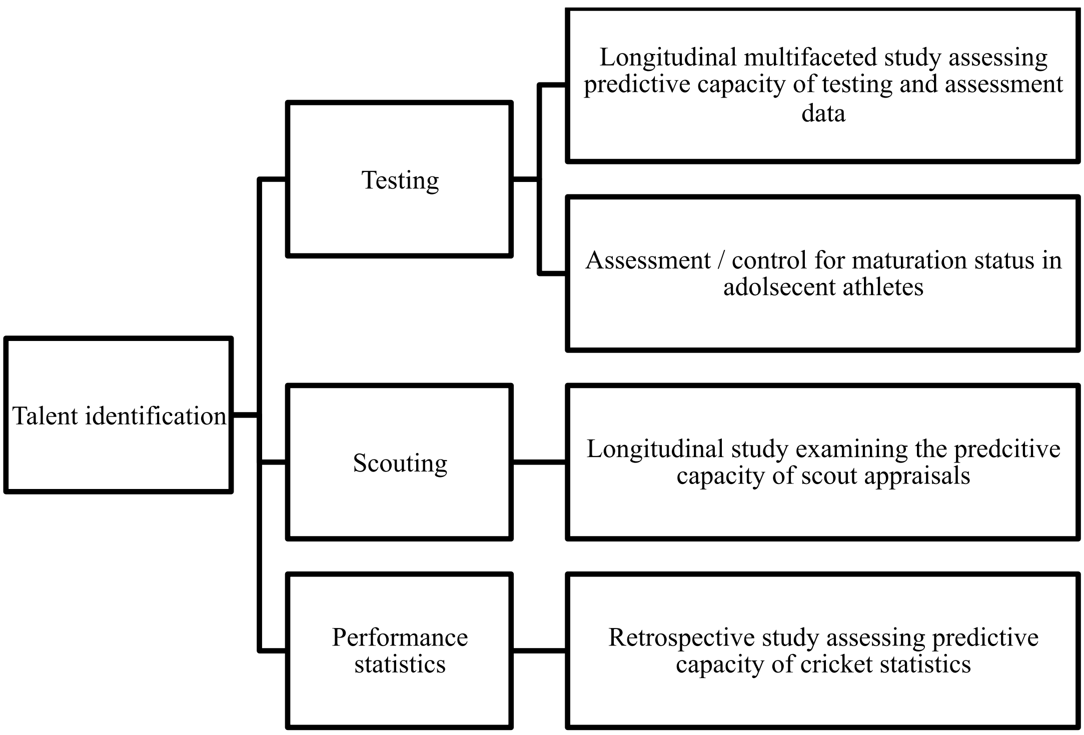
Initial research (year one) focused on the ECB’s existing talent testing framework, the England Development Programme Talent Testing (EDP TT). Preliminary pilot work sought to develop the reliability and discriminant validity of the skill-based assessments, whilst developing a broad and multifaceted assessment framework. During this work, talent identification and basic research principles clearly supported the need to: (i) triangulate data collection methodologies

(Mulaik, 1972); and (ii) ensure that some data collection methodologies utilised representative design (Pinder, Davids, Renshaw & Araujo, 2011). For this reason, in years two and three, the thesis was broadened to develop and examine a scouting methodology, and analyse performance statistics, whilst maintaining the testing framework. In addition, significant emphasis was placed on implementing a robust skeletal maturation assessment (Tanner, Healy, Goldstein & Cameron, 2001). Clearly, given the breadth of such a project, it has not been possible to document all data collection and analyses. This thesis details preparatory work conducted within the testing framework and exploratory analysis of scouting and performance statistics. Subsequent research, will feed off the longitudinal data that has been generated.

At this point, it is worth stating that the project was not solely research owned. The project was completed in collaboration with the ECB; and for this reason there were a number of compromises in test design and scouting form structure. Where applicable, these are documented in the empirical chapters. The following section provides a brief applied introduction to each of the three areas (testing, scouting and performance statistics).

Project overview

Figure 1.1. Methodological approaches to talent identification research



Testing – England Development Programme Talent Testing

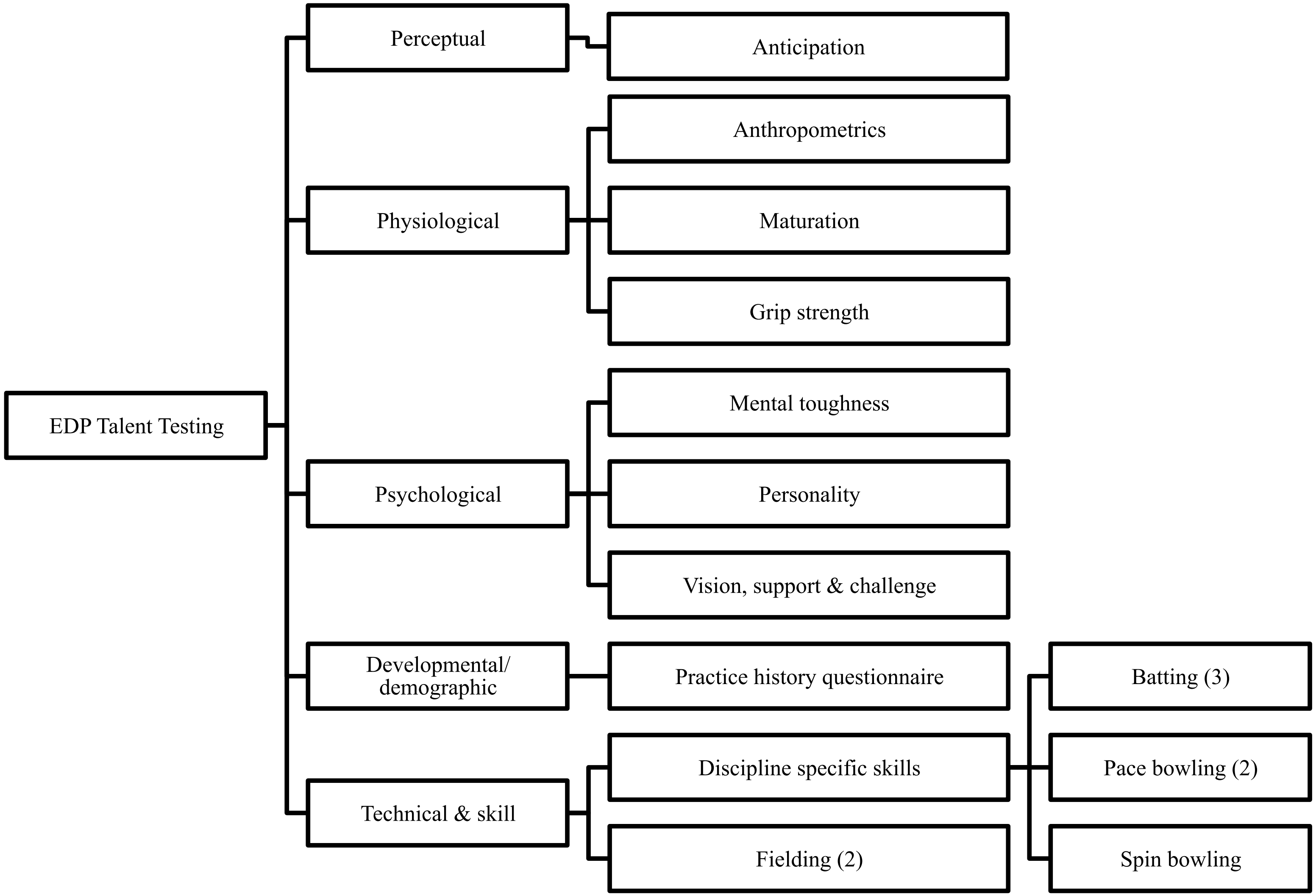
England Development Programme Talent Testing (EDP TT) was designed as a longitudinal project, addressing a number of the previously documented limitations. EDP TT is a broad, multifaceted and longitudinal testing framework, administered to the highest potential U12, U14 and U16 cricketers in England and Wales on an annual basis. The programme assesses and collects informant ratings of players across a range of technical, skill, tactical, physiological, maturation and psychological variables, as can be seen in Figure 1.2.

With such broad assessment, it would be unrealistic to present analysis and justification of all data collection processes in the thesis. Furthermore, given the longitudinal requirement of talent identification research, documenting repeated cross-sectional analyses across multiple assessments would add little to talent identification research. However, given the relative dearth of skill-based assessment literature (reliability and discriminant validity of skill-based assessments), significant emphasis was placed on this. The research detailed in chapter two, documents the preparatory work in constructing, modifying and selecting skill-based assessments that may have predictive validity in a longitudinal study of cricket performance.

Scouting

England Development Programme (EDP) scouting was implemented in 2011 and has since been conducted on an annual basis. In the first instance, it was an ECB owned project aimed at ensuring meritocratic selection for the U16 EDP. Chapter three focuses on pilot analysis of scouting data from 2011 and 2012. With little peer-reviewed analysis on the topic of scouting, the data sets provided opportunity to examine two broad questions. Firstly, what variables: skill-based, psychological, or physiological, are of greatest discriminant validity in differentiating between player abilities? (In time, predictive analysis will be conducted on a longitudinal data set). Secondly, what is the most appropriate method to scout and gain accurate player appraisals? This question was constituted as a number of sub-questions which focussed on the value of indoor versus outdoor scouting, the value of scouting players on single versus multiple occasions, and, whether

Figure 1.2. Technical, skill, tactical, physiological, maturation and psychological variables within England Development Programme Talent Testing framework



multiple appraisals from the same, or multiple appraisals from different scouts yielded more representative player appraisals.

Performance statistics

In cricket, performance statistics have been collated in a number of databases over substantial time periods. These data sets allow a particularly original approach to talent identification research because of their longitudinal nature. Furthermore, the extensive detail within scorecard data allows novel interrogation of talent related variables (e.g., the ability to learn) that may be helpful in understanding what (if anything) is predictive of future success. Therefore, the aim of chapter 4 was to take a simple approach to the examination of performance statistics in a talent identification context, examining the relationship between age-group and international performance statistics. At this stage it is worth stating that chapter 4 is a simple, correlational and exploratory study, seeking to examine the relationship between performance statistics at varying stages of development.

Contributions

Given the integrated nature of the research (Bangor University and the England and Wales Cricket Board), the following section summarises the contribution from stakeholders (NGB and supervisors), with a specific focus on hypotheses generation and experimental / study design for each empirical chapter.

England Development Programme Talent Testing (EDP TT)

A draft EDP TT programme was in place when embarking on the research, which included a number of skill-based (batting, bowling, fielding), physiological and anticipatory assessments. Coaches and practitioners at the ECB had shaped these assessments. However, they were limited by (i) a lack of academic grounding, (ii) a lack of consideration of the talent identification context (e.g., assessments that aim to have predictive capacity), (iii) poor assessment design, and (iv) poor protocol administration. For these reasons, initial work was conducted by the lead researcher and an advisory team (Professor Lew Hardy; Professor Mike Khan; Professor Bruce Abernethy) examining the ECB's EDP TT framework. In brief, it was concluded that:

- The skill-based assessments had the potential to be problematic. Work should be undertaken with the ECB to examine 'what' was being measured, and what if anything, was the rationale underpinning assessments.
- There was little basis for the extensive physiological assessment inventory (e.g., Yo-Yo intermittent recovery test, Bangsbo, Iaia & Krustrup, 2008) when considering the context (cricket) and talent identification literature.
- Work should be undertaken considering the broad and multifaceted nature of 'talent'. In doing so, attributes such as anticipation and practice history (e.g., hours practiced and type of practice) should be considered.

Following this, the lead researcher worked with National Skill leads to design a first round of testing protocols for EDP TT. At this time, the lead researcher undertook the reliability and validity research (Chapter 2). All research questions, recruitment of participants and administration of testing was conducted by the lead researcher. At the same time (year 1) the lead researcher took responsibility for devising the full research framework (as detailed on page 31). Although empirical data is not presented in the thesis on all parameters, a number of crucial assessments were designed following extensive examination of the extent literature. Most pertinent would be (i) the research design, filming, editing and implementation of an anticipation assessment (visual occlusion paradigm, see: Müller, Abernethy, & Farrow, 2006), and (ii) the implementation of the gold standard skeletal maturation assessment (Tanner-Whitehouse 3 method: Tanner, Healy, Goldstein & Cameron, 2001). In relation to both projects, the ECB provided financial resource and a small amount of input where require for ethical approval of the skeletal maturation study. Bruce Abernethy provided some advisory input in the initial stages of the anticipation project.

Scouting

During the first year of research, the ECB chose to embark on a scouting project to assist with talent identification practices. Given the on-going research, it was agreed that the lead researcher would assist in shaping the scouting process. Although the design of the scouting guidebook was not research owned, all research questions and analysis was. In the second year of scouting, the project was solely research owned. The lead researcher was responsible for developing the scouting guidebook and form, recruiting scouts, leading scout CPD, administering scouting assignments and regularly communicating with scouts regarding progress. All aspects of the research (question design and analysis) were entirely research led and orientated towards examining the value of scouting as an additional talent identification methodology.

Performance statistics

A limitation of the research detailed to date is the lack of longitudinal data. Having operated within the ECB environment three years, the lead researcher developed a strong understanding of applied talent identification practices that were in place. One commonly referenced 'tool' was performance statistics. However, on examining the extent literature it was apparent that there was a relative lack of research in performance statistics in cricket, but extensive bodies of research in other similar sports that generate performance statistics. The progression of this performance statistics project: developing specific hypotheses, metrics of interest (non-traditional) and the methodology (e.g., two part) was led by the lead researcher. Where relevant, expertise was sought from the Performance Analysis department (ECB) to assist with the project. All data collection and analysis of performance statistics was conducted by the lead researcher.

Thesis Format

The remainder of the thesis comprises four empirical chapters. Chapters two, three and four focus on different talent identification methodologies. Chapter five presents maturation-based data in relation to the relative age effect. The final chapter concludes the thesis with an outline of the future direction that the programme of research will take.

1. Chapter 2 contains two separate pilot studies that examine the reliability and validity of five batting and two pace bowling assessments. The assessment inventory includes tests of high ecological validity and tests that examine simple, underlying abilities. This preliminary work was conducted with the aim of shaping the long-term EDP TT framework. Theoretical implications of the research are discussed.
2. Chapter 3 utilises a novel data set, scouting reports. The chapter details scouting report design, examines the discriminant validity of skill, physical and psychological scouting variables, and, examines the most appropriate methodological approach for gaining accurate scouting appraisals.
3. Chapter 4 presents a longitudinal analysis of performance statistics in cricket. The relationship between age-group and senior England performance statistics is analysed, with particular emphasis placed on the predictive validity of standard (e.g., batting average or bowling average) versus non-traditional performance statistics (e.g., the ability to perform well on transitioning to a new environment). Discussion focuses on performance statistics in relation to age, environment (Test and One Day International cricket), discipline (batting and bowling) and emergent themes of traditional and non-traditional performance statistics.
4. Chapter 5 reports on relative age effect (RAE) across the entire cricket talent development pathway (male and female). Skeletal maturation data is discussed in relation to the RAE and discipline choice at younger stages of the pathway.
5. Chapter 6 provides a summary and assimilated discussion of the thesis findings. Theoretical and applied implications of the research are considered. The chapter concludes with limitations to the thesis and future research directions.

It is important to note that the thesis is presented as a series of research papers. This reflects the dual objectives of: (i) generating a thesis; and (ii) learning how to write for publication. For this reason, some information contained in the Chapter 1 is repeated as introductory information in the empirical chapters (Chapter 2 – 5). In addition, given the complexity of the thesis, a ‘research progression' section has been written between each chapter. This aims to remind the reader of previous findings and document the rationale for the following chapter.

Chapter 2

Pilot studies examining the reliability and validity of five batting and two bowling cricket tests

Research Progression

Following on from the general introduction, Chapter 2 presents findings from the first methodological approach, testing. Chapter 2 details two pilot tests that examined the reliability and validity of five batting, and two bowling tests for use in a talent assessment battery (England Development Programme Talent Testing).

Given the relative dearth of talent identification literature examining the predictive validity of skill-based assessments, a broad inventory of assessments was designed. From a batting perspective, the tests required the batsmen to perform target-based assessments against spin bowling, pace bowling, and with a thin bat – measures of accuracy (target-based) and quality of bat-ball contact were implemented. More complex batting assessments that combined aspects of tactical decision-making and performance under pressure were developed and are referred to as scenario based assessments – these were assessed in relation to runs scored and wickets lost. The bowling tests required the players to bowl accurately and with maximum speed at targets. A range of assessments was deemed worthwhile because of the lack of prior research on which to make an informed decision. Following on from initial design of tests, assessing the reliability and validity was the first step in assessing their potential utility in a talent identification context.

Two pilot tests were conducted. In Pilot Test 1, nine U16 England Development Programme (EDP) considered batsmen (high ability), and nine EDP unconsidered batsmen (low ability), and, eleven EDP unconsidered bowlers and nine considered bowlers were recruited to evaluate the discriminate validity of the tests. Participants completed one trial. In Pilot Test 2, the reliability and discriminate validity of tests were evaluated. Eleven Marylebone Cricket Club University (MCCU) batsmen (high ability) and fourteen school batsmen (low ability), and, nine MCCU and eight school bowlers completed the skill tests. Participants completed two set of trials separated by at least three days and no more than ten days. Significant differences were revealed between high and low ability batsman and bowlers in Pilot Test 1 and 2. Batting against pace generated the greatest degree and consistency of discrimination between ability groups. Some evidence was revealed for a learning effect, suggesting that high ability batsmen learn and adapt to a greater extent than low ability batsmen. Evidence was found in the thin bat test that simple measures of hand eye-coordination (quality of bat-ball contact) discriminate between ability levels. Varying results were found within the bowling assessment for discriminant validity and reliability. In conclusion, given that the tests may be used for talent prediction purposes, it would be worthwhile to maintain a broad battery of skill-based assessments as little is known about the predictive validity.

The aim of this study was to determine the discriminant validity and reliability of batting and bowling skill-based assessments that may have utility in talent prediction. Batting and bowling can be viewed as primary skills that contribute to winning a game of cricket (Petersen, Pyne, Portus & Dawson, 2008). Given the importance of such skills, it is unsurprising that extensive bodies of research have examined the processes that underpin successful execution of batting and bowling skills. The majority of work in batting has focussed on the task constraints of sub-second interceptive action (Müller, Abernethy & Farrow, 2006; Weissensteiner, Abernethy, Farrow & Müller, 2008), whilst in bowling the most substantial body of literature has centred on the prevalence and prevention of injuries (see Elliot, Burnett, Stockill & Bartlett, 1996; Elliott, 2000). It is somewhat surprising that little research has focussed on the execution and measurement of skills with a view to accurately benchmarking and enhancing skill development. In part, this may be attributable to the relative dearth of empirically documented skill-based assessments.

In utilising skill-based assessments it is crucial that they provide reliable and valid data. Reliability refers to the consistency or reproducibility of performance from the same individual on multiple occasions (Hopkins, 2000), whereas validity is concerned with the extent to which a test differentiates as intended. Whilst validity of skill-based assessments is most frequently associated with discriminatory ability, the extent to which an assessment differentiates between players of differing standard, it is not the only form of validity, particularly with concern to talent identification. The primary concern when implementing assessments for talent identification purposes is that they demonstrate predictive validity, arguably the sole directive of talent prediction research at the current time. This validity can only be established having implemented talent test assessments and completed subsequent performance analysis after a number of years. With no such longitudinal work having been conducted, it is vital to ensure that this work is initiated, with informed and justified decisions made regarding the inclusion and structure of skill-based assessments that may have utility in talent prediction.

In recent years it has been clearly stated that there is a lack of consensus in relation to how talent should be defined and identified (Vaeyens, Lenoir, Williams & Philippaerts, 2008). In adopting a broad, multifaceted and longitudinal approach to talent prediction, the England and Wales Cricket Board's (ECB's) talent research aims to answer fundamental questions related to talent identification. The ECB's approach adopts a three-strand methodology: implementation and subsequent analysis of a national scouting programme (the observation and subjective quantification of performance), analysis of longitudinal performance statistics, and the initiation and ensuing analysis of a national talent testing programme; England Development Programme Talent Testing (EDP TT). The research detailed in this study, documents preparative work in constructing, modifying and selecting skill-based assessments that *may* have predictive validity in a longitudinal study of cricket performance (EDP TT). The findings of the following two pilot studies informed which batting and pace bowling skill-based assessments were administered to the national talent pool from 2011 onwards. It is important to remember that regardless of the findings detailed in this study, nothing can be said about the predictive validity of tests that are reported.

Batting: Skill-based assessments

Empirically documented batting assessments have drawn on three areas, quality of bat-ball contact, accuracy within a target-based framework, and the temporal and sequential execution of interceptive actions. Müller and Abernethy (2008) detail a simple categorical tool for the assessment of interceptive skill, whereby in the indoor environment when facing a spin bowler, a batsman's quality of bat-ball contact can reliably and validly be categorised by a trained assistant or elite cricket coach in relation to video analysis. Whilst Müller and Abernethy (2008) did not address the discriminant validity of such an assessment, their previous work (Müller & Abernethy, 2006) and the work of Houghton, Dawson and Rubenson (2011) on a simulated batting innings, does provide substantial support for coach-rated assessments of bat-ball contact in distinguishing between batsmen of differing ability levels. The value of such an assessment in talent identification is yet to be established. It is interesting to note that the discriminant findings of bat-ball contact were applicable regardless of the ball delivery mechanism. Müller and Abernethy (2006) utilised spin bowlers (with randomised variations), whilst Houghton et al. (2011) delivered balls from a bowling machine which have received substantial criticism for altering movement patterns, removing the need for anticipatory actions and diluting skill-based differences (Gibson & Adams, 1989; Pinder, Renshaw & Davids, 2009; Mann, Abernethy & Farrow, 2010). With findings remaining robust regardless of delivery mechanism, it would seem assessing quality of bat-ball contact is a viable mechanism through which to assess interceptive action.

It is, however, worth drawing attention to the limitations of the somewhat narrow assessments used in the above studies. Quality of bat-ball contact as an outcome measure may be more indicatory of fundamental motor and perceptual abilities, rather than 'skill', which in cricket refers to the batsman's ability to combine basic movement and perceptual abilities with the extraneous and cognitive demands of the situation, such as tactical scenarios (Davids, Button, & Bennett, 2008; Knapp, 1977). At this stage, with very little work having been conducted in the predictive factors of future success (either in cricket or other sports), it would be remiss to suggest that more focus in talent identification should be orientated towards the assessment of fundamental abilities over skill, or vice versa. Rather, more longitudinal work focussing on the predictive validity of both is required, which would mark substantial progression in the field of talent identification research.

Portus, Timms, Spratford, Morrsion and Crowther (2010a) detail an alternate approach to assessing skill-based ability. Pace bowling deliveries from a bowling machine were administered to batsmen at three pre-defined lengths and batsmen were required to execute pre-designated shots to a range of targets with an assigned scoring system. Although the assessment was shown to have some level of construct validity, no measure of reliability was assessed. Whilst aspects of the assessment do reflect a greater degree of ecological validity, with testing having been conducted outdoors on a normal wicket, the pre-mediated nature of shots at pre-designated lengths is cause for concern. It would seem likely that this removes a substantial degree of perceptive ability and may generate unrepresentative movement patterns in order to achieve the desired performance outcome (Mann, Abernethy & Farrow, 2010; Pinder, Renshaw & Davids, 2009; Renshaw, Oldham, Davids & Golds, 2007). Indeed, Renshaw et al. (2007) provide compelling evidence for the importance of representative batting conditions in the practice environment. On this basis, it would seem likely that maintaining ecological perception-action coupling where possible should be respected when designing or implementing assessments.

In a more recent investigation of batting expertise Weissensteiner, Abernethy and Farrow (2011) utilised a temporal and sequential, target-based and bat-ball quality assessment in exploring the factors that were most linked to expertise. Task difficulty was manipulated through the use of varying bat widths (full-, half- and third-width bat) and analyses demonstrated that higher skilled batsmen were significantly earlier at initiating and completing definitive front foot movements. Furthermore, the skilled batting group generated significantly higher accuracy scores, supporting the use of such target-based assessments. Interestingly, the bat-width findings were somewhat in contrast to the expected results, with expert novice differences diminishing as the task became more difficult. Significant differences were evident with a full-width bat, and remained significant, but reduced at half-width bat, only to become undifferentiated at the third-width bat. Although, intuitively, one may assume that the more difficult the test, the easier it would be to establish between group differences, this does not seem to be the case. Though speculative, the most parsimonious explanation, may be that skilled batsman have practiced more with the full-width bat and are actually relative novices with the reduced bat widths. As such, this is perhaps an example of a skill-based assessment that could be utilised as a protocol under which players 'ability to learn', potentially a predictor of future success, could be examined. Indeed, a 'learning' study framed in this manner would be a novel addition to the literature.

In summary, as the long-term predictors of subsequent performance in any sport are as yet un-established, it would seem worthwhile to adopt a broad, but justified array of fundamental movement and skill-based batting assessments. There seems to be adequate support for the use of bat-ball contact and target-based assessments, however limitations of the currently detailed target assessments with respect to pre-designated movement and limited unrepresentative targets need to be addressed. Given the varying degrees (and general lack) of ecological validity in the framework discussed, to date, no assessments have really reflected the complexity of batting skill. Although bowling is relatively repetitive with variations in execution of skill (i.e., line, length and type of delivery) determined by the bowler, batting is open to far more degrees of freedom. A batsman will be required to execute their shots taking into account variations in ball delivery, tactical considerations such as field placements, personal strengths and weaknesses and fundamentally make appropriate decisions when under pressure. As such, assessments that encompass these variables would be desirable.

Bowling: Skill-based assessments

There is less empirical documentation of the reliability and validity of pace bowling assessments. Cricket Australia's conference proceedings detail work by Portus, Timms, Spratford, Morrison and Crowther (2010b), who evaluated Australian cricketers over a period of 4 years with a target-based, and bowling speed assessment. Speed and accuracy are common variables of interest in assessments of this nature (see Ali et al., 2007 and Russell, Benton, Kingsley, 2010 for examples in football). Delivering a cricket ball with high velocity is deemed to be so crucial because the delivery time (timed from point of release to reaching the batsman) can be less than the sum total of visual reaction time and movement time of the lower limbs (Müller et al., 2006). In this manner, the batsman is required to predict various aspects of delivery in order to avoid losing their wicket and / or execute a run scoring shot.

When assessing speed and accuracy the "speed-accuracy trade-off" (Fitts & Posner, 1967) is of primary importance. It has been suggested that more highly skilled sportsmen are able to maintain both aspects of execution, whilst lesser skilled sportsmen degrade across either, accuracy, or, speed in order to maintain the other. On this basis, and the premise that bowling is a relatively repetitive and closed loop skill, it would seem that assessments drawing on both the speed and accuracy of skill execution would be appropriate. Portus et al. (2010b) detailed preliminary findings that would support the use of such variables, however reliability findings were again lacking. A version of this assessment has undergone further validity testing, again with no regard for reliability (Phillips, Portus, Davids, & Renshaw, 2012). Phillips et al. assessed three groups of bowlers, national, emerging and junior (descending order of ability) with respective mean ages of 29.1, 21.2 and 17.3 years of age. When considering the age differential and subsequent physiological prowess of older groups, it is of little surprise that national bowlers bowled significantly quicker. Furthermore, with such differentiation in skilled-based ability (national versus junior) it is unsurprising that national bowlers were significantly more accurate and were able to vary their length in order to hit three different targets. It is only in controlling for developmental differences that a meaningful discriminatory value of assessments such as these will be elicited.

Glazier, Paradisis and Cooper (2000), and Portus, Sinclair, Burke, Moore and Farhart (2000), detail that bowling speed is related to certain anthropometric and biomechanical variables in both adult and adolescent bowlers. More recently Loram et al. (2005) and Salter, Sinclair and Portus (2007) accounted for in excess of 85% of the variance in ball release speed through regression models utilising biomechanical knee, shoulder and delivery stride variables. However, the lack of longitudinal, developmental or maturation-controlled research, negates suggestions about the predictive value of these variables, and at this stage, it would be unwise to over emphasize the importance of speed and accuracy of delivery as predictors of future performance, particularly when other variables have been proposed as central to bowling performance. In reviewing fast bowling research, Bartlett, Stockill, Elliott and Burnett (1996), and Bartlett (2003), detail two ways in which technique is fundamental to performance. Firstly, correct bowling technique is central to the avoidance of injury; and secondly, bowling technique assists in generating lateral movement of the ball (normal and reverse swing, and lateral deviation of the ball off the wicket). Accurately measuring biomechanical technique and lateral movement could require 3D modelling and or Hawk-Eye data (Basingstoke, UK), and hence be prohibitive from a cost and time perspective.

However, high-speed video footage and subsequent coach appraisals of technique against pre defined and empirically evidenced technique parameters, may be viable and potentially offer an additional insight into predictive bowling measures.

In summary, the lack of adequately justified skill-based assessments in cricket, led to the development and refinement of assessments that may be appropriate for not only assessing skill-based abilities, but may also have a degree of predictive validity in talent identification terms. Assessments need to draw on both ecologically representative scenarios that may be akin to a players' current level of performance, as well as underlying and fundamental assessments, such as bat-ball contact that may themselves be more predictive. Thus, the purpose of this work was to conduct pilot analysis examining the reliability and validity of two bowling, and five batting tests that were in use at the England and Wales Cricket Board (ECB). These assessments were designed by ECB national skill leads in conjunction with input from senior EDP coaches. Analyses of the discriminant validity of these tests may allow informed and justified decisions to be made regarding the inclusion, exclusion or modification of assessments for future England Development Programme Talent Tests (EDP TT).

Methods

Pilot Test 1 Participants and Design

Participants were nominated for Pilot Test 1 by County Academy Directors (CAD's) and ECB Regional Performance Managers (RPM's). A selection panel comprised of four RPM's, the National Performance Manager and the Head of the EDP then selected those that were perceived to be the best 62 male under-16 players (based on performance statistics and personal knowledge). Due to injury and voluntary attrition, only 58 players (M_{age} = 16.6, SD = 0.3) attended Pilot Test 1. The participants were randomly split into two groups and each group completed testing at the National Cricket Performance Centre over a 1 ½ day period in August 2010. Participants completed a discipline specific assessment where applicable (pace bowling, spin bowling or wicket keeping) and all participants completed the batting assessments (batting against pace, batting against spin, match performance chasing and match performance setting). Due to low participant numbers, it is only the pace bowling (n = 20) and 1st discipline batting (n = 18) data that are reported in this analysis.

A retrospective grouping, based on selection lists for the under-16 England Development Programme (EDP) was applied to the players for the purposes of discriminant batting analyses. Players that were considered for the EDP were the high ability group, termed 'long list' (n = 9, M_{age} = 16.6, SD = 0.3) and those who did not feature on the selection list were the low ability group and have been termed 'unconsidered' (n = 9, M_{age} = 16.0, SD = 0.3). Twenty bowlers completed the pace bowling assessment with nine featuring on the long list (M_{age} = 16.5, SD = 0.3) and 11 players being unconsidered (M_{age} = 16.6, SD = 0.3).

Following on from Pilot Test 1 analyses, anecdotal observations were made by both national skill leads and the researchers, this led to a number of test modifications and the subsequent exploration of the reliability and validity of skill-based assessments in the Feb-April 2011, Pilot Test 2.

Pilot Test 2 Participants and Design

Five batting tests, those outlined previously with the addition of a 'thin' bat test were administered at the National Cricket Performance Centre to a group of school 1st XI standard batsmen (n = 14, M_{age} = 16.9, SD = 1.3) and a group of Marylebone Cricket Club University (MCCU) batsmen (n = 11, M_{age} = 20.0, SD = 1.1). The school 1st XI batsmen were of a high calibre and included a number of county age-group players; however, for these analyses they were regarded as the low ability group. MCCU's have been implemented with the purpose of providing an opportunity for exceptional cricketers to progress whilst continuing further education. As such, MCCU's recruit the highest calibre cricketers in university attendance and were therefore termed the high ability group. The order in which the players completed the batting assessments is detailed in appendix 1.

Two bowling tests (knockout and accumulation) were administered at indoor net facilities to the group of school 1st XI standard bowlers (n = 8, M_{age} = 16.6, SD = 1.58) and the group of MCCU bowlers (n = 9, M_{age} = 21.3, SD = 1.47). All bowlers completed the accumulation test before the knockout test. All participants (batsmen and bowlers) completed two main trials (test and retest) separated by at least three days and no more than ten days. Two MCCU bowlers were unable to complete the retest. Information regarding the purpose and process of testing was provided prior to attending. In addition, a clear explanation with opportunity for questions was provided on attendance at the testing centre. Informed consent was sought from each player, and or parent, when the player was less than 18 years of age. All procedures had the prior approval of a university Ethics Committee. All tests (Pilot Test 1 & 2) were administered by experienced and qualified coaches. These coaches were responsible for the scoring and administration, whilst the programme was overseen by the lead researcher.

Test design and scoring

Batting

Batting against pace: Pilot Test 1. Batsmen received deliveries from a standard Bola bowling machine (Cotham, Bristol, UK) at a speed of 70 mph. The bowling machine was positioned to replicate a right-arm over bowler to a right-handed batsman. Bias was set at left + 1 for right-handed batsmen, and right + 1 for left-handed batsmen; this was with the purpose of ensuring that the ball was always swinging away from the batsman. Batsmen were required to hit the ball to a pre designated target positioned at mid-off, cover, 3rd-man, square leg, mid-wicket or mid-on (the order of deliveries and test administration order is detailed in appendix 1 & 2). Targets were positioned using a measurement taken from the central stump and each target was 2m in width (see appendix 2 for distances from centre stump). The batsman was awarded either a score of 5 points for hitting the ball through the target, 2 points for hitting the ball in close proximity to the target whilst demonstrating good technique, or 0 points if neither of the previous criteria were met. Batsmen received 12 deliveries at a full length before progressing to 12 deliveries at a short length.

All deliveries were pre-designated and the batsman received two deliveries per target before progressing to the subsequent target (see appendix 2 for further details of the line and length of delivery and the target order and positions). In total, batsmen received 24 deliveries over 2 lengths. Prior to receiving deliveries at each length the batsmen received 6 "sighters".

Pilot Test 2. Six targets were positioned at mid-off, cover, 3rd-man, square-leg, mid-wicket and mid-on; however the targets were two-zone having a central target and an outer target. This was with the purpose of removing elements of subjectivity contained in Pilot Test 1. The central targets were equal in size (15° wide from the position of centre guard) with an additional 0.5m of target on either side (see appendix 3 for further details). A further modification was the randomisation of target order, with the aim of avoiding pre-emptive movement / shots. With the arm and ball raised above the bowling machine, the feeder randomly designated a target and fed the machine. The batsman was awarded a score of 4 points for hitting the ball through the central target, 2 points for hitting the ball trough the outer target, or 0 if they failed to hit the target. A block of 6 deliveries (1 ball per target) was administered at a half volley length at 65mph, before being repeated to complete 4 blocks (6 balls x 4 blocks). This process was then repeated at a short length (65mph), before being replicated at a higher speed (75mph) at both lengths (see appendix 1 and 3 for further details). In total, batsmen received 96 assessed deliveries when batting against pace (24 deliveries x 2 lengths x 2 speeds). Batsmen received 2 sighters prior to facing each set of 24 deliveries.

Batting against spin*: *Pilot Test 1. Batsmen received deliveries from a standard Merlyn bowling machine (Bola: Cotham, Bristol, UK) at a speed of 49 mph. The bowling machine was positioned to replicate a right-arm over bowler and the laser was centred on middle stump. See appendix 4 for spin settings. In the same fashion as with batting against pace, batsmen were required to hit the ball to one of 6 pre-designated targets. As the 'feed' button was depressed the test administrator designated the target. The targets, scoring, number of deliveries and warm-up shots mirrored batting against pace Pilot Test 1 (24 deliverers, 12 per length with 6 sighters proceeding each length); however, in order to ensure the pitch mark was representative of spin bowling the lengths were adjusted (see appendix 4).

Pilot Test 2. Batsmen received deliveries in the same fashion; however, the speed was adjusted to 45 mph. The six targets were positioned as detailed in batting against pace Pilot Test 2. Batsmen received deliveries in 4 blocks of 6 balls (24 deliveries), two spin types (off spin and leg spin – see appendix 4 for spin settings) and two lengths (half volley and short as detailed in batting against spin Pilot Test 1). Batsmen received 2 sighters prior to each set of 24 deliveries. In total, batsmen received 96 assessed deliveries when batting against spin (24 deliveries x 2 lengths x 2 spin types).

Batting with a thin bat against pace: Pilot Test 2. Batsmen received deliveries from a standard Bola (Cotham, Bristol, UK), delivering balls to the same parameters as detailed in batting against pace Pilot Test 2. All participants were provided with a half-width bat (Duncan Fearnley: Worcester, UK). Batsmen were required to hit the ball to one of 4 randomly assigned targets positioned at cover, point, mid-wicket and mid-on. The targets were two-zone and constructed of a central and outer target (4 and 2 points respectively, see appendix 5 for target positions). During the thin bat test the frequency of bat-ball contact was recorded[1]. The batsman was awarded 1 point for making bat-ball contact regardless of quality of contact, or 0 points if they failed to make contact. In order to assess the batsman's ability to play the pull and cut shot, it was compulsory for short deliveries to be hit with a cross bat when point and mid-wicket targets were designated. Batsmen received deliveries in 4 blocks of 4 balls (16 deliveries), at two speeds (65 mph and 75 mph), and at two lengths (half volley and short). Batsmen received two sighters prior to receiving deliveries at each length and speed. In total, batsman received 64 assessed deliveries when completing the thin bat test (16 deliveries x 2 lengths x 2 speeds).

Match Performance Setting (MPS): Pilot Test 1. MPS constituted a hypothetical game scenario. The batsman was informed that they would face 12 deliveries against a 'seam bowler'

[1] Assessing bat-ball contact was not initially included in the protocol and was introduced midway through the testing process as coaches deemed it worthwhile of exploratory investigation. For this reason the data set is incomplete and test - retest reliability has not been conducted.

(away swinger, bias left +1 for right handed batsman) and within the 12 deliveries there may be a number of variations bowled; within each 4 deliveries one variation (in swinger, bias right +1, for right handed batsman) was bowled (75 mph). It was the test administrator's discretion as to when this was bowled. Bola was set at a short length as detailed in batting against pace Pilot Test 1 and the batsman received no sighters. Batsmen were informed that they were batting at number 3 and the score was 40-1 from 8 overs in a 50 over game. They were instructed to score as many runs as possible given the situation that they faced. The scorer determined how many runs were scored from each delivery and the batsman was required to run these. If the batsman was dismissed, either caught, leg before wicket, bowled or stumped, as determined by the scorer, they were deducted 2 runs. A standard field, depicted with cones, was set. Compulsory and pre-designated field changes were made throughout the test (see appendix 6 for further details).

Pilot Test 2. The protocol was conducted as detailed above with the following modifications. The field was set as detailed in appendix 6 and the scorer made a number of pre-designated changes that were not defined to the batsman in the pre-test instructions. Field changes were implemented in order to increase the ecological validity of the assessment and to ensure that the batsman responded to the game situation as would be required in a normal match situation. In addition, the batsman was no longer required to run respective lengths of the wicket if he was deemed to have scored 1, 2 or 3 runs. Each batsman completed the scenario twice (block 1 and block 2) on both the test and retest. Although 24 balls were delivered, block 1 and 2 should be viewed as independent 12 ball tests and have not been collapsed into one 24 ball test for analyses, as the scenario and batsman's understanding of the assessment was as a 12 ball protocol.

In order to assess concordance between scorers, two ECB Level 4 cricket coaches[2] independently rated each batsman as they completed the MPS scenario. Bola delivered away swinging deliveries (75 mph at a short length) and within each 6 balls one variation was bowled (no bias). The batsman received no sighters.

[2] The ECB level 4 coaching award is the highest formal coaching qualification available to cricket coaches in the United Kingdom. Level 4 coaching status was achieved by the majority of coaches recruited to assist on Pilot Test 1 and 2, although a number were of Level 2 status.

Match Performance Chasing (MPC): Pilot Test 1. The MPC scenario was performed against off spin at a full length. Merlyn delivered balls at 49 mph. The batsman was informed of a hypothetical scenario whereby there were only two overs left in the game and they were required to score 18 runs to win the match. One in four deliveries was a variation (top-spinner) and the test administrator decided when to deliver this ball. For each dismissal (as deemed by the scorer) the batsman was deducted 5 runs from their score. A standard field was set with pre-designated field changes throughout the test (see appendix 7 for further details).

Pilot Test 2. Each batsman completed the scenario as detailed in MPC Pilot Test 1. The batsman completed the scenario twice (block 1 and block 2 i.e., 24 balls in total) on both the test and retest. The field was set as detailed in appendix 7 and the scorer made a number of pre-designated field changes within the 12 balls. Merlyn delivered off spinning deliveries at 45 mph as detailed in appendix 7. Within each 6 balls, one variation was bowled (top-spinner). The batsman received no sighters.

Pace bowling

Introduction. As Phillips et al. (2012) suggest, skilled bowlers are required to deliver a range of delivery lengths on demand – this is considered a fundamental and key aspect of their skill. Two bowling tests were designed with the purpose of assessing individuals' skill under a range of varying constraints.

The 'accumulation test' was designed with a relatively high level of ecologically validity in mind. The bowler was required to bowl stock deliveries and variations in delivery consistently and accurately over a relatively prolonged period of time, mirroring the demands of match bowling requirements. In contrast, the 'knockout test' was designed with a view to placing the bowler under a greater degree of pressure than may be the case when completing standard bowling assessments. The bowler's aim was to progress through a 4-stage knockout assessment taking as few deliveries as possible. If the bowler failed at any stage, then the test was terminated, thus creating a greater perception of pressure. Following interviews with internationally renowned 'mentally tough' cricketers, Bull, Shambrook, James and Brooks (2005) suggest that players clearly relish individual challenge, and whilst the knockout challenge itself is not fundamentally different in task execution to the accumulation test, it was hypothesised that a staged knockout test, where the bowler was required to bowl specific wicket taking deliveries on demand, whilst being observed by other test participants would provide a greater degree of pressure and competition.

Accumulation test procedure: Pilot Test 1. The bowler had 24 deliveries to hit pre-designated targets The target order was as detailed in table 1 below. The bowler was awarded 1 point for hitting the target. A measure of bowling speed was taken for stock deliveries for the first 2 overs. Bowling speed was measured by Trackman (Vedbæk, Denmark) or a handgun (Road Runner TCA; London, UK).

Table 1: *Accumulation test delivery order – Pilot Test 1*

Ball No.	Over 1	Ball No.	Over 2	Ball No.	Over 3	Ball No.	Over 4
1	Top of off RH	7	Top of off LH	13	Bouncer	19	Yorker
2	Top of off RH	8	Top of off LH	14	Bouncer	20	Yorker
3	Top of off RH	9	Top of off LH	15	Bouncer	21	Yorker
4	Top of off RH	10	Top of off LH	16	Bouncer	22	Yorker
5	Top of off RH	11	Top of off LH	17	Bouncer	23	Yorker
6	Top of off RH	12	Top of off LH	18	Bouncer	24	Yorker

Pilot Test 2. The bowling test was conducted in the same fashion as the Pilot Test 1 with three amendments. An additional outer zone target was added to the original target. This was in an effort to increase the reliability of the assessment, by rewarding near misses of the target more than distant misses. The bowler was awarded 4 points for hitting the centre target and 1 point for hitting the outer target. The bowling order was modified so that bowlers were required to switch their line and length within each over (as detailed below in table 2). It was suggested that this would reflect a greater degree of ecological validity as intended with the assessment. Further, the bouncer target was positioned on a stand over the batting crease at approximate batsman head height (1.6m) instead of on the pitch, thus ensuring that the bowler, as in a game scenario, was responsible for controlling any deviation of the ball through the air and off the pitch (Portus et al., 2010b). Bowling speed was recorded for stock deliveries by Trackman (the first 3 balls of each over). Regardless of accuracy, a score of 0 points was awarded in the case of a no-ball being delivered and the bowler was not awarded an additional delivery.

Table 2: *Accumulation test delivery order – Pilot Test 2*

Ball No.	Over 1	Ball No.	Over 2	Ball No.	Over 3	Ball No.	Over 4
1	Top of off RH	7	Top of off LH	13	Top of off RH	19	Top of off LH
2	Top of off RH	8	Top of off LH	14	Top of off RH	20	Top of off LH
3	Top of off RH	9	Top of off LH	15	Top of off RH	21	Top of off LH
4	Bouncer	10	Yorker	16	Bouncer	22	Yorker
5	Yorker	11	Bouncer	17	Yorker	23	Bouncer
6	Bouncer	12	Yorker	18	Bouncer	24	Yorker

Knockout test procedure: Pilot Test 1. The bowler had 6 attempts to hit the first target (top of off stump to right-handed batsman). On hitting the target, the bowler immediately progressed to the second target (top of off to left-handed batsman) with a further 6 attempts. The third and fourth target represented a bouncer and yorker respectively. If the bowled failed to hit the target in 6 deliveries the test was terminated. For each target, scoring was assigned such that an accurate delivery with the first ball was awarded 6 points, 5 points for the second ball, 4 for the third ball and so on. In this fashion, the maximum score possible for the knockout test was 24 points e.g., the bowler hit each target on his first attempt, taking only 4 balls to complete the test. The minimum score possible was 0 points e.g., the bowler failed to hit the first target in 6 attempts, and hence, the assessment was terminated.

Pilot Test 2. The test was conducted in the same fashion as the Pilot Test 1 with the following amendments. The bouncer target was positioned on a stand over the batting crease at approximate head height (1.6m) instead of on the pitch, and the yorker target was increased in dimensions from three foam 60mm cubes, to a floor target measuring 230mm x 300mm. In the case of an accurate no-ball being delivered, it was deemed to be a miss and the delivery was not repeated.

Prior to completing the assessments, bowlers were provided with a 15-minute period to complete their warm-up. With indoor surfaces varying across facilities, bowlers were encouraged to familiarise themselves with the pitch-lengths in order to hit the targets. Bowlers completed the assessment in a group of 3-4 players. Bowlers rotated through deliveries i.e., all bowlers in a group bowled their first delivery before moving onto their second, and so on. With all bowlers having completed the accumulation test they were provided with a break of approximately 15 minutes before completing the knockout test. All bowlers used a new Readers Invicta cricket ball (Kent, England).

Statistical analyses

Batting

Pilot Test 1: Two group multivariate analyses of variance (MANOVA) exploring the discriminant validity of the batting tests were conducted on the accuracy score for batting against pace and batting against spin. The two dependent variables in each analysis were, the score for the first 12 balls, at a full length, and, the score for the second 12 balls, at a short length. The players were filtered to include only those who were 1st discipline batsman. This resulted in 9 long list players (high ability) and 9 unconsidered batsmen (low ability). This criterion acted as the independent variable. Following a significant multivariate effect, independent t tests were conducted to examine the between group differences at a short and full length.

Independent t tests were used to examine between group differences for total score achieved in the MPC and MPS scenarios. The EDP long list criterion was again applied as the independent variable.

Pilot Test 2: MANOVA's were used to examine differences between institution (school and university as independent variables) when batting against pace, batting against spin and batting with a thin bat against pace. Six MANOVA's were performed on the data from each target-based assessment. The MANOVA's were completed on partial breakdowns of the total score: balls 1 to 12, 13 to 24 and 1 to 24 for the batting against spin and batting against pace test, and balls 1 to 8, 9 to 16 and 1 to 16 for the thin bat test, on both test and re-test data. For each MANOVA, there were 4 dependent variables; when batting against pace and batting with a thin bat against pace they were accuracy scores for 65 mph-half volley, 75 mph-half volley, 65 mph-short, and 75 mph-short. For batting against spin, the dependent variables were accuracy scores for off spin-half volley, leg spin-half volley, off spin-short and leg spin-short. Independent t-tests were conducted as follow-up tests following a significant multivariate effect. Independent t tests were conducted on the MPC and MPS data with institution as the independent variable.

Pearson's correlation (r) was used to assess reliability between test and retest scores for all batting tests. Further correlations were run on-sub sets of the total deliveries in order to establish the point at which reliability was achieved. For example, was there a comparable level of reliability having faced half the deliveries to when having faced all deliveries?

Bowling

Pilot Test 1: Independent t tests, utilising the EDP long list versus unconsidered bowler criteria as the independent variable, were conducted on the total scores for the accumulation and knockout test, as well as the average and max bowling speed (mph).

Pilot Test 2: Discriminant validity analyses were conducted as detailed above on Pilot Test 2 data. The institution criterion (university versus school) was applied as the independent variable.

The reliability of bowling scores was explored by conducting Pearson's correlations (r) on the total bowling score for both the accumulation and knockout test, as well as the average and maximum bowling speed (mph). With the developed scoring mechanism for the accumulation test (1 point for the outer target, 4 for the inner target), an additional reliability analysis was conducted. The accumulation bowling score for each participant was collapsed into a hit frequency score, regardless of whether the delivery hit the inner or outer target. A test - retest correlation was then run on the total frequency of hits when completing the accumulation test. This allowed a comparison of correlations under the 'normal' and 'hit frequency' scoring system. Statistical significance was set at $p < 0.05$ for all batting and bowling analyses.

Results

Batting

Batting against pace: Pilot Test 1. A MANOVA (*Hotelling's T^2*) was conducted on Pilot Test 1 data to establish whether there were any significant differences between 1st discipline EDP long list batsmen and 1st discipline unconsidered batsmen: $F(2,15) = 3.10$, $p = 0.08$. Although not statistically significant, given the exploratory nature of analyses, univariate follow-up tests were conducted. Long list batsmen scored significantly higher than unconsidered batsmen for short deliveries $t(16) = 2.48$, $p = 0.03$, but not for full deliveries $t(16) = 1.83$, $p = 0.09$.

Pilot Test 2. MANOVA's (dependent variables of accuracy at 65 mph-half volley, 75 mph-half volley, 65 mph-short, and 75 mph-short) were conducted on the scores at 12 ball intervals on both the test and retest. Of the three target-based batting assessments, batting against pace demonstrated the greatest discriminant validity regardless of test, retest or the number of balls faced (see table 3 and appendix 8-9). However, the greatest consistency in discrimination between groups was revealed when analysing balls 1-24 of the retest: $F(4,20) = 2.99$, $p = 0.04$. Univariate follow-up tests showed that university batsmen scored higher for each dependent variable (65 mph-half volley, 75 mph-half volley, 65 mph-short, and 75 mph-short). A multivariate effect for group was also found for balls 13-24 of the retest: $F(4,20) = 3.04$, $p = 0.04$, with two dependent variables reaching significance and the remaining two approaching significance (see table 3). These findings support the notion that practice, or, test familiarisation prior to assessment, assists in eliciting discriminant validity. With respect to test design, it seems that after adequate familiarisation, length and speed of delivery do not discriminate to a greater or lesser extent. A greater degree of reliability was generated at the slower speed (65mph: $r = 0.54$, 75 mph: $r = 0.42$).

Batting against spin: Pilot Test 1. Analysis of 1st discipline batsmen with the long list versus unconsidered criteria applied revealed no significant differences: $F(2,15) = 0.43$, $p = 0.66$.

Pilot Test 2. The MANOVA (dependent variables of batting accuracy for off spin-half volley, leg spin-half volley, off spin-short and leg spin-short) revealed no significant main effects for group at any point, for any block of balls within the test or retest (see appendix 8). Of the three target-based batting assessments, batting against spin demonstrated the greatest test - retest correlation (r = 0.70). A summary of all test – retest correlations can be found in appendix 10-12.

Batting with a thin bat against pace: Pilot Test 2. No multivariate effects were revealed for thin batting when analysing target accuracy scores (see appendix 9). A separate MANOVA was used to compare hit frequency of all deliveries when using the thin bat at two lengths and two speeds in the retest (table 4). Analysis was only conducted on the retest data, as this measure was introduced midway through the first test. Each shot was scored as either making ball contact (1 point) or no ball contact (0 points). Utilising Hotelling's T^2, the MANOVA revealed a significant main effect for group: $F(4,19) = 10.34$; $p = 0.00$. Univariate follow-up analysis revealed significant between group differences for 65mph short and 75 mph short with university batsmen scoring higher.

The thin bat test demonstrated a poor test - retest correlation for the total target based score (r = .20). A complete test - retest correlation for the frequency of bat-ball contact could not completed as this data collection method was introduced part way through the test. A correlation was however conducted on the cumulative bat-ball contact score for balls 1-8 versus balls 9-16 of the retest, r = 0.68.

Table 3: *Test of multivariate and between-subject effects when batting against pace*

		Test			Retest		
		1-12	13-24	1-24	1-12	13-24	1-24
Hotelling's T^2		0.770	0.581	0.305	0.349	0.608	0.599
Multivariate test statistic		$F(4, 20) = 3.849$, $p = 0.018$	$F(4, 20) = 2.907$, $p = 0.048$	$F(4, 20) = 1.532$, $p = 0.233$	$F(4, 20) = 1.745$, $p = 0.180$	$F(4, 20) = 3.038$, $p = 0.041$	$F(4, 20) = 2.993$, $p = 0.044$
Speed 1 (slow)	Half volley	$F(1, 23) = 7.577$, $p = 0.011$	$F(1, 23) = 0.596$, $p = 0.448$	$F(1, 23) = 7.577$, $p = 0.011$	$F(1, 23) = 1.773$, $p = 0.196$	$F(1, 23) = 5.695$, $p = 0.026$	$F(1, 23) = 5.754$, $p = 0.025$
	Short	$F(1, 23) = 0.955$, $p = 0.399$	$F(1, 23) = 8.094$, $p = 0.009$	$F(1, 23) = 0.955$, $p = 0.399$	$F(1, 23) = 4.908$, $p = 0.037$	$F(1, 23) = 2.915$, $p = 0.101$	$F(1, 23) = 4.845$, $p = 0.038$
Speed 2 (fast)	Half volley	$F(1, 23) = 14.555$, $p = 0.001$	$F(1, 23) = 0.133$, $p = 0.718$	$F(1, 23) = 4.411$, $p = 0.047$	$F(1, 23) = 3.062$, $p = 0.093$	$F(1, 23) = 3.350$, $p = 0.080$	$F(1, 23) = 4.507$, $p = 0.045$
	Short	$F(1, 23) = 0.002$, $p = 0.964$	$F(1, 23) = 0.430$, $p = 0.518$	$F(1, 23) = 0.161$, $p = 0.692$	$F(1, 23) = 4.767$, $p = 0.039$	$F(1, 23) = 4.550$, $p = 0.044$	$F(1, 23) = 6.807$, $p = 0.016$

Table 4: *Test of multivariate and between-subject effects for bat-ball contact (frequency) when batting against pace with a thin bat*

		Retest 1-24
Hotelling's T^2		2.177
Multivariate test statistic		$F(4, 19) = 10.340, p = 0.000$
Speed 1 (slow)	Half volley	$F(1, 22) = 1.367, p = 0.255$
	Short	$F(1, 23) = 4.220, p = 0.052$
Speed 2 (fast)	Half volley	$F(1, 23) = 4.563, p = 0.044$
	Short	$F(1, 23) = 35.554, p = 0.000$

Match Performance Setting: Pilot Test 1. There were no significant differences when comparing long list batsmen and unconsidered batsmen: t(16) = 0.78, $p = 0.45$ on total MPS scores.

Pilot Test 2. The MPS scenario was completed twice within both the test and retest (block 1 and block 2 of test or retest). In order to establish the discriminant validity of the MPS scenario, four independent sample t-tests were conducted (on block 1 and block 2 for each scorer). Significant differences were found for 3 of the 4 blocks with university batsmen scoring higher, as detailed below in table 5.

Table 5: *Independent t tests exploring MPS results for each block and scorer*

	Mean	
	University	School
Scorer 1, Block 1: t(22) = -3.28, p = 0.003	21.20	12.00
Scorer 1, Block 2: t(22) = -2.50, p = 0.021	22.40	14.79
Scorer 2, Block 1: t(22) = -2.29, p = 0.032	24.20	16.21
Scorer 2, Block 2: t(22) = -1.78, p = 0.090	23.90	17.71

In addition, as inter-rater reliability work was being conducted, two scorers were utilised for each block. Correlating the score of block 1 with the score from block 2 for each scorer generated a test - retest reliability score. In contrast to the ‘true’ test - retest correlations across a period of 3 to 10 days, this was a within test (or retest) correlation having repeated the MPS scenario in quick succession on the same day. There was a moderate positive correlation in both instances (scorer 1: $r = 0.53$; scorer 2: $r = 0.64$). By averaging all available scores (i.e., both scorers) for both the test and retest, an average score was created for each batsman for both the test and retest. This resulted in an informative, but somewhat confounded (due to the inconsistency of scorers) test - retest correlation, $r = 0.52$.

As the MPS and MPC scenarios were subjectively assessed, inter-rater reliability analysis was conducted. Two scorers independently assessed the batsman as they completed the MPS scenario. This process was completed on 24 batsmen (20 from the test and 4 from the retest) for the repetitions of the MPS scenario (block 1 & 2). The score of block 1, for scorer 1 was correlated with that of scorer 2. This was repeated for block 2 and the results revealed strong support for the reliability of subjective assessments, of runs scored in a MPS scenario by trained coaches (block 1: $r = 0.79$; block 2: $r = 0.76$). When individual rater scores were combined for block 1 and block 2 (24 balls) and subsequently correlated, the cumulative correlation increased, however this was by a negligible amount (block 1 & 2: $r = 0.80$).

Match Performance Chasing: Pilot Test 1. Independent t tests revealed that long list batsmen scored significantly higher than those who were unconsidered ($M = 18.56$ and 9.00 respectively; $t(16) = 2.81$, $p = 0.01$).

Pilot Test 2. Four independent t tests were conducted utilising the score from block 1 and block 2 of both the test and retest as dependent variables. No significant differences between school or university players were revealed, however university players did have a higher average score for each block (see appendix 9).

MPC was assessed by one scorer, and this scorer was not always the same for the test and retest. However, as the MPC assessment was repeated twice (block 1 and block 2) on both the test and retest a within day, test - retest correlation could be generated in order to gauge reliability. Block 1 and block 2 of the test revealed a correlation of 0.57, whilst block 1 and block 2 of the retest showed no evidence of any relationship, $r = -0.07$. When averaging both scorers' scores for the test (i.e., two scorers and block 1 & 2) and doing similar for the retest, a test - retest correlation could be completed, revealing a moderate relationship, $r = 0.56$.

Pace bowling

Pilot Test 1. Independent t tests were conducted on the accumulation score, knockout score, average and maximum bowling speed for Pilot Test 1. A significant difference was revealed for the accumulation test $t(18) = -3.07$, $p = 0.01$ with long list players scoring higher than unconsidered ($M = 4.11$ and 1.91 respectively). However, no significant difference were revealed on the knockout test $t(18) = -0.17$, $p = 0.86$. Average bowling speed did discriminate between ability levels, $t(18) = -2.30$, $p = 0.03$ (long list $M = 72.8$ mph, unconsidered $M = 69.0$ mph), and the difference for max bowling speed approached significance, $t(18) = -1.88$, $p = 0.08$ (long list $M = 74.6$ mph, unconsidered $M = 71.6$ mph).

Pilot Test 2. Independent t tests on target accuracy scores revealed no significant differences between the university and school bowlers for the accumulation or knockout test. It is noteworthy, that the school bowlers generated higher average scores for the knockout and accumulation test. University bowlers were significantly quicker (both average and max speed) as detailed in table 6.

A number of Pearson's correlations were conducted on the Pilot Test 2 bowling data in order to establish reliability. Both bowling tests demonstrated poor to moderately poor correlations (accumulation test, $r = 0.29$; knockout test, $r = 0.47$), however given the low participant numbers (n = 15) the findings are far from conclusive. Interestingly, correlating the frequency of hits (collapsing all data into hit or miss regardless of hitting the centre or outer target) generated a higher correlation indicating a more reliable measure of ability ($r = 0.44$ versus $r = 0.29$). Bowling speed generated the most reliable data with strong positive correlations for both maximum and average speed ($r = 0.95$ and 0.96 respectively).

Table 6: *Independent t tests exploring test accuracy and speed differences between school and university bowlers*

			Average score	
			MCCU bowlers	School bowlers
Average speed (mph)	Test	$t(15) = -3.90$, $p = 0.00$	71.9	65.1
	Retest	$t(13) = -3.33$, $p = 0.01$	70.1	63.7
Max speed (mph)	Test	$t(15) = -3.16$, $p = 0.01$	73.5	67.8
	Retest	$t(13) = -2.54$, $p = 0.03$	71.7	66.5

Discussion

The aim of this pilot work was to (i) examine the reliability and discriminant validity of five batting tests and two bowling tests, and (ii) generate an informed and justified rationale for the inclusion, exclusion or modification of the seven tests. Essentially, the pilot work would determine which skill-based assessments would be administered within a talent test study, to the national cricket talent pool (EDP TT) on an annual basis.

Batting assessments

Batting against pace. The greatest degree and consistency of discrimination for target-based assessments was found in the batting against pace test; both Pilot Test 1 and 2 corroborated this. Further analysis of the discriminant validity, was assessed by examining partial breakdowns of Pilot Test 2 data. Whilst initially it would seem that a minimum of 24 balls per length and type is appropriate to elicit discriminatory results, a multivariate effect was found in the last 12 balls of the retest, with follow-up tests revealing significant differences between school and university batsmen for three of the four dependent variables (and the fourth approaching significance). On this basis and the concurring discriminatory findings of Pilot Test 1 data (12 balls per length), a 12-ball protocol at each length with adequate familiarisation may be appropriate.

In a comparable assessment, Portus et al. (2010a) elicited discriminatory findings with elite batsmen scoring higher than emerging and junior batsmen. In addition, a logistic regression correctly classified sixty-two percent of players. Perhaps of more interest are the significant variables that contributed to the regression analysis. Of numerous variables measured, different bowling speeds and target accuracies at different field placements, the total test score and total number of central target hits were the only significant predictors. As such, one could conclude that test design should emphasise broad execution of skills, rather than specific task constraints, such as target accuracy related to particular shots. Although no analysis was conducted on the varying ability of batsmen to hit different targets, the speed and length of delivery findings do concur and suggest that skill-based abilities are not differentiated by specifics i.e., ability at different length or speeds of delivery, but rather an overall aptitude reflected in total scores. On the basis of reliability, a slower speed would be advisable due to marginally higher test - retest correlations.

In addition, and perhaps of greater interest in the Pilot Test 2 batting against pace data, was the increasing consistency in discrimination between ability groups on the retest, alluding to a possible learning effect of higher skilled batsmen. It would seem that practice allows higher calibre batsmen to familiarise themselves and develop their skills to a greater extent than lower ability batsmen. It is of interest that Phillips et al. (2012) document evidence that higher skilled individuals are better able to ‘learn’ when performing skill-based assessments. They detail the manner in which national and emerging bowlers (highly skilled) were better able to modify their actions within a five-over spell, in order to increase accuracy when compared to junior bowlers (low skilled). Although a tentative suggestion based on these findings, the researchers contend that further empirical work examining the differing learning ability of more, and less ‘talented’ performers, would be a valid avenue of future research in the field of talent identification.

Batting against spin. Although the batting against spin test was the most reliable, the assessment failed to generate significant effects in Pilot Test 1 or 2. The findings may be a product of limited experience against the bowling machine (Merlyn), lack of batting against spin in training, and / or inappropriate test difficulty. Although not conclusive, the work of Müller, Abernethy and Farrow (2006) offers another explanation, suggesting that highly skilled batsman demonstrate a greater reliance on advance cue information from the bowlers hand when facing spin bowlers, than when facing pace bowlers. In this manner, the lack of pre-delivery cues when batting against pace in these tests makes relatively little difference, however when batting against Merlyn (a static spin bowling machine) some of the skill-based differences between higher and lower ability groups are negated, and hence discriminatory results in our test are not generated. Although a possible resolution would be to utilise spin bowlers in delivering balls, the lack of consistency in delivery, and inconsistency in recruiting spin bowlers year-on-year make this a dubious option. What is more pertinent, is the manner in which our findings allude to the importance of anticipation in facing spinning deliveries. Based on the extensive body of anticipation research, detailing significant differences in perceptual abilities of higher and lower ability batsmen, it would seem relevant to include an assessment of anticipation in EDP TT. As such, an anticipation assessment that sits within a visual occlusion paradigm has been instigated within the EDP TT framework.

Batting with a thin bat against pace. The target-based component of the thin bat test demonstrated varying levels of discriminant validity, however analyses of bat-ball contact elicited highly discriminant results, particularly with regard to short deliveries. It is interesting that such a crude measure of interceptive action distinguishes between batsmen of varying standard and these findings are concordant with those of Müller and Abernethy (2008) and Houghton et al. (2011). As the longitudinal nature of this research develops it will be intriguing to explore whether simple measures of hand-eye co-ordination are more, or less predictive than other ecologically representative skill-based assessments, such as the Match Performance scenario.

A mechanism by which to improve the assessment was with respect to the bat-ball contact classification. In this study, the measure may have been overly simplistic (contact versus no contact) and it would seem worthwhile to adjust the scoring system to reflect that of Müller and Abernethy (2008): no contact, poor contact or good contact. If, at a later date, it becomes evident that contact versus no contact is the more appropriate measure, this can be retrospectively established through the proposed criteria.

The thin bat test demonstrated poor test - retest reliability with respect to target accuracy, which may in part have been due to lower delivery numbers per test category (16 as opposed to 24) and potentially the greatest degree of within task variance due to the reduced bat width. Although it was not possible to complete full test - retest correlations examining the reliability of bat-ball contact, a within retest correlation did suggest relatively good reliability of bat-ball contact.

Match Performance Chasing. The MPC scenario revealed no discriminatory findings in Pilot Test 2, but substantial discriminant validity in Pilot Test 1. As suggested by Ali et al. (2007) introducing high ecological validity has the potential to reduce the reliability of the test and this was reflected in the test - retest correlations. In part, the weak reliability may be a product of the scoring system; if a player was deemed dismissed they were deducted 5 runs from their score and from an anecdotal position it was easy to note the change in approach to the scenario, with an increased level of risk in order to overcome the additional deficit of 5 runs, often resulting in further dismissals and subsequently, a low score.

Match Performance Setting. Of the more ecologically valid game scenarios, the MPS assessment revealed conflicting results. Pilot Test 2 generated discriminatory findings whilst Pilot Test 1 did not. Bearing in mind the limitations of the Pilot Test 2 sample group; the fact that the university and school group were substantially different in age, both groups were older than the intended EDP TT test groups, and that there was a relatively small sample size, the discriminatory results of Pilot Test 1 are potentially more pertinent.

Inter-rater reliability. Inter-rater reliability analyses revealed high levels of concordance between raters on both a 12-ball and 24-ball protocol. With relatively little difference between the 12- and 24-ball test-retest correlations it would seem that the 12-ball protocol was an adequate number of deliveries in order to achieve acceptable inter-rater reliability. Although inter-rater reliability was only assessed in the MPS scenario it is likely that rater reliability in the Match Performance Chasing scenario would be worse; this being due to the greater variation of shots played, with particular reference to an increased number of shots played in the air. This would likely lead to a discrepancy between balls being awarded boundaries, or, alternatively, being judged caught out (a possible discrepancy of 11 runs per shot: 6 runs given for a shot that passes the boundary without bouncing or -5 runs awarded for the same shot which is caught on the boundary). Unfortunately, it was not possible to assess inter-rater reliability in the MPC scenario, however it would be possible to improve the reliability and validity of assigned scores by including two scorers and averaging their scores for each batsman as demonstrated by Hardy (1984).

Bowling assessments

The bowling assessments were developed around the core constructs of accuracy and speed of delivery. Whilst the target-based scores did not discriminant between ability groups within Pilot Test 2, they did within Pilot Test 1 for the accumulation test. In a similar fashion as detailed for the Match Performance scenarios, Pilot Test 1 was deemed the most representative data from which to inform decisions, and hence, the assessments were proposed as viable additions to the skill-based inventory.

Given the discriminant validity of bowling speed within Pilot Test 1, in conjunction with the high test - retest correlation of Pilot Test 2, it would seem that bowling speed may be one parameter, by which to distinguish between current level of performance with respect to adolescent athletes. However, bowling speed is no-doubt a function of anthropometric and physiological parameters and the predictive validity is yet to be determined. It is of some concern that this discrimination may purely be the product of advanced maturity, which over time will be negated. In an informative study, Sherar, Baxter-Jones, Faulkner and Russell (2007) demonstrated the manner in which ice-hockey selectors systematically rewarded individuals who were advanced in biological maturity, regardless of the fact that their projected height and physiological attributes were similar. On this basis, it would be remiss to focus solely on physiologically related parameters in pace bowling assessments and additional measures should be retained, with emphasis placed on skill execution.

In most instances, the bowling and batting assessments were shown to have moderate to poor levels of reliability, whilst still generating a relatively high degree of discriminant validity. In part, the poor reliability may due to the relatively low participant numbers, 25 players (in excess of a number of other reliability studies of similar nature: Ali et al., 2007 and Russell et al., 2010), however Atkinson and Nevill (1998) do suggest a minimum of 40 players are required for reliability studies of this nature. What is perhaps initially perplexing is the manner in which assessments commonly generated discriminant findings with relatively moderate, or poor levels of reliability (such as the batting against pace assessment). Surely, for a test to generate discriminant validity there must be an underlying level of reliability? Whilst it is only possible to hypothesise, the lack of test - retest reliability may relate to the lack of consistency of skill execution in participants. The tests themselves may not necessarily be unreliable, but rather the tests may produce unreliable results because the participants may not be at the stage where they can consistently perform on the tests. Therefore, it is not a product of the tests, but rather the participants. In summary, reliability of these skill-based assessments is problematic and at the very least requires further examination.

Limitations

A number of limitations to the bowling and batting analysis are worth noting. Firstly, there was substantial modification of the protocols between Pilot Test 1 and 2. Most significant for batting was the removal of subjectivity of scoring, the randomisation of target order and the definitive designation of target positions. Within the pace bowling assessments substantial procedural changes, such as the adoption of a two-zone bowling target altered the amount of data collected, and these alterations need to be born in mind when considering the interpretation and comparison of findings. In addition, data collection of the bowling tests at Pilot Test 1 was hindered by ambiguity in the written protocol, which meant that some bowlers bowled at the yorker target before bowling at the bouncer target in both the accumulation and knockout test. Although in Pilot Test 2 the test - retest environments were identical for each player, the surfaces on which subsets of players bowled were different, and from an anecdotal position it was easy to see that bowling bouncers was more difficult on some surfaces. Furthermore, with respect to the Pilot Test 2 data, the differing ages and therefore maturational stages of university and school players is likely to have played a significant role in some parameters, such as bowling speed which is likely a function of physical maturity. Matthys, Vaeyens, Coelho-Silva, Lenoir and Philippaerts (2012) recent work would support this notion. They detailed significant differences in physiological and anthropometric factors between early and late maturing handball players. Interestingly, maturational differences had no bearing on sport-specific skills, which seems positive and would support the notion of skill-based assessments in talent identification practices.

In part, the structure of these tests and their scoring methods have been informed by the literature and on going reliability / validity analyses. A further factor has, however, been influential in dictating test content and structure, the preference of ECB national skill leads[3]. National skill leads have been particularly focussed on the underpinning educational principles that players could derive from completing EDP TT. For example, the pace bowling test utilises a relatively small target (in 2010 measuring 30 cm x 30 cm). The purpose of such a small target was to ensure that young bowlers realise the importance of delivering highly accurate balls, a ball that deviates by a few inches from the intended position may, in a game result in a completely different outcome, perhaps a wicket, versus 4 runs. Whilst this motive is understandable and the educational stance may be pertinent, it remains likely that a continuous measure, perhaps radial accuracy (in a similar fashion as adopted by Phillips et al., 2012) would provide a greater degree of reliability for the assessment. A further constraint from the ECB is the directive that EDP TT should assess approximately 80 to 100 players per year at each age group. Whilst there may be good rationale for broad talent identification catchment at relatively young ages, the participant numbers do constrain the number of deliveries and test protocol time per individual. Should a smaller group of 40 – 50 players be acceptable then protocol lengths could be doubled and potentially further improve the reliability of assessments.

Applied recommendations

As a result of Pilot Study 1 and 2, a number of recommendations were made to the ECB regarding the inclusion/exclusion of skill-based assessments. Firstly, with little

[3] As an ECB funded research project National skill leads impart a substantial influence over the on-going practices of EDP TT

discriminant validity it was proposed that the batting against spin test was redundant for EDP TT purposes. Secondly, batting against pace should be retained, however the findings clearly demonstrate the importance of familiarisation. Under the participant number limitation (as previously detailed) it would not be viable to conduct lengthy familiarisation (in excess of 36 balls per length and type) prior to undertaking the assessment at EDP TT. Therefore, it was proposed that protocols should be distributed to players, parents and coaches, with the suggestion of completing a minimum amount of practice prior to attending. Although this does have the potential to somewhat confound the results through commitment to practice, this was accepted on the basis that it reflects the 'real world' and that such an indirect behavioural measure of motivation could be of significant relevance when considering the long-term objectives of this research. Thirdly, the thin bat test was recommended as a worthwhile assessment, with the delivery numbers increased in order to improve the reliability and potentially the discriminatory power. Finally, it was suggested that the Match Performance Setting scenario should be removed from the battery of EDP TT assessments with, based largely on Pilot Test 1 discriminant findings, the Match Performance Chasing assessment retained. This has the additional benefit of maintaining an element of batting against spin.

Conclusion

In summary, the two Pilot Studies provide some rational for the inclusion/exclusion of skill-based assessment. It is important to note, that whilst the documented findings are informative, nothing can be said about the predictive validity of these measures, which is the primary objective of the broader research programme. For this reason, the researchers have proposed that a number of assessments (with varying levels of ecological validity) are retained.

Chapter 3

Pilot studies exploring the discriminant validity of age group cricket scouting

Research Progression

Chapter 2 examined the reliability and discriminant validity of five batting and two bowling tests, with the purpose of generating an informed and justified rationale for the inclusion, exclusion or modification of batting and bowling 'talent identification' tests. The battery of tests aimed to examine simple underlying attributes as well as more ecological representative abilities, which reflect the complexity of batting and bowling skill. The batting tests required batsmen to perform target-based assessments against spin- and pace-bowling machines, execute scenario-based performances, and execute batting skill with a thin bat. The bowling tests required the player to bowl accurately and with maximum speed at targets.

Batting against pace generated the greatest degree and consistency of discrimination between ability groups. Evidence was found in the thin bat test that simple measures of hand eye-coordination (quality of bat-ball contact) discriminated between ability levels. In addition, there was some evidence of a learning effect, suggesting that high ability batsmen learn and adapt to a greater extent than low ability batsmen. The match performance scenarios findings were variable, but did suggest some level of discriminant validity. Varying results were found within the bowling assessment for discriminant validity and reliability. Given that little can be said about predictive validity, it was concluded that it would be worthwhile to maintain a broad battery of skill-based assessments.

Given some criticisms of talent identification tests (sterile, and at points, unrepresentative e.g., Pinder, Renshaw, & Davids, 2013), the lead author considered other, more ecologically valid methodologies, which may account for unique variance when examining talent. Scouting, the process of observing athletes in the performance environment and concurrently evaluating against pre-defined criteria, provided an opportunity for assessment in an ecologically valid environment. In addition, through scouting, it may be possible to collect accurate psychological data without the limitations of self-report, interview, or personality based assessments, which are often confounded by social desirability, and self-presentation confounds.

In Chapter 3, a Scouting Guidebook and Form was devised that focussed on three core areas: skill, physiological and psychological variables, with the specific variables developed by the lead researcher and an applied team. Given the findings in Chapter 2 (discriminant validity across simple and complex measures of skill), emphasis was placed on ensuring that the Scouting Form examined holistic skill-based abilities (e.g., overall performance) as well as narrower technique-based abilities (e.g., defending versus pace). An existing ECB psychological framework was used as the basis for psychological assessment. In the main, this was derived from the work of Bull, Shambrook, James and Brooks (2005) and their examination of mental toughness in cricket.

Two studies were conducted, examining (i) the discriminant validity of scouting assessments (skill, physiological and psychological), and (ii) the most accurate methodologies (indoor versus outdoor, multiple versus single observations, multiple versus single scouts) through which scouting could be conducted. In a similar fashion to Chapter 2, discriminant validity was examined, prior to the examination of longitudinal data sets. Accurate scouting methodologies were examined from a theoretical perspective (e.g., forecasting techniques) and an applied perspective (e.g., what is the most appropriate mechanism for collecting scouting reports with finite resource).

Fifty-eight male under-15 players were observed on 148 occasions in study 1. In study 2, seventy-six under-15 players were observed on 275 occasions. Players were categorised as very-high ability (selected), high ability (short-list) or low ability (long-list) for discriminant analysis. Results revealed that scouting may have substantial utility in differentiating between player ability. Skill-based ratings consistently discriminated between high and low ability players. Psychological ratings were the only variables that discriminated between very high and high ability players. Initial findings are supportive of scouting as a talent identification methodology, most likely, because of the high levels of ecological validity, combined with the role of intuitive appraisal by experts. The research provides some support for the role of motivation and perseverance as key determinants of high-level athletic success. Effective methodological parameters for scouting are discussed.

Talent identification is becoming an integral aspect of the professionalised elite sporting environment. As Martindale, Collins and Abraham (2007) stated, "talent identification and development (TID) is currently big business. Undoubtedly, effective systems will help enhance the quality and sustainability of our elite level teams, bringing with it large financial rewards and recognition" (p. 187). However, controversy does exist regarding the shape and format that talent identification should adopt; it is the focus of much deliberation in the burgeoning area of talent identification: "there remains a lack of consensus in relation to how talent should be defined or identified and there is no uniformly accepted framework to guide current practice" (Vaeyens, Lenoir, Williams & Philippaerts, 2008, p. 703). In addition, Abbott and Collins (2002) drew attention to the manner in which talent identification schemes have typically focused on singular factors rather than take a multifaceted approach. More recently, this limitation has been addressed in a number of schemes, which place greater emphasis on psychological profiling, technical skills and tactical awareness (see Elferink-Gemser, Visscher, Lemmink & Mulder, 2007; Falk, Lidor, Lander & Lang, 2004). Whilst the research is somewhat embryonic and not without significant limitation, it does provide some support for a broad multifaceted approach to talent identification.

Although the shift towards multi-faceted approaches is a seemingly positive development, criticisms have been, and will continue to be made, regarding the sterile nature of talent identification methodology. In open loop sports such as cricket, skills are not performed in stable environments but are dynamic and shaped by temporal and spatial variability, dependent on the opposition's play, tactics, players' interpretation, and pressure. Hackfort (2006) suggests that when designing and implementing talent assessments, it is crucial to ensure that human actions are viewed as dynamic interrelations between both the players performing the task and the environment in which the skill is being observed. This philosophy is supported by the work of Ericsson and Charness (1994), who highlight the need to ensure that studies of expertise utilise representative tasks. Arguably, the only method through which true representativeness can be achieved is through assessment in the 'natural' environment. Scouting, the process whereby players are observed performing in the competitive environment and concurrently evaluated against a number of sport specific, psychological and physiological criteria, provides a potential mechanism through which an ecologically valid representation of performance can be gained.

Perlini and Halverson (2006) and Tingling, Masri and Martell (2011) detail the manner in which scouting has been used to identify the best prospects in the National Hockey League (NHL). Players are graded on a number of 'job-related' criteria and the higher a player is assessed on the scouting report, the higher the player is rated in the draft and the more attractive the player is deemed to be to the team. Given the predictive element of any draft decision, effectively an insinuation about how the player may develop or perform over time, the constituent elements and predictive validity of the 'job-criteria' are crucial. Broadly, these constituent elements can be summarised in three categories: skill-based ability, psychological attributes and physiological parameters.

From a skill-based perspective (technical and tactical) it is easy to see why scouting has been adopted in a number of open loop sports (e.g., NHL, National Football League and Premier League Football Academies). Scouting provides an opportunity for assessment of dynamic, skill-based attributes that are highly dependent on the environment, and less easily quantified through prescriptive tests that may lack ecological validity. Although not as common, scouting of psychological attributes may have substantial utility over and above self-report, interview, or personality-based psychological assessments, which are often atheoretical and troubled by social desirability and self-presentation confounds (e.g., Gee, Marshall & King, 2010). Indeed, there is growing empirical support that the psychological characteristics of elite athletes may be a key determinant of senior success (Durrand-Bush & Salmela, 2002; Gould, Dieffenbach & Moffett, 2002; Gould, Weiss & Weinberg, 1981; Orlick & Partington, 1988). However, as yet, little has been established regarding the importance, development of, and expression of these attributes during athlete development. Longitudinal research seeking to explore the discriminant and predictive value of such attributes would mark substantial progression. In contrast to skill and psychological attributes, there is some evidence to support the assertion that physiological parameters may be better assessed by standard testing protocols (Gonaus & Müller, 2012). Regardless, there is a need to empirically establish the value of scouting physiological variables.

In addressing the topic of scouting, a question remains as to the mechanism underpinning effective scouting. Whilst on occasions scouting has been criticised for being overly subjective (Burgess & Walters, 2009), there are extensive bodies of work that provide compelling evidence for the role of intuitive decision-making by experts. Indeed, the Naturalistic Decision Making (NDM) approach (Klein, 1999) clearly details that under certain conditions (a given predictability of the environment in which the judgment is made, and, opportunity for the individual to learn the regularities of the environment) intuitive decision-making holds substantial utility. The value of such decision-making, has been documented in numerous fields such as nursing (Crandall & Getchell-Reiter, 1993), horse racing experts (Ceci & Liker, 1986), live-stock judges, and test pilots (Shanteau, 1992). Furthermore, recent research by Bechara, Damasio, Tranel and Damasio (1997) documents the biological basis and importance of unconscious biases in intuitive decision-making. As Klein (1999) contends, the ambiguity around intuitive decision-making arises because experts have difficulty explaining the basis of their judgments, and in some fields, (e.g., economic) there is a lack of predictability in the environment, combined with misplaced confidence in expert judgment. A further point is noteworthy; a common finding in studies examining the accuracy of judgments in a creative context, is the manner in which *experts* tend to agree in their appraisals, with inter-rater reliabilities in excess of .80 (Baer, Kaufman & Gentile, 2004; Kaufman, Lee, Baer, & Lee, 2007). This is in contrast to non-experts, who demonstrate far lower levels of agreement, and would support the argument that valid scouting requires suitably skilled personnel. In reverting back to the current context, a systematic scouting process with defined variables, experienced scouts, and opportunity for learning, may have substantial utility in the quest to accurately understand player ability and potential.

Whilst scouting is commonplace in American sport (e.g., NHL, NFL, MLB) and widely adopted in Premiership Football Academies (Williams & Reilly, 2000), it is yet to be implemented as a mechanism of assessing players in many British sports. This is somewhat surprising given the relative ease (in comparison to large scale talent identification assessments) and the potential reward of observing players in their performance environment. Perhaps more surprising, given the significant financial investment in scouting, estimated at several million US dollars for an average NHL team (Joyce, 2007), is the lack of research and quantitative evidence in support of the discriminant / predictive validity of scouting assessments and, or, the best mechanism by which to scout. No doubt, the requirement to maintain a competitive advantage and private ownership of clubs is in part responsible for the lack of published research. However, independent scouting organisations and growing evidence in support of analytical selection processes (Wolfe et al., 2007) would suggest that research in this area is worthwhile. Indeed, Williams and Reilly (2000) called for greater academic access: “clubs should also allow sports scientists greater access to those involved in the talent identification process. Scientists need to determine the nature of the subjective and implicit criteria that coaches and scouts use to identify talented players” (p. 664). To the author’s knowledge, very little has changed on this front over the past 10+ years. As such, the point of this series of studies was to explore effective scouting processes and the utility of scouting as a means of discriminating between, and in time, predicting player ability.

The following analyses focus on an embryonic, but developing scouting programme that was implemented by the England and Wales Cricket Board (ECB), with the aim of rigorously and coherently assessing the best prospects for the under-16 England Development Programme (EDP; a four year programme aimed at developing future world class England players). The process was initiated in 2011, after which preliminary pilot analysis was completed (Study 1). After slight modification, the scouting process was repeated in 2012 on a more extensive basis, allowing comprehensive investigation (Study 2). The two data sets provided opportunity for work examining two broad questions. Firstly, what variables; skill-based, psychological or physiological, are of greatest discriminant validity in differentiating between player ability? And, secondly, what is the most appropriate method to scout and gain accurate player appraisals? This question was broken down into a number of constituent questions that focussed on (i), the value of indoor versus outdoor scouting, (ii), the value of scouting the player on single versus multiple occasions, and (iii), whether multiple appraisals from the same, or multiple appraisals from different, scouts yield more representative player appraisals.

Study 1

Method

Participants. Male under-15 (U15) cricket players that were deemed to have ‘demonstrated potential’ were nominated by County Academy Directors (CAD’s) and Emerging Player Programme Head Coaches (EPPHC’s) to feature on an U15 EDP scouting list. All players’ date of birth fell between 31/08/94 and 01/09/95. The list comprised 58 players (M_{age} = 15.0, *SD* = 0.32). All nominees were England qualified.

Measures: 2011 Scouting Form. The ECB National Performance Manager, four Regional Performance Managers and lead coaches constructed a Scouting Guidebook[4] and Scouting Form. The Guidebook was implemented with a view to ensuring that EDP scouts operated in a coherent and consistent fashion. The Guidebook detailed all criteria against which players were to be assessed, EDP Talent Profiles[5] and details of the scouting process. The Scouting Form consisted of 3 sections; these were discipline (batting, pace bowling, spin bowling, wicket keeping and fielding), psychological and physical attributes. Each discipline section of the Scouting Form was constructed of 6-7 items that included overall performance, technical ability and tactical awareness. Additional items were: for batting - defends versus pace, attacks versus pace, defends versus spin, and attacks versus spin; for pace bowling - pace and bounce, control, lateral movement, and variation; for spin bowling - spin, variation and control; and, for fielding - catching, throwing, stops, and athletic movement.

Each item was scored on a 4-point likert scale. The scale referred to the quality of the skill performed, with individual descriptors assigned to each point of the likert scale. For example, descriptors attached to the batting likert scale, 'overall performance' were: (1) performs poorly against his peers at County and Regional levels, (2) sometimes performs well against his peers at County and Regional levels, (3) produces consistently good performances against his peers in County and Regional cricket and (4) consistently out-performs and dominates his peers in County and Regional cricket. The scout was requested to assign the score (1-4), which was most representative of the player when observed. In order to support the scouts in their player appraisal, a number of prompts in the form of rhetorical questions were provided for each quality item of the scouting report. These were derived from the ECB's national Talent Profiles. For example, the batting 'overall performance' item utilised the following prompts: Does he appear in control and able to perform in any situation

[4] The Scouting Guidebook can be requested from the England and Wales Cricket Board.
[5] An internal ECB document detailing desirable characteristics for players to demonstrate at each stage of the pathway.

/ conditions? And, does he consistently produce match-winning performances? (p. 6, 2011 EDP Scouting Guidebook).

The psychological section of the Scouting Form contained eight items. These were derived from the work of Bull, Shambrook, James and Brooks (2005) and an allocution from the ECB England cricket coach, detailing the values that are expected of players at the highest level. It is noteworthy, that whilst there is some academic rigour behind the psychological variables, they are not without limitation, having been derived from retrospective and qualitative research. Regardless, the eight items are a variable set that has been adopted and operationalised by the ECB for applied purposes. The eight items can be summarised in three categories: mental toughness, other talent-related variables, and values.

The mental toughness items included fight, the player's desire to thrive in high-pressure competitive scenarios, originally documented in the seminal article on mental toughness by Jones, Hanton and Connaughton (2002). The second item, inner drive, relates to continued self-motivation and perseverance, a trait that has been consistently recognised as a distinguishing characteristic of achievement in a sport, and non-sporting context (see Durrand-Bush & Salmela, 2002; Gould, Dieffenbach & Moffett, 2002 and Duckworth, Peterson, Matthews & Kelly, 2007 respectively). The third, critical moment control, is the ability to "make the right decisions and choose the right options under conditions of extreme pressure, even when the situation contains ambiguity" (Jones, Hanton and Connaughton, 2007, p. 255). The final mental toughness item was resilience, referring to positive adaptation in the face of significant adversity (Luthar, Cicchetti & Becker, 2000), essentially the ability to 'bounce back' after setbacks.

The talent-related variables were coping with emotions and capacity for change. Coping with emotions is not a new concept in sport psychology, originally proposed in 1977 by Mahoney and Avener. Athletes who posses this ability, can regulate their feelings so they are in the correct frame of mind for performance. Whilst the sport-specific evidence underpinning capacity for change (otherwise termed ‘ability to learn’ or ‘coachability’), as a key determinant of athlete development is weak, the intuitive, anecdotal, and qualitative evidence (see Bloom, 1982; Gould, Diffenbach & Moffett, 2002; Hill, 2012) provides a rationale for its inclusion. In addition, seminal work by Thorndike (1908) in educational psychology, clearly demonstrated differential ‘learning’ abilities within a population, when individuals were exposed to the same amount of practice. Ackerman (1999) has furthered these findings, demonstrating the manner in which the more complex the learning task, the greater the differentiation in learning ability. Whilst these findings are yet to be replicated in a sporting context, it would be remiss not to hypothesise as to the importance of capacity for change in athletic development.

The values espoused by the England cricket coach, and subsequently contained within the psychological section were, team player and honesty. With these underpinning values embraced by senior ECB personnel, they may be of importance when recruiting young athletes. All psychological constructs were scored on a 4-point likert scale where, 1 = demonstrates little-, 2 = demonstrates some-, 3 = demonstrates good-, and 4 = demonstrates excellent-levels of the respective variable.

The physiological section of the scouting form was comprised of seven items: injury status, speed, strength, endurance, agility and body composition. These were derived from the ECB Talent Profiles and input from the EDP Strength and Conditioning Coach. These were scored on a 4-point likert scale with specific descriptors for each item.

Procedure. The scouting list was broken down by region and scouting assignments were delegated to four Regional Performance Managers (RPM’s) and six Regional Scouts. Regional Scouts were appointed by the ECB based on their familiarity and experience with county age group cricket, professional cricket and the ECB pathway. RPM's and Regional Scouts underwent training in the form of a 1-day workshop prior to undertaking any scouting.

In an effort to triangulate observations about both the 'player' and the 'person', scouts were encouraged to find appropriate opportunities to talk to coaches, umpires and opponents. These conversations were with the purpose of gaining a well-rounded opinion of the player and were detailed in the qualitative section of the scouting report, but may also have been used to inform scoring on the likert scales. Initial scouting was conducted between April and June 2011. Each time a player was viewed, the scout was required to submit a new scouting report using the ECB's online Talent Tracking database.

In late June, the EDP selectors conducted a selection process that generated a 'reduced list' of high potential players (n = 24). Selections were informed by players' performance statistics, county reports, input from national skill lead coaches, summary scouting reports, evidence presented by RPM's / Regional Scouts, and predominantly, performances at regional trials. The 24 selected players were scouted on subsequent occasions until the end of August 2011. At this point, a second selection meeting was convened and 10 players deemed to have the greatest potential were invited to join the U16 EDP. For the purpose of analysis, these players are referred to as 'selected'. The final selections were informed by the same data sources, with the addition of performances at Bunbury Cricket Festival (national U15 cricket competition). The lead researcher was present at all selection meetings, and whilst the scouting process was implicit within the selection process, it was one data source of many.

Statistical analysis. In order to explore (a), the discriminant validity of scouting reports, and (b), the most appropriate processes through which to conduct effective scouting, three independent tests were run on each discipline specific section of the Scouting Form (batting, pace bowling, spin bowling and fielding). For each skill, independent t tests were conducted on the core variables of overall performance, technical ability and tactical awareness[6] (dependent variable), resulting in twelve t tests (4 disciplines x 3 t tests). Selection stage (long list versus short list) was utilised as the independent variable.

A univariate, rather than multivariate approach was adopted due to the highly exploratory nature of the work. Although this increased the chance of generating a Type I error (i.e., rejecting the null hypothesis when it is true) the research structure, re-examination under a more refined statistical approach in Study 2, negated this issue. Furthermore, the authors adopted an alpha level of $p < .05$ under a two-tailed, rather than one-tailed hypothesis, in order to ensure a degree of conservatism.

Given that the objective of this exploratory work is two fold; to understand the discriminant value of scouting *and* understand the impact of different scouting processes (e.g., indoor versus outdoor scouting), the trend in significance and effect size is of primary importance, not solely, the significance value. Partial eta-squared values (η_p^2) were computed to determine the proportion of total variability attributable to each variable. As detailed by Cohen (1988), η_p^2 values between .2 and .5 were considered small, between .5 and .8, medium, and those > .8, large.

For batting analyses, only 1st discipline batsmen were included. This was on the basis that it would provide an accurate data set to compare skill-based differences, without the confound of 'tail-end' batsmen. As the majority of scouting was conducted in county age-group cricket, where players would only bowl if they were perceived to be high potential, all players scouted whilst bowling were included in analyses. All fielding data was included in the analyses. It is noteworthy that growing emphasis within the EDP is placed on age-group fielding ability, given the requirement at senior level to be a multi-dimensional cricketer.

[6] For the sake of simplicity, only analyses for the three core variables have been presented in the manuscript. Analyses of the remaining items for each discipline can be found in appendix 1.

Results

In total, 148 scouting reports were filed on 56 U15 players in 2011. Descriptive statistics are presented in Table 7.

Table 7

Descriptive statistics detailing player numbers and number of reports filed

Year	Number of players	Total reports	Selection stage	Number of players	$M_{reports}$	(SD)
2011	56	148	Long list	32	2.2	(1.4)
			Short list	24	3.1	(1.6)
			Short list	14	2.6	(1.7)
			Selected	10	3.8	(1.2)

Due to a lack of familiarity with the psychological and physiological constructs, scouts were reticent about completing this section of the scouting report. As such, there was much missing data and no analysis was performed on the psychological and physiological variables.

Discriminant validity. ***Skill-based data.*** In order to establish which scouting variables were most discriminating of ability, 12 independent t tests were conducted on the core, batting, pace bowling, spin bowling and fielding variables (overall performance, technical ability and tactical awareness). As multiple reports were filed on each player, the average score was calculated for each item for use as the dependent variable. Independent t tests revealed that short list players scored significantly higher than long list players for overall performance, technical ability and tactical awareness when spin bowling and fielding. When batting and pace bowling, short listed players scored significantly higher than long listed players for tactical awareness, but not for overall performance or technical ability (Table 8).

Table 8

Results of independent t tests comparing short and long listed players – All reports

		All reports	
		T value	η_p^2
Batting (1st discipline)	Performs	$t_{(12)}$ 2.00	.25
	Technical	$t_{(12)}$ 1.25	.12
	Tactical	$t_{(9)}$ 4.87**	.43
Pace bowling	Performs	$t_{(16)}$ 1.40	.11
	Technical	$t_{(16)}$ 1.77	.16
	Tactical	$t_{(16)}$ 2.93*	.35
Spin bowling	Performs	$t_{(12)}$ 2.66*	.37
	Technical	$t_{(12)}$ 2.83*	.40
	Tactical	$t_{(12)}$ 2.22*	.29
Fielding	Performs	$t_{(48)}$ 3.80**	.23
	Technical	$t_{(44)}$ 3.99**	.24
	Tactical	$t_{(48)}$ 2.30*	.10

Note: ** $p < .01$, * $p < .05$

Scouting parameters. ***Indoor versus outdoor scouting reports.*** In order to assess the contribution of indoor scouting, reports filed during the indoor scouting period were removed (those filed prior to May 1st 2011). This reduced the total number of scouting reports by 21, however the total number of players scouted remained the same across all disciplines. With indoor scouting reports removed, the same 12 independent t tests examining the differences between short and long listed players were conducted, with scores for overall performance, technical ability and tactical awareness (batting, pace bowling, spin bowling and fielding) acting as the dependent variables. Short list players scored significantly higher for nine of the twelve variables (Table 9). A descriptive comparison of these independent t tests (outdoor scouting), with those of the previous analysis (indoor and outdoor scouting) revealed similar effect sizes for batting, spin bowling, and fielding variables (Table 8 & 9). Interestingly, the pace bowling data generated greater effect sizes for all variables when considering only outdoor reports.

Table 9

Results of independent t tests comparing short and long listed players – Only outdoor reports

		Outdoor reports	
		T value	η_p^2
Batting (1st discipline)	Performs	$t_{(12)}$ 1.97	.24
	Technical	$t_{(12)}$ 1.16	.10
	Tactical	$t_{(9)}$ 4.87**	.43
Pace bowling	Performs	$t_{(16)}$ 1.80	.17
	Technical	$t_{(16)}$ 2.19*	.23
	Tactical	$t_{(16)}$ 3.54**	.44
Spin bowling	Performs	$t_{(12)}$ 2.26*	.30
	Technical	$t_{(12)}$ 2.84*	.40
	Tactical	$t_{(12)}$ 2.33*	.31
Fielding	Performs	$t_{(48)}$ 3.78**	.23
	Technical	$t_{(44)}$ 2.22**	.25
	Tactical	$t_{(48)}$ 2.35*	.10

Note: ** $p < .01$, * $p < .05$

Multiple versus single scouting reports. The discriminant analysis (12 independent t tests) were performed on the 1st report of the outdoor data set with initial selection stage (long list versus short list) utilised as the independent variable. A comparison was then made with the results from the outdoor only data analysis.

Independent t tests on overall performance, tactical awareness and technical ability, detailed significantly greater scores for short-listed players on eight of the twelve variables (Table 10). Lower effect sizes were observed for eight of twelve variables when comparing the single report to multiple reports (Table 9 & 10), supporting the assertion that a more accurate player appraisal is achieved through combining multiple reports.

Table 10

Results of independent t tests comparing short and long listed players – 1st outdoor report

		1st outdoor report T value	η_p^2
Batting (1st discipline)	Performs	$t_{(12)}$ 2.47*	.34
	Technical	$t_{(12)}$ 1.69	.19
	Tactical	$t_{(9)}$ 3.67**	.30
Pace bowling	Performs	$t_{(16)}$ 2.13*	.22
	Technical	$t_{(16)}$ 2.80*	.33
	Tactical	$t_{(16)}$ 3.41**	.42
Spin bowling	Performs	$t_{(12)}$ 1.90	.23
	Technical	$t_{(12)}$ 2.48*	.34
	Tactical	$t_{(12)}$ 2.04	.26
Fielding	Performs	$t_{(48)}$ 3.33**	.19
	Technical	$t_{(44)}$ 3.78**	.21
	Tactical	$t_{(48)}$ 1.93	.07

Note: ** $p < .01$, * $p < .05$

Multiple versus single scouts. The scouting process involved scouting the same individual on several occasions. In doing so, players were frequently observed on multiple occasions by both the same, and different scouts. Pilot analysis was conducted in order to establish whether two reports from the same scout, or two reports from different scouts generated a greater level of discriminant validity. Analysis of this nature has the potential to inform effective deployment of scouts.

The data was filtered to include every player that had been scouted twice by the same scout. The score across both reports for each variable was averaged and independent t-tests were completed on overall performance, technical ability and tactical awareness (dependent variable). In a similar fashion, the data was filtered to include every player that had been scouted twice by different scouts, with independent t tests completed in the same fashion. As relatively few pace and spin bowlers had been scouted twice by the same scout, it was not possible to run separate analyses on these disciplines. Instead, the pace and spin bowlers were combined into one bowling group for comparative analysis.

Table 11

Results of independent t tests comparing short and long listed players for two reports from different scouts and the same scout

		Different scouts – 2 reports averaged		Same scout – 2 reports averaged	
		T value	η_p^2	T value	η_p^2
Batting (all)	Performs	$t_{(22)}$ 1.44	.09	$t_{(17)}$ -0.13	.00
	Technical	$t_{(22)}$ 0.03	.00	$t_{(17)}$ -0.33	.01
	Tactical	$t_{(22)}$ 1.84	.13	$t_{(17)}$ -0.61	.06
Bowling	Performs	$t_{(12)}$ 2.52*	.35	$t_{(11)}$ 0.22	.00
	Technical	$t_{(12)}$ 2.37*	.32	$t_{(11)}$ 1.11	.10
	Tactical	$t_{(12)}$ 4.69**	.65	$t_{(11)}$ 2.46*	.36
Fielding	Performs	$t_{(11)}$ 1.72	.16	$t_{(16)}$ 0.10	.06
	Technical	$t_{(18)}$ 2.10*	.20	$t_{(16)}$ 1.07	.07
	Tactical	$t_{(18)}$ 1.88	.17	$t_{(16)}$ 1.09	.13

Note: ** $p < 0.01$, * $p < 0.05$

Eight of the nine independent t tests revealed greater effect sizes when two reports from different scouts were averaged, as opposed to when two reports from the same scout were averaged (Table 11). To establish whether this value (eight of nine) deviated significantly from the expected value (n = 4.5) a chi-squared test was conducted; this revealed a significant effect: $x^2(1) = 5.44$, $p = .02$.

Discussion

With significant effects and meaningful effect sizes documented throughout the statistical analyses (Table 8-10), there is clearly some value in scouting as a means of differentiating between player ability. However, in general, the analyses were somewhat limited by the low participant numbers and a lack of psychological and physiological scouting data. As such, the aim of Study 2 was to conduct similar analysis on a larger data set, with a view to exploring psychological / physiological scouting data and extending initial skill-based findings.

Preliminary findings from Study 1, did suggest that the most accurate appraisal of cricketers is gained by scouting players on multiple occasions in an outdoor environment. Furthermore, it would seem that utilising multiple scouts rather than the same scout repeatedly, elicits a clearer representation of player ability. Presumably, scouts are either biased by what they have previously seen of the player, or, have a tendency to observe similar characteristics when re-scouting players.

It is noteworthy, that the involvement of the researchers in the 2011 scouting process highlighted two significant limitations within the scouting form. Firstly, on occasions, dual constructs were contained within the same item. This was the case for pace bowling (production of pace *and* bounce) and fielding (power *and* accuracy of throwing). Clearly, splitting each item into individual constructs would allow the scout to differentiate between attributes that are presumably, to some greater or lesser extent, independent of each other. Secondly, the likert scale descriptors often included aspects of skill *and* frequency. In constructing the 2011 Scouting Form, ECB personnel had combined aspects of frequency (sometimes and consistently) with the quality of skill execution (poorly, well, good and out-performs). Furthermore, this was only the case on certain points of the likert scale (point 2, 3 and 4 in the documented example). Consequently, the 2012 Scouting Form was revised with the aim of removing dual constructs and assigning clear progressive descriptors to the likert scale.

Study 2

Method

Participants. Seventy-six male U15 players (M_{age} = 15.2, *SD* = .33) were nominated by CAD's and EPPHC's to feature on the 2012 EDP scouting list. All nominated players were England eligible and deemed to be of high potential.

Measures: 2012 Scouting Form. Two changes were made to the Scouting Guidebook and Form. Firstly, the dual construct items for pace bowling and fielding were split into separate items. Secondly, the likert scale for all skill-based items was simplified such that (1) = performs poorly relative to his peers in County and Regional cricket, (2) =

performs well relative to his peers in County and Regional cricket, (3) = performs very well relative to his peers in County and Regional cricket, and (4) = out-performs his peers in County and Regional cricket. In this way, there was no reference to frequency; instead, the scout was required to assign the score (1-4), which they felt was most representative of the player when observed.

In Study 2, an increased emphasis was placed on the filing of complete reports, particularly with respect to the psychological and physiological section. The EDP's performance psychologist provided training during two, one-day workshops on the psychological variables. In assessing the psychological characteristics, the scouts were encouraged to find appropriate opportunities to engage with the player's county coach, county psychologist, and any significant other who might be able to provide a valuable insight into the player's psychological character.

Procedure. Regional Scouts and RPM's were designated scouting assignments and required to submit reports online using the ECB's talent tracking database. Scouting commenced in April 2012 at the beginning of the outdoor season and ran until the end of June 2012 when the scouting list was shortened. This generated a reduced list of high potential players (n = 30), with subsequent scouting conducted until the end of July when nine players were selected for the EDP.

Statistical analysis. In order to develop a greater understanding of (a), the discriminant validity of scouting reports, and (b), the most appropriate processes through which to conduct effective scouting, a more in-depth statistical analysis framework was devised. For each skill, two Hotelling's T^2 tests and an independent t test were conducted. Hotelling's T^2 tests were conducted on those variables within each discipline deemed to be theoretically linked. Technical and tactical ratings were combined in the first multivariate analysis. These variables represent the cricketer's overarching performance within the game context. Discipline specific variables within each discipline were combined for the second Hotelling's T^2 tests. These variables were: for batting - defends versus pace, attacks versus pace, defends versus spin, and attacks versus spin; for pace bowling – pace, bounce, control, lateral movement, and variation; for spin bowling - spin, variation, and control; and, for fielding - catching, throwing, stops, and athletic movement. Univariate *t*'s were conducted as a post-hoc procedure following a significant multivariate result. Overall performance for each discipline was analysed via an independent t test. Selection stage (long list versus short list) was utilised as the independent variable in analyses.

Hotelling's T^2 tests were completed on the mental toughness items, other talent related items and values in order to examine between group differences. As with the skill-based data, univariate *t*'s were conducted following a significant multivariate effect.

Exploratory analysis was conducted on the six physiological items. Each item was analysed via an independent t test. A univariate approached was adopted because of the lack of theoretical relationship between items (e.g., agility, endurance, and injury status). Partial eta-squared values (η_p^2) were computed to determine the proportion of total variability attributable to each variable or combination of variables, for both multivariate and univariate analyses. Further to the previously documented effect sizes for independent t tests, effects sizes for multivariate analyses were adopted where, η_p^2 values of between .10 and .25 were considered small, between .25 and .40, medium, and those > .40, large. Statistical significance was set at $p < .05$ for all analyses.

Results

Two hundred and seventy-five reports were filed on 76 U15 players. Descriptive statistics are presented on the following page (Table 12).

Table 12

Descriptive statistics detailing player numbers and reports filed

Year	Number of players	Total reports	Selection stage	Number of players	$M_{reports}$	(SD)
			Long list	46	3.2	(1.6)
			Short list	30	4.2	(1.9)
2012	76	275				
			Short list	21	4.1	(2.0)
			Selected	9	4.3	(1.6)

Multicollinearity diagnostics were conducted on each discipline. In line with Myers (1990) recommendations that variance inflation factors in excess of 10 are cause for concern, multicollinearity did not seem to be problematic, with the greatest values being 6.5, 3.8, 2.9 and 1.8 for pace bowling, fielding, batting and spin bowling respectively.

Discriminant validity. ***Skill-based data.*** *Long list versus short list.* As multiple reports were filed on each player during the 2012 scouting process, the average score was calculated for each variable and was utilised as the dependent variable.

Multivariate analysis for technical ability and tactical awareness, revealed significant effects for batting (associated $F(2, 28) = 11.03$, $p < .00$, $\eta_p^2 = .44$), pace bowling (associated $F(2, 24) = 6.87$, $p < .00$, $\eta_p^2 = .36$) and spin bowling (associated $F(2, 15) = 8.77$, $p < .00$, $\eta_p^2 = .54$), but not for fielding (associated $F(2, 63) = 2.76$, $p = .07$, $\eta_p^2 = .08$). Univariate follow-up tests for significant multivariate tests can be found in Table 13.

Hotelling's T^2 for the discipline specific items, revealed significant multivariate effects between long and short list players for batting (associated $F(4, 26) = 4.68$, $p = 0.01$, $\eta_p^2 = .42$), and spin bowling (associated $F(3, 14) = 4.73$, $p = 0.02$, $\eta_p^2 = .50$), but not for pace bowling (associated $F(5, 21) = 2.36$, $p = .08$, $\eta_p^2 = .36$) or fielding (associated $F(5, 60) =$

1.18, p = .33, η_p^2 = .09). Univariate follow-up tests for batting and spin bowling are shown in Table 13.

Table 13

Results of univariate follow-up tests, to significant Hotelling's T^2 tests

		All / Outdoor reports T value	η_p^2
Batting	Technical ability	$t_{(29)}$ 4.51**	.41
	Tactical awareness	$t_{(29)}$ 3.57**	.31
	Defends versus pace	$t_{(29)}$ 4.12**	.37
	Attacks versus pace	$t_{(16)}$ 2.19	.14
	Defends versus spin	$t_{(29)}$ 3.44**	.29
	Attacks versus spin	$t_{(29)}$ 1.50	.07
Pace bowling	Technical ability	$t_{(25)}$ 2.75*	.23
	Tactical awareness	$t_{(25)}$ 2.85**	.25
Spin bowling	Technical ability	$t_{(16)}$ 2.84*	.33
	Tactical awareness	$t_{(16)}$ 4.02**	.50
	Spin	$t_{(14)}$ 4.16**	.37
	Variation	$t_{(16)}$ 1.78	.17
	Control	$t_{(16)}$ 2.76*	.32

Note: ** p < .01, * p < .05

Table 14

Results of independent t tests comparing short and long listed players on overall performance

	All / Outdoor reports T value	η_p^2
Batting (1st discipline)	$t_{(16)}$ 3.81**	.37
Pace bowling	$t_{(11)}$ 3.37**	.38
Spin bowling	$t_{(16)}$ 3.85**	.48
Fielding	$t_{(64)}$ 1.31	.03

Note: ** p < .01, * p < .05

Independent t tests examining the difference between long and short listed players for overall performance, revealed significant differences for three of the four disciplines, with short-listed players scoring higher. The variable that did not reveal a significant effect was overall performance when fielding (Table 14).

Short list versus selected. In order to establish the discriminant validity of scouting reports at a higher skill level, the generic analyses framework (Hotelling's T^2 tests and an independent t test) was conducted at the subsequent EDP selection stage, short list versus selected. Data from all reports were averaged for use as the dependent variable. No significant differences were revealed between short list and selected players in any analysis.

Psychological based scouting data. *Long list versus short list.* Whilst in Study 1, complete scouting reports, particularly with respect to psychological data were rarely filed, in Study 2, 57 of the 76 long listed players received at least one complete psychological submission (see Table 15 for further descriptive details). As such, preliminary analysis of the discriminant validity of psychological reporting was conducted.

Table 15

Descriptive statistics detailing player numbers and reports filed for psychological and physiological data

Scouting category	Number of players	Total reports	Selection stage	Number of players	$M_{reports}$	(SD)
Psychological	57	157	Long list	31	2.7	(1.5)
			Short list	26	2.8	(1.7)
			Short list	17	2.7	(1.8)
			Selected	8	3.1	(1.5)
Physiological	66	217	Long list	38	3.1	(1.9)
			Short list	28	3.6	(2.1)
			Short list	19	3.4	(2.4)
			Selected	9	4.0	(1.3)

Hotelling's T^2 tests were conducted on the mental toughness related variables (fight, inner drive, critical moment control and resilience), the other talent related variables (capacity for change and coping with emotions), and the value based variables (team player and honesty). A multivariate effect was revealed for mental toughness (associated $F(4, 52)$ =

2.48, $p = .04$, $\eta_p^2 = .18$). Univariate follow-up tests revealed significant effects for two of four variables; fight: $t(55) = 2.94$, $p = .01$, and resilience: $t(55) = 2.80$, $p = .01$. A multivariate effect was also revealed when comparing long and short-listed players on the talent related psychological variables (associated $F(2, 54) = 7.19$, $p < .00$, $\eta_p^2 = .21$). Follow-up tests revealed significant differences between groups, with short-listed players scoring higher for coping with emotions $t(55) = 3.57$, $p < .00$. A multivariate effect was not revealed for the value-based variables (associated $F(2, 54) = 2.28$, $p = .11$, $\eta_p^2 = .08$).

Short list versus selected. Hotelling's T^2 tests were completed on the mental toughness, other talent related and value-based variables, in the same fashion as previously detailed, but with the independent variable altered to short-list versus selected players. A multivariate effect was revealed for the mental toughness related data (associated $F(4, 21) = 3.38$, $p = .03$, $\eta_p^2 = .39$) with univariate follow-up tests showing short-list players scored significantly higher on inner drive ($t(24) = 3.72$, $p < .00$). There was no multivariate effect when comparing short-list and selected players on the other talent related or value-based items (associated $F(2, 23) = 2.36$, $p = .12$, $\eta_p^2 = .17$; associated $F(2, 23) = 0.66$, $p = .52$, $\eta_p^2 = .06$ respectively).

Physiological based scouting data. *Long list versus short list.* With 66 of the 76 long listed players scouted from a physiological perspective, exploratory analysis was completed on the physiological items. Each item was analysed via an independent t test with selection stage (long versus short list) utilised as the independent variable. For players who had been scouted more than once, the average value was calculated for each item for use as the dependent variable.

Analysis of all players (regardless of discipline) did not reveal significant effects for any item (all t values < 0.9). However, as pace bowling is the most physiologically demanding skill and therefore, potentially, most closely related to physiological scouting, the analysis was repeated on this discipline group. No significant differences were revealed, however, there was some evidence of short-list players displaying higher levels of agility than long-list players (t(18) = 1.79, p = .09; mean score = 3.09 & 2.82 respectively).

Scouting parameters. ***Multiple versus single scouting reports.*** In order to confirm Study 1 findings relating to the additive effect of filing multiple reports on players, the discriminant analysis framework (two Hotelling's T^2 tests on the theoretically linked items, and an independent t test on overall performance for each discipline) was applied to the 1st report of the outdoor data set. A descriptive comparison was then made with the results from the outdoor data analysis. Initial selection stage (long-list versus short-list) was utilised as the independent variable.

Multivariate analysis on technical ability and tactical awareness for each discipline revealed a significant effect for pace bowling (associated $F(2, 24) = 3.96$, $p = .03$, $\eta_p^2 = .25$) and spin bowling (associated $F(2, 15) = 7.14$, $p < .00$, $\eta_p^2 = .49$). Univariate follow-up tests can be found in Table 16. Significant effects were not found for batting (associated $F(2, 28) = 2.42$, $p = .11$, $\eta_p^2 = .15$) or fielding (associated $F(2, 63) = 1.57$, $p = .22$, $\eta_p^2 = .05$).

When considering the discipline-specific technical skills, a multivariate effect was present in the first outdoor report data for spin bowling (associated $F(3, 14) = 3.93$, $p = .03$, $\eta_p^2 = .46$) with significant follow-up effects for spin and control (Table 11). Significant effects were not found for batting (associated $F(4, 26) = 2.35$, $p = .08$, $\eta_p^2 = .27$), pace bowling (associated $F(5, 21) = 2.26$, $p = .09$, $\eta_p^2 = .35$) or fielding (associated $F(5, 60) = .98$, $p = .44$, $\eta_p^2 = .08$). When comparing multivariate effects of the 1st outdoor report with all outdoor reports, lower effect sizes were found for all four disciplines strongly supporting the assertion that multiple reporting assists in generating discriminant validity.

Table 16

Results of follow- up tests to significant Hotelling's T^2 tests

		All / Outdoor reports T value	η_p^2
Pace bowling	Technical ability	$t_{(19)}$ 1.46	.07
	Tactical awareness	$t_{(25)}$ 2.73*	.23
Spin bowling	Technical ability	$t_{(16)}$ 2.50*	.28
	Tactical awareness	$t_{(16)}$ 3.67**	.46
	Spin	$t_{(16)}$ 2.55*	.29
	Variation	$t_{(16)}$ 1.08	.04
	Control	$t_{(16)}$ 2.47*	.28

Note: ** $p < .01$, * $p < .05$

Independent t tests on the remaining item, overall performance for each discipline, revealed significant differences for batting, but no other discipline. Three of the four independent t tests revealed smaller effect sizes when comparing the 1st report with all reports.

Table 17

Results of independent t tests comparing short and long listed players on overall performance

	1st outdoor report T value	η_p^2
Batting (1st discipline)	$t_{(29)}$ 1.71	.10
Pace bowling	$t_{(25)}$ 3.87**	.37
Spin bowling	$t_{(16)}$ 1.46	.12
Fielding	$t_{(64)}$ 1.32	.03

Note: ** $p < .01$, * $p < .05$

Multiple versus single scouts. The data set was examined in order to establish whether repeat reports from the same scout, or, multiple reports from different scouts, held a greater level of discriminant validity. As in Study 1, the three core variables (technical ability, tactical awareness and overall performance) were examined, via a Hotelling's T^2 test and an independent t test. The low player numbers for pace and spin bowling made this analysis prohibitive, however, as the core dependent variables were the same, the researchers combined the pace and spin bowlers into one bowling group in order to complete analysis. The data was filtered to include every player that had been scouted twice by the same scout. The score across both reports for each variable was averaged.

Subsequently, the data was filtered to include every player that had been scouted twice by different scouts with the same analysis framework applied. Of the six analyses completed, four yielded greater effect sizes when averaging the reports of two different scouts, rather than two reports from the same scout (see table 18 & 19).

Table 18

Results of Hotelling's T^2 tests comparing short and long listed players on technical and tactical ratings

	Different scouts – 2 reports averaged		Same scout – 2 reports averaged	
	F-ratio	η_p^2	*F*-ratio	η_p^2
Batting (all)	$F_{(2, 48)}$ 12.96**	.35	$F_{(2, 38)}$ 7.66**	.29
Bowling	$F_{(2, 38)}$ 19.60**	.51	$F_{(2, 25)}$ 14.13**	.53
Fielding	$F_{(2, 47)}$ 5.04*	.18	$F_{(2, 39)}$ 0.57	.03

Note: ** $p < 0.01$, * $p < 0.05$

Table 19

Results of independent t tests comparing short and long listed players on overall performance

	Different scouts – 2 reports averaged		Same scout – 2 reports averaged	
	T value	η_p^2	T value	η_p^2
Batting (all)	$t_{(33)}$ 2.14*	.10	$t_{(27)}$ 2.58*	.16
Bowling	$t_{(39)}$ 5.30**	.42	$t_{(26)}$ 3.89**	.37
Fielding	$t_{(48)}$ 0.51	.01	$t_{(40)}$ -0.01	.00

Note: ** $p < .01$, * $p < .05$

General Discussion

The purpose of the present series of studies was to (a), explore the parameters through which scouting can be conducted most effectively, and (b), develop an understanding of the discriminant validity of scouting reports (skill-based, psychological and physiological) in relation to current performance / selection standards. In general, the findings of Study 1 and 2 are consistent, which is positive, considering the iterative nature and annual refinement of the Scouting Guidebook / Form plus associated scout education. Whilst conclusions cannot be drawn regarding the use of scouting as a talent identification tool, initial impressions, based on discriminant validity are that a systematic and rigorous scouting programme may have substantial utility. Further, the findings provide consistent evidence in relation to the most effective scouting processes.

Discriminant validity

Skill-based discrimination. The scouting analyses from Study 1, but more so Study 2, generated consistent and strong discriminant validity between short and long-listed players for a number of batting, pace bowling and spin bowling variables. The initial pilot work (Study 1) alluded to the importance of tactical awareness, over and above performance and technical abilities. Study 2 findings supported the importance of tactical awareness, however similar effect sizes were found for technical ability and some discipline specific variables. In time, and with longitudinal analysis it will be informative to examine whether certain within discipline variables hold greater predictive validity than others. With skill-based variables failing to discriminate between short-list and selected players, it would seem that these parameters are valued by selectors during initial stages of selection, but decrease in importance at subsequent selection stages.

Psychology-based discrimination. In addition to skill-based discrimination, the psychological attributes of: fight, resilience and coping with emotions differentiated between short and long-list players. One psychological attribute, inner drive, was the only variable that differentiated between short-list and selected players. This is particularly interesting on two levels. Firstly, it would seem that psychological variables, not skill-based abilities, may be of overarching importance when selecting players that are deemed to be high potential. Indeed, MacNamara, Button and Collins (2010) highlight psychological factors as a key determinant of sporting excellence and clearly state that they should receive more attention in talent identification and development processes.

Secondly, and more noteworthy, is the manner in which different psychological variables differentiated between groups at subsequent stages of selection; suggesting that the psychological qualities required to progress through selection stages are not the same. Inner drive (the individual's continued self-motivation and perseverance) was the attribute that differentiated at the later stage, in contrast to fight, resilience and coping with emotions at the earlier stage. In an elite senior context, Connaughton, Wadey, Hanton and Jones (2008), Durrand-Bush and Salmela (2002) and Gould, Dieffenbach and Moffett (2002) provide substantial support for the importance of motivation. Although not replicated in a sporting context to date, Duckworth, Peterson, Matthews and Kelly (2007) have demonstrated the *predictive* validity of 'grit' ('perseverance and passion for long-term goals' p. 1087) in accounting for significant incremental variance in attainment. The finding of this study, in conjunction with the extant literature provides support for the role of motivation and perseverance as key determinants of higher levels of athletic success.

Scouting parameters

Indoor versus outdoor reporting. With a relatively extensive data set it was possible to explore a number of themes that relate closely to effective scouting and the deployment of scouts. The first of these focussed on the relative merits of indoor and outdoor scouting. As one would intuitively expect, scouting in the indoor 'artificial' environment does not seem to be of the same value as scouting outdoors. Although the results from Study 1 are not definitive, they do suggest that outdoor scouting is at least equal to, if not of greater value than indoor scouting. This finding is even more remarkable when considering the relatively minor difference between the two data sets, with only 21 of 148 reports (~15%) being removed in order to conduct the outdoor only analysis. Essentially, the data sets are relatively concordant, but still generate a seemingly significant pattern.

Based on the findings of Study 1, in 2012, an emphasis was placed by the ECB on scouting in the outdoor environment. Whilst from an applied perspective this was practical, it meant that similar analysis on the 2012 data set in order to verify findings could not be conducted. Whilst it is only possible to speculate as to the reason for 'inaccurate' indoor scouting, a number of hypotheses can be proposed. Firstly, it is entirely plausible that the training activities observed indoor are not reflective of the perceptual, cognitive and motor demands of outdoor competition. In other words, scouts do not see players executing skills in the same fashion as when competing in the outdoor environment. Indeed, there is a growing body of research supporting the assertion that indoor training structure is often devoid of ecologically valid contexts (Ford, Yates & Williams, 2010). Secondly, as this was the first occasion on which systematic age-group scouting has been conducted on cricket in the UK, it is entirely feasible that scouts had a relatively weak understanding of the U15 cohort prior to scouting. Initial scouting over the winter period may have allowed scouts to calibrate the cohort and subsequently generate more accurate reports during the 2011 summer/outdoor season. Should indoor scouting be considered desirable in future, sufficient emphasis should be placed on ensuring appropriate, ecologically valid scenarios are created in order to gain a realistic overview of the performer in the competitive environment. In addition, it would be possible to examine whether players can deal with specific challenges (e.g., tasks that require resilience, adaptability, creativity) as possible markers of future success. Further research on indoor scouting would be pertinent.

Single versus multiple reports. It was unsurprising to find that a greater level of discriminant validity was consistently documented when utilising multiple player reports over one report. Future scouting directives should ensure that multiple scouting reports are filed on each player, with averages calculated for each item / variable for the most accurate player appraisal.

Multiple versus single scouts. Another novel direction of the current research, was its focus on exploring the relative merits of utilising different, versus the same scout on multiple occasions. The findings across both Study 1 and 2, clearly detail the manner in which utilising different scouts to scout the same player, is of more value than assigning a scout the same player to observe on multiple occasions. This ‘forecasting technique’ (combining multiple appraisals from different raters) is not new to psychological literature and practice. Einhorn, Hogarth and Klempner (1977), clearly demonstrated the benefit of combining individual judgements and, whilst some debate remains, regarding the requisite number of independent forecasters, there is evidence to suggest that the major improvement in accuracy will be achieved with the combination of the first two or three judgements (Libby & Blashfield, 1978), a value achievable in the scouting context.

Limitations

Although the research offers encouraging support for the utility of scouting in the selection of cricketers, it is not without limitation. There are a number of methodological and procedural considerations that limit the interpretation of these findings. Firstly, and perhaps most significantly is the outcome variable (selection stage), which was used across all analyses. In utilising selection stage, there is the implicit assumption that categorisation of players as long or short-list (the selection process) provides a true reflection of each player’s ability and future potential. Whilst selectors would no doubt contend that this is the case, empirically, there is little objective evidence to support this argument. In fact, there is some evidence to suggest that selections are poorly correlated with later performance (Berri & Simmons, 2011). An alternate approach would have been to dichotomously categorise players based on performance statistics. Unfortunately, this approach is prone to significant issues itself, in the lack of comparability of statistics across leagues, counties and age-groups. As such, the researchers affirm, that given the exploratory nature of analyses, selection stage was the most appropriate methodology by which to categorise players.

Secondly, these analyses have been confounded by the use of *this* scouting data in the selection process. Although scouting reports were not the only data source used in the selection process (performance statistics, county reports and input from national skill leads also utilised) the reports did form a component of the process (more so in 2012). In other words, the scouting data (dependent variable) will have contributed to the independent variable (selection stage) prior to any analysis having been conducted. This is far from ideal and reflects the applied environment in which the research is conducted. Such potential confounding cannot negate the differential findings that were obtained across skill, physiological and psychological variables. The difference in these findings, psychological variables being the only category to differentiate at short list versus selected, must reflect the weightings that selectors value in assessing players' future potential.

Thirdly, discriminant analyses have been conducted in an overly simplistic fashion. Players will have been considered for the EDP (e.g., featured on the short-list) based on their abilities across at least their 1st discipline, fielding abilities, psychological profile and physiological status, if not 2nd discipline as well. However, the discriminant analysis did not differentiate between the players first and second discipline (other than for batting) and did not combine skill-based, psychological and physiological variables in seeking to account for unique variance. In time, and with growing data sets the researchers intend to combine these aspects in a multivariate fashion. Furthermore, the intention is to combine performance statistics with EDP Talent Testing and scouting data in order to conduct holistic talent identification research.

Conclusion

In summary, the current research offers a novel and informative insight into the value of scouting for player recruitment. Study 1 and 2 document confirmatory findings in relation to the two broad research questions. Firstly, there is repeated evidence that scouting offers substantial discriminant validity in differentiating between player ability, but furthermore, psychological factors are clearly of utmost importance when discriminating between the most successful and not quite so successful athletes. The continuity and magnitude of discriminant findings provide heartening support for the potential of scouting as a predictive tool. Secondly, outdoor scouting and multiple reports by different scouts generate the most accurate player appraisal.

Chapter 4

A longitudinal study of performance statistics in cricket

Research Progression

The first empirical chapter examined the reliability and validity of skill-based tests. Varying levels of reliability and validity were found. Evidence was presented for the value of simple tests (e.g., thin bat assessment) as well as more complex skill-based assessments that are more ecologically valid. Some evidence suggested that ability to learn might be an important factor in differentiating between ability groups. Chapter 3 took a novel approach to the examination of talent by implementing and examining scouting appraisals – perhaps the most ecologically valid mechanism of assessing ability. More specifically, the purpose of Chapter 3 was to examine what variables; skill-based, psychological or physiological, have greatest discriminant validity. And secondly, establish what parameters generate the most accurate appraisal of player ability. This question was examined in relation to (i), the value of indoor versus outdoor scouting, (ii), the value of scouting players on single versus multiple occasions, and (iii), whether multiple appraisals from the same, or multiple appraisals from different scouts, generate the most accurate player appraisals. These questions were examined in two studies (year 1 and 2).

Study 1 and 2 generated confirmatory findings in relation to both research questions. Results revealed that scouting might have significant value in differentiating between player ability. Skill-based scouting data consistently discriminated between high and low ability groups. Psychological data were the only variables that discriminated between very high and high ability players. As such, it would seem that psychological variables, not skill-based variables, are of utmost importance when selecting high-ability players. In relation to scouting methodology; outdoor scouting, multiple reports and the use of multiple scouts was the most accurate way examining player ability.

In considering research thus far, the lead researcher considered the lack of longitudinal data, arguably the most significant criticism of the extent talent identification literature. Whilst not considered at the outset, one longitudinal data set (performance statistics) is available in a cricket context.

A particular strength of this data is the manner in which it can be interrogated against different hypotheses. Traditionally (particularly in cricket) performance statistics are examined (and utilised in an applied environment) in relation to basic metrics e.g., runs scored and batting average. However, given the rich data contained within performance statistics, it is possible to examine other non-traditional statistics. Linked to Chapter 2 (and the findings relating to learning), the lead researcher explored the possibility of interrogating performance statistics in relation to new metrics e.g., the ability to learn on entering new environments.

The value of traditional metrics and 'new' metrics was examined in a two-part longitudinal study. Study 1 focused on the relationship between England cricketers' performance in domestic cricket (pre-international debut) and international performance. Study 2 examined the relationship between age-group statistics and the domestic statistics that had been found to have some relationship with international performance. Correlational analysis was completed. Generally speaking, traditional performance statistics (e.g., batting and bowling averages and strike rates) did not correlate with subsequent performance statistics. This was particularly prevalent in Study 1. However, non-traditional performance statistics (e.g., adaptability in a new environment) repeatedly demonstrated significant relationships with outcome variables in Study 1 and 2. Study 2 provided some evidence that performance statistics in age-group cricket are relatively meaningless until players feature in under-17 cricket. In summary, the research provides empirical evidence that performance statistics reflecting learning and adaptability may have the greatest relationship with future performance.

Talent identification is a complex issue that involves understanding the multidimensional nature of sporting potential. The intricacy of the challenge, combined with the methodological rigour required to appropriately investigate an individual's latent ability, has hindered progression of the extant literature. Two criticisms that have been levelled at the literature are: (i) typically, research focuses on a limited range of physical and anthropometric factors (Abbott & Collins, 2004); and (ii) there is a dearth of longitudinal research that seeks to detail predictive validity of talent-related variables (Vaeyens, Lenoir, Williams & Philippaerts, 2008). The purpose of the present studies was to progress research in line with these criticisms. Examination of players' longitudinal performance statistics is a novel approach, and, given the rich data set, has the potential to enlighten the field of talent identification on performance characteristics which are, and, *are not*, related to subsequent success. At the outset, we state that this is a simple, exploratory investigation, seeking to examine the relationship between performance statistics at progressive stages of cricket development.

Generally, performance analysis in skill-based sports, involves notational analysis (Hughs & Franks, 2004). In cricket, at the most basic level, this generates individual performance statistics; a batsman's innings is recorded in relation to runs scored and mode of dismissal. A bowler, will be coded in relation to overs bowled, runs conceded, wickets taken and extras. These variables can also be converted into simple metrics, such as batting and bowling averages, strike rates and economy rates when bowling (for definitions see Appendix 15). Unsurprisingly, data rich sports, such as cricket, have developed an awareness and familiarity with performance statistics, to the extent that examining, interpreting and utilising statistics is commonplace by the media, players, parents, coaches and selectors. Whilst statistics are clearly embedded in day-to-day practice, there is little empirical evidence in support of the discriminant, or predictive validity of such metrics.

Given the relative dearth of empirical research examining performance statistics in cricket, it would be incongruous to progress further, without drawing on sabermetrics (empirical analysis of in-game baseball activity), the most seminal body of work in sports analytics. In 2003, Michael Lewis published Moneyball, an influential book concerning the inefficiency of the Major League Baseball labour market in generating on field wins. Lewis (2003), argued that players salaries (specifically hitters), did not reflect batting skills that were most related to winning. In quantifying a player's value, there was an over-reliance on batting average[7] and slugging percentage[8], which fail to account for relevant dimensions of batter productivity (walks). Whereas, on-base percentage[9] takes this dimension into account. The inefficiency was so pronounced, that knowledge of its existence and the ability to exploit it, enabled the Oakland Athletics to gain a substantial advantage over their competition. Although this work was not peer-reviewed, subsequent academic examination (Baumer, 2008; Hakes & Sauer, 2006) provides rigorous support for the inefficiency. Whilst this well documented example focussed on professional sport, translating a similar philosophy to adolescent sport in a talent identification context, could have substantial utility.

The Pitcher Empirical Comparison and Optimization Test Algorithm (PECOTA, Silver, 2003) is one such model. Based on nearest neighbour analysis (Samet, 2006), PECOTA compares a player of interest, to players within a database that display similar statistical and anthropometric characteristics. PECOTA was initially used for professional players and was shown to have equal or better predictive validity than Baseball America on core metrics (innings pitched, earned run average and, walks and hits per inning pitched) (Silver, 2004). However, the findings in relation to minor league prediction (adolescent

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[7] Ratio of hits to total at-bats
[8] Total bases divided by at-bats
[9] The fraction of plate appearances (including both official at-bats as well as walks) in which the player reached base successfully through either a hit or walk

players) were weaker, reflecting the challenge in increasing the temporal period between observation and senior performance.

Another sport, that lends itself well to the study of performance statistics, is golf. Golf is particularly well suited, because of the discrete, sequential, independent and quantifiable nature of skill execution. Each shot is coded in relation to distance, accuracy, and, when putting, success. Belkin, Gansneder, Pickens, Rotella and Striegel (1994) and Nix and Koslow (1991) demonstrated how simple performance statistics; greens in regulation, putts per round and driving distance were strongly related to scoring average, accounting for in excess of 80% of the variance. Clearly, the high degree of accounted variance is a product of the simple and direct relationship between independent and dependent variables. The more informative findings are the relative weightings of different factors, with greens in regulation being most related to scoring average. In a cricket and talent identification context, we aim to move beyond short-term prediction, examining the variables which are most related to subsequent achievement.

More recently, researchers in sport have sought to account for contextual differences in game scenario. Adjusted scoring averages have been used to compensate for the difference in course difficulties and weather conditions when playing golf (Finley & Halsey, 2004; Quinn, 2006). This adjusted metric, has been shown to correlate more highly with earnings, and may be a better measure than standard scoring average, when comparing players over time (Finley & Halsey, 2004). This weighting approach has been mirrored in baseball, predominantly in relation to ‘park factors’. Baseball stadiums are nonstandard in dimension and pitches vary considerably in size. By examining players’ batting average in each stadium, weighting factors can be created to adjust for stadium size (Acharya et al., 2008). In a soccer context, Lago (2009) demonstrated how performance statistics could be adjusted to account for match location, match status and most pertinently, quality of opposition. In a cricket context, a particularly high score against a strong bowling attack is obviously ‘worth more’ (when comparing ability of players), to a high score against a relatively weak bowling attack. However, this has not been empirically examined in the literature. In examining player statistics in sport, there is clearly a need to account for the context of sporting performance (Mackenzie & Cushion, 2013).

One criticism levelled at research on performance statistics in golf, is the lack of progression over the past 20 years. The majority of work has repeatedly examined the same dependent variables, with minor changes to predictor variables or the temporal period of study. There have been repeated calls (e.g., Dorsel & Rotunda, 2001) to examine other competitive and psychological factors in seeking to explain performance. Given the rich nature of performance statistics in sport, there is opportunity to move beyond traditional statistics, tapping indirect measures of psychological, skill and physiological abilities. In the golf context, Finley and Halsey (2004) demonstrated the manner in which ‘bounce back’ (the percentage of times players followed a bogey or worse, with a birdie or better), accounted for significant variance in predicting scoring average. This finding is suggestive, that better golfers display more resilient skills, following adversity. Applying a similar philosophy, to the examination of performance statistics in cricket would be worthwhile, given the narrow manner in which statistics are currently used, and the burgeoning body of research pointing to the importance of psychological attributes in the development of elite performance (Gould, Dieffenbach & Moffet, 2002; Van Yperen, 2009).

The limited body of performance statistics research in cricket focuses almost exclusively on limited overs, One Day International (ODI) and ‘Twenty-Twenty’ (T20). In part, this may attributable to the growing financial investment in players recruited to franchise teams, such as those in the Indian Premier League. Lewis (2005) and Lemmer (2011) have presented evidence that traditional performance statistics, particularly batting and bowling averages, 'have severe limitations in assessing the true performances and abilities of players' (Lewis, 2005, p. 804). Batting averages are prone to distortions when few games have been played, or when the batsman has been 'not-out' on multiple occasions. This is particularly pertinent in the current context, given that relatively few games are played within county age-group cricket, an area of interest. Barr and Kantor (2004), Lemmer (2011) and van Staden (2004) present evidence that strike rate metrics (runs scored per ball faced, or wickets taken per delivery) when accounting for the opposition and or game context, provide better representations of current performance. Whilst there is good rationale for strike-rate related metrics, use of such statistics in the current context is difficult, as this data is not systematically collected outside of 1st Class and international cricket. Furthermore, this research is not orientated towards predicting current performance. Instead, the aim is to examine those statistics, which are indicative of *future* achievement.

In this way, the aim of this manuscript was to take a simple approach to the examination of performance statistics in a talent identification context. As such, the authors hypothesised that ability to learn (e.g., adapt and perform well in new environments) and the ability to demonstrate exceptional performances (e.g., perform very highly, if only on one important occasion) may be of relevance when seeking variables predictive of subsequent levels of achievement. Based on findings in others sports, there was an expectation that adjusted performance statistics, i.e., accounting for the strength of opposition, would provide more reliable, and subsequently, more predictive findings. Furthermore, the authors hypothesised that the shorter the temporal period between predictor and dependent variable, the stronger the relationship with the dependent variable.

In utilising performance statistics as a talent identification methodology, there was a desire to examine the relationship between age-group and international performance statistics. However, as performance statistics were not systematically collected within age-group cricket until relatively recently, there was no record of current and recently retired England players' age-group statistics. Therefore, the research was implemented as a two-stage process. Study 1, examines the correlations between professional (1st Class & List A) and international (Test & ODI) cricket. Study 2, focuses on the correlations between age-group and professional statistics. Within both studies, emphasis has been placed on examining the value of traditional versus 'new' talent-related performance statistics. Due to the exploratory nature of the study, the analyses are correlational in nature. At the outset, it is re-iterated that this is an exploratory investigation – the first of its kind in cricket – seeking to examine the relationship between performance statistics at different stages of development.

Method

Sample

Performance statistics were sourced from Cricket Archive (http://cricketarchive.com/) for all cricketers who had represented England for the years 2003 – 2013[10]. This resulted in a database of 101 players. For each player, all available historical records were retrieved from Cricket Archive, resulting in 116,206 individual player records. Players were coded in relation to their first and second discipline by the ECB's Performance Analysis department. This resulted in 42 first discipline batsmen. Due to the relatively small sample size and relative lack of disparity between pace and spin bowling statistics, all bowlers were grouped for analysis. This resulted in 46 first discipline bowlers.

As the player list included current England players, there was a need to ensure that 'live' players did not bias analyses. It was feasible, that a recent debut player may have unrealistically high, or low, international performance statistics (as detailed by Lemmer, 2011; Lewis, 2005). For this reason, those players who were considered likely to feature in future England teams *and* were not established within the England team, as classified by the

[10] The time period selected reflects a desire to use the most current data available, whilst also generate a data set large enough to complete exploratory work

ECB's Performance Analysis department, were removed from analysis (n = 5 for batting, n = 13 for bowling). Two Test bowlers had bowled less than 20 overs each and were removed from the analysis.

Procedures

Performance statistics were extracted from Cricket Archive in a game-by-game fashion for each player. The data extraction template sourced the players' individual performance statistics (batting and or bowling) as well as scorecard statistics for individuals on their, and the opposing team. Pre-England debut performance statistics were extracted for both forms of domestic cricket (List A and 1st Class), and two forms of international cricket (ODI or Test), giving a 2 x 2 matrix of performance statistics (domestic cricket x international cricket). List A refers to limited-overs (one-day) cricket. 1st Class cricket comprises matches of three or more days scheduled duration, allowing for teams to play two innings each. When analysing ODI statistics, List A statistics pre-ODI debut and First Class statistics pre-ODI debut were examined. When examining Test cricket performance, List A statistics pre-Test debut and 1st Class statistics pre-Test debut were utilised.

Predictor variables. The batting and bowling predictor variables can be summarised in five groups. Group 1, was age on debut in domestic cricket (1st Class and 2nd XI) and international cricket. It was hypothesised that age of debut in domestic cricket may provide a representation of the players' perceived potential. In other words, the younger the domestic debut, the more likely the player was to excel in international cricket. Furthermore, age at 2nd XI debut may be more indicative of this hypothesis, given that selection to this environment is influenced by fewer external factors, such as professional player recruitment as in 1st Class cricket. Group 2 included traditional performance statistics (e.g., batting and bowling average). Although these metrics are commonly utilised in ECB player selections (England Development Programme, England Performance Programme and England), it was theorised that they would not relate to subsequent achievement in international cricket. It has been proposed that these metrics are crude (Barr & Kantor, 2004; Bracewell & Ruggiero, 2009; Kimber & Hansford, 1993) and fail to account for the context in which the performance has been achieved. More pertinently, the author contests that these metrics represent *current* performance, not the attributes that may be more closely related to *future* achievement. Group 3 was the ratio of certain landmark scores (e.g., 50's scored when batting, or 3 wicket hauls when bowling). As players made their England debut having played different amounts of List A and 1^{st} Class cricket, the frequency of landmark scores was converted into a ratio using number of innings. Ratio values were calculated for a range of metrics (e.g., 40 through 100 at 10 runs increments when batting). The authors sought to examine whether the commonly adopted metrics (number of half centuries and centuries) were the most relevant metrics when considering a players future ability.

Group 4 and Group 5 included 'non-traditional' metrics. Recent literature (Gould, Diffenbach & Moffett, 2002; Hill, 2012; Orlick & Partington, 1988; Vaeyens, Lenoir, Williams & Philippaerts, 2008) has postulated that higher performing individuals adapt and learn to a greater extent than their less successful counterparts. However, as yet, there is little empirical evidence underpinning this argument. Given the relatively extensive performance statistics data set, it was possible to examine variables that were reflective of adaptability in a new environment. Group 4 was the number of innings (from debut) to achieve landmark scores e.g., number of innings taken to first score 50 runs or take a 3-wicket haul. Group 5 was the number of innings taken to accumulate certain landmark totals (e.g., 500 runs or 20 wickets). It was hypothesised, that more successful individuals would demonstrate greater levels of adaptability e.g., achieve landmarks scores / totals in fewer innings than their less successful counterparts.

Table 20

Predictor variables for batting and bowling analyses: List A and 1st Class cricket pre England debut (unless otherwise stated)

Group	Batting	Bowling
Group 1	Age on debut in Test, ODI, 1st Class and 2nd Class cricket	Age on debut in Test, ODI, 1st Class and 2nd Class cricket
Group 2	Number of domestic appearances, number of innings, batting average, total runs scored, maximum score	Number of domestic appearances, number of innings, bowling average, strike rate, economy rate, wicket ratio, maiden ratio
Group 3	Ratio of landmark scores: 40, 50, 60, 70, 80, 90, 100 runs	Ratio of landmark scores: 3, 4 and 5 wicket hauls
Group 4	Innings taken to achieve landmark scores of 40, 50, 60, 70, 80, 90, 100 runs	Innings taken to achieve landmark scores of a 3, 4, 5 wicket haul
Group 5	Innings taken to achieve cumulative run totals of 200, 500, 750, 1000 runs	Innings taken to achieve a sum total of 5, 10, 20, 40 wickets

Dependent variables. In some sports, effort has been directed towards generating encompassing statistics that represent holistic player contribution e.g., Wins Above Replacement Player (WARP) in baseball[11]. In cricket, the only encompassing metric is the International Cricket Council (ICC) World batting ranking (http://www.relianceiccrankings.com/). This was adopted as a dependent variable, however as the formula for this metric is not publically available, and, as there is no empirical evidence in support of this metric, a number of other dependent variables were adopted for batting and bowling.

Batting. The second was batting average (runs / number of dismissals) and has traditionally been deemed a good metric for measuring individual contribution to innings, combining two primary measures of performance (runs scored and wickets lost). Two further dependent variables, number of innings and total runs, which are more representative of continued selection were also adopted.

[11] The WARP statistic aims to quantify a player's contribution to the team. WARP calculates how many wins a player provides, over a theoretical replacement player that could be obtained for minimal cost and effort.

Bowling. The following variables were generated for use as dependent variables: bowling average, strike-rate, economy rate, number of innings and highest world ranking.

Statistical analysis

To identify which performance statistics at domestic level (pre England debut) were related to subsequent England performance, a series of Pearson's correlations (*r*) were employed. Significant correlations are tabulated and presented in the results section. Correlations that approached significance across two or more dependent variables are also included.

The exploratory nature of analyses, with a lack of specificity in a priori hypotheses, increased the likelihood of generating a Type I error (i.e., rejecting the null hypothesis when it was correct). The increased likelihood was amplified on two accounts. First, each predictor variable was examined in relation to four dependent variables for batting, and five for bowling. Second, the predictor variables were not always independent of each other. In fact, the sequential nature of variables such as innings taken to achieve first 50, 60, 70 on so on, meant that predictor variables were highly related to each other. In this way, there was repeated testing of the data in relation to the predictor and outcome variables. One possible solution, would have been to apply a Bonferroni correction, dividing the alpha level by the number of statistical tests hypothesised to be significant. However, as Moran (2003) details, applying a Bonferroni correction will increase the chance of committing a Type II error (accepting the null hypothesis when it is correct). Given the exploratory nature of analyses and the relatively small sample size, the authors decided that it was reasonable to proceed with an unadjusted alpha level. However, rather than adopt a 1-tailed hypothesis aligned with the a priori hypotheses, a 2-tailed hypothesis was adopted in order to maintain some degree of conservatism. In addition, in cases of ambiguity the authors referenced the same correlation matrix, but with the player list altered to include all first and second discipline batsmen. This partially acted as a confirmatory process. These results are not presented in the manuscript and can be requested from the lead researcher and the England and Wales Cricket Board.

To further examine which predictor variables accounted for unique variance, multiple linear regression analyses (forced entry) were completed. Statistical significance was set at $p < .05$.

Adjusted predictor variables

List A and 1st Class variables (runs scored for batting and runs conceded for bowling) were adjusted to account for the strength of the opposition. Formula 1 was adopted for batting, where, Gbo = Global bowling average (of relevant form of cricket), N = Number of bowlers, Bo_i = Career average of i^{th} bowler and R = runs scored.

Formula 1. Adjusted runs when batting

$$\text{Adjusted runs} = \mathrm{R} \div \left[\frac{\sum_{i=1}^{N} Bo_i}{Gbo \times N}\right]$$

Formula 2. Adjusted runs conceded when bowling

$$\text{Adjusted runs conceded} = \mathrm{Rc} \div \left[\frac{\sum_{i=1-6}^{N} Ba_i}{Gba \times N}\right]$$

Formula 2 was adopted for the adjustment of bowling statistics, where, Rc = runs conceded, Gba = Global batting average (of relevant form of cricket), N = Number of batsmen and Ba_i = Career average of i^{th} batsmen. Batsmen 7-11 were not included in analyses because of the disproportionate impact that lower order batsmen have on a bowler's statistics.

A comparison was made between the findings of actual and adjusted predictor variables. In general, adjusted batting variables increased the size and significance of findings. There was no pattern for bowling. In the following analysis, adjusted variables have been used for batting and unadjusted variables for bowling. Further discussion of adjusted variables, can be found in the final discussion.

Study 1

Results

Forty-two batsmen and 46 bowlers were included in the sample; however, a proportion of players failed to achieve the predictor variable (e.g., an innings of 80 runs or more in List A cricket pre Test debut). For this reason, there are a varying number of participants across correlations.

Test Batting

Significant correlations were revealed between predictor variables and two dependent variables: total runs and batting average in Test cricket. Innings taken to reach a score of 80 runs in List A cricket was significantly correlated with batting average in Test cricket (r = -.42), suggesting that the fewer innings taken to achieve a score of 80, the higher the batting average in Test cricket. The ratio of innings in which 60 runs was scored (1^{st} Class) was significantly correlated with total runs scored in Test cricket (r = .38). Indicating, that the more frequently batsmen achieved scores of 60 (1^{st} Class), the greater the total runs scored in Test cricket.

Innings taken to reach a score of 60 runs (1^{st} Class) approached significance in relation to number of innings, total runs and highest world ranking in Test cricket (r = -.36, r = -.36 and r = .33 respectively). Although not statistically significant, there was evidence to suggest that innings taken to accumulate runs in List A cricket (1000 runs, Table 21 and innings taken to accumulate 500 and 750 runs, un-presented data) was related to Test batting average (Table 21).

Table 21

Relationship between professional (List A and 1st Class, pre debut) and Test batting performance statistics

		Number of innings	Total runs	Batting average	Highest World Ranking
Innings to 1st 80 (List A, pre Test)	Pearson Correlation	-.27	-.27	-.42*	.34
	Sig. (2-tailed)	.19	.19	.04	.10
	N	25	25	25	25
Innings to 1000 runs (List A, pre Test)	Pearson Correlation	-.09	-.15	-.41	.18
	Sig. (2-tailed)	.69	.54	.07	.46
	N	20	20	20	20
60 ratio (1st Class, Pre T)	Pearson Correlation	.38	.39*	.22	-.32
	Sig. (2-tailed)	.06	.05	.28	.12
	N	26	26	26	26
Innings to 1st 60 (1st Class, pre Test)	Pearson Correlation	-.36	-.36	-.26	.33
	Sig. (2-tailed)	.07	.07	.19	.10
	N	26	26	26	26

ODI Batting

Significant correlations were found in relation to the dependent variables of, number of innings, total runs and highest world ranking in ODI cricket. ODI batting average approached significance when correlated with the ratio score of number of innings in which 70 runs were scored (List A).

The ratio score of number of innings in which 70 runs was scored (List A), was significantly correlated with highest ODI World ranking (r = -.35), indicating that the greater the frequency of 70 run innings, the better the World ranking. Innings taken to achieve a first score of 90 runs (1st Class) was significantly related to number of innings and total runs scored in ODI cricket, suggesting that the quicker a batsmen were able to achieve a first score of 90 runs, the better they performed in ODI cricket.

Table 22

Relationship between professional (List A and 1st Class, pre debut) and ODI batting statistics

		Number of innings	Total runs	Batting average	Highest World Ranking
70 ratio (List A, pre ODI)	Pearson Correlation	.23	.29	.33	-.35*
	Sig. (2-tailed)	.21	.11	.06	.05
	N	32	32	32	32
Innings to 1st 90 (1st Class, pre ODI)	Pearson Correlation	-.43*	-.44*	-.26	.27
	Sig. (2-tailed)	.02	.01	.16	.14
	N	31	31	31	31

Test Bowling

Age at 2nd Class debut correlated significantly with players' highest world ranking (r = .37). The younger the player at 2nd Class debut, the higher the subsequent world ranking. Innings to first 5-wicket haul and innings taken to accumulate 10 wickets (1st Class) were significantly correlated with bowling average and economy rate. These positive correlations were counter to the hypothesised direction. The fewer games taken to achieve the first 5-wicket haul and to accumulate 10 wickets, the worse the international bowling average and economy rate in Test cricket.

Table 23

Relationship between professional (List A and 1st Class, pre debut) and Test bowling performance statistics

		Innings	Bowling average	Strike rate	Econ. rate	Highest World Ranking
Age at 2nd Class debut	Pearson Correlation	-.17	-.24	-.31	-.02	.37*
	Sig. (2-tailed)	.38	.20	.09	.93	.04
	N	31	31	31	31	31
Innings to 1st 5 wkt haul (1st Class, pre Test)	Pearson Correlation	-.10	.37*	.21	.42*	-.08
	Sig. (2-tailed)	.61	.04	.25	.02	.66
	N	31	31	31	31	31
Innings to 10 wkts (1st Class, pre Test)	Pearson Correlation	-.23	.39*	.22	.40*	.19
	Sig. (2-tailed)	.21	.03	.23	.03	.31
	N	31	31	31	31	31

Table 24

Relationship between professional (List A and 1st Class, pre debut) and ODI bowling performance statistics

		Innings	Bowling average	Strike rate	Econ. rate	Highest World Ranking
Innings to 10 wkts (list A, pre ODI)	Pearson Correlation	.36	-.30	-.39*	.04	-.16
	Sig. (2-tailed)	.06	.12	.04	.83	.43
	N	28	28	28	28	28
Strike rate (1st Class, pre ODI)	Pearson Correlation	.25	.27	.48**	-.34	-.06
	Sig. (2-tailed)	.18	.15	.01	.06	.76
	N	31	31	31	31	31
Economy rate (1st Class, pre ODI)	Pearson Correlation	-.06	-.16	-.39*	.39*	-.21
	Sig. (2-tailed)	.74	.41	.03	.03	.26
	N	31	31	31	31	31
3 wkt haul ratio (1st Class, pre ODI)	Pearson Correlation	.38*	.31	.46**	-.24	-.25
	Sig. (2-tailed)	.04	.09	.01	.20	.17
	N	31	31	31	31	31

ODI Bowling

Three-wicket haul ratio (the number of innings in which 3 wickets were taken, relative to number of innings) correlated significantly with number of ODI innings. This indicated that bowlers who consistently achieved 3-wicket hauls in 1st Class cricket (pre debut) went on to play more international one-day cricket.

Innings taken to accumulate 10 wickets (List A), strike rate, economy rate and 3-wicket haul ratio (1st Class), correlated significantly with ODI strike rate. Meaning, the fewer innings taken to accumulate 10 wickets, the more wickets taken per over, and the more frequently a player took 3 wickets in domestic cricket, the more frequently a player took wickets in ODI cricket.

Economy rate (1st Class) was significantly correlated with economy rate in ODI cricket (r = .39) suggesting that the ability to bowl frugally in 1st Class cricket transfers to ODI cricket. In examining international statistics (batting and bowling), this was the only significant correlation between the same statistic when used as the predictor and dependent variable (strike rate and economy rate).

Discussion

The aim of Study 1 was to examine the relationship between performance statistics in professional and international cricket. Performance statistics are commonly used in identification and selection practices, however, as yet, the authors are not aware of any literature in cricket that examines the relationship between pre and post debut statistics. Due to the dearth of literature in this area, specific a priori hypotheses were limited, however the researchers sought to examine whether traditional statistics were more, or less, predictive than 'unconventional' statistics.

Batting

When considering the correlations between professional, and Test and ODI batting statistics, a number of tentative conclusions can be drawn. Firstly, similar predictor variables correlated with both forms of international cricket. Significant relationships were revealed between (1) innings taken to achieve a landmark score (80 and 90 runs) and international statistics, and (2) ratio values (60 and 70 runs) and international statistics. Given the exploratory nature of analysis, the replicability of findings across different forms of the game is positive and provides some support for the validity of these findings.

Secondly, non-traditional variables (e.g., innings to first score of 80 runs) seem to provide relevant information when considering a player's potential in Test and ODI cricket. This variable appears to represent an adaptability-based characteristic, whereby players who perform at a high level on entering a new environment (e.g., List A or 1st Class) go on to perform at a higher level in international cricket. Intuitively, this seems appealing and would be supported by the work of Ackerman (1999; 2007), which suggests the more complex the skill acquisition task, the greater the individual differences in learning. Transitioning from 2nd

to 1st Class cricket is a complex task with increasing levels of complexity. The ability to adapt and learn quickly in this environment (presumably in a psychological and skill acquisition sense) may relate to subsequent international performance.

Thirdly, although one may hypothesise that 1st Class cricket is more related to Test cricket, and, List A to ODI, there was no evidence in support of this. List A and 1st Class variables correlated significantly with both forms of international cricket.

Bowling

When considering the relationship between professional and Test bowling statistics, age at 2nd Class debut correlated significantly with world ranking. The younger the player at 2nd Class debut, the higher the world ranking. The a priori hypothesis was that age at 2nd Class debut might provide a ‘clean’ representation of a player’s perceived potential during adolescence. As 2nd XI cricket is less outcome driven from a County perspective, coaches may be able to expose players to this level of cricket when it is perceived to be most appropriate e.g., a relatively young age. Whereas, exposure to 1st Class and List A cricket may be more related to extrinsic factors, such as strength and depth of ability within professional county contracts.

Traditional statistics (strike rate and economy rate in 1st Class cricket), innings to accumulate 10 wickets (List A), and 3-wicket haul ratio (1st Class) correlated significantly with ODI performance statistics. There were consistent and strong correlations between the aforementioned predictor variables and strike-rate (ODI), which is positive given the importance of strike-rate in limited overs cricket (Lemmer, 2011). Three-wicket haul ratio (consistency of taking 3 wickets in an innings) seems to be a metric of relevance when considering the moderate and significant correlations with multiple dependent variables. This would suggest that continually exhibiting enough skill to take 3-wickets in 1st Class cricket is of primary importance when considering future potential in international cricket. It is noteworthy, that five of the six significant performance-based predictor variables (across Test and ODI cricket analyses), were from 1st Class cricket. As such, it would seem that bowling performances in 1st Class cricket is of more relevance than List A performance, when considering future international performance in either form of the games (Test or ODI).

The Test bowling findings were counter-intuitive, with increased time taken to achieve first 5 wicket haul, and innings taken to accumulate 10 wickets (1st Class), correlating positively with better Test bowling average and economy rates. All explanations for this are post-hoc and counter to the hypothesised direction. However, it may be that selectors over-reward bowlers who perform particularly well on debut in 1st Class cricket before they are in a position to perform effectively in international cricket. Essentially, bowlers may need time in 1st Class cricket to develop robust skills before performing in international cricket. Clearly, this is speculative and requires further investigation.

Study 2

As talent recruitment practices occur during adolescence, currently, U15 and upwards within the ECB, and at a younger age within the county system, there was a need to examine the relationship between age-group and England statistics. However, as county age-group statistics have only been systematically collected relatively recently, it was not possible to examine this relationship on the relatively old England player group. For this reason, a two-stage process was adopted. Study 1 focussed on the relationship between professional and England statistics, and Study 2, examined the relationship between age-group and relevant professional statistics (those elicited from Study 1).

Method

Sample

Statistics were sourced from Cricket Archive for all players who were England qualified, aged 25 or under at the end of the 2013 cricket season, and had played 15 matches or more in 1st Class and List A cricket combined. The cut-off age was based on pilot analysis, suggesting that age-group records were systematically recorded for players of this age. For each player, all available historical records were retrieved in the template as detailed in Study 1.

Players were coded in relation to their first discipline by England Development Programme staff. This resulted in 51 batsmen. As with Study 1, spin and pace bowler's statistics were combined for analysis, resulting in 50 bowlers. The player numbers for each county age-group stage can be seen in Table 25.

Table 25

Number of players included in analyses at progressive England cricket pathway stages and average number of games contributing to statistics

		Batsmen	Bowlers
List A	Number of players	50	50
	Average innings	23.2	22.5
1st Class	Number of players	51	49
	Average innings	64.6	46.2
2nd XI	Number of players	51	50
	Average innings	42.7	40.6
U17	Number of players	50	46
	Average innings	9.8	10.7
U15	Number of players	48	42
	Average innings	7.7	7.2
U13	Number of players	28	14
	Average innings	4.5	5.6

Procedures

Performance statistics. ***Predictor variables – Batting.*** Predictor variables were extracted from the data template for U13, U15, U17 and 2nd XI cricket. These can be summarised in five categories and are the same as those detailed in Study 1. Group 1 was age on debut. Group 2 was traditional performance statistics: number of innings, batting average (runs/number of times out), total runs scored and maximum score. Group 3 was the number of landmark scores as a ratio, for 40's – 100's, at 10 run increments. Group 4 was the number of innings that it took the batsmen to reach their first landmark score for 60 through 100, at 10 run increments. Group 5 was the number of innings that it took batsmen to achieve a cumulative total of 100 through 600, at 100 run increments.

Predictor variables – Bowling. In the same fashion as with Study 1, the following variables were calculated for U13, U15, U17 and 2nd XI cricket. Group 1 included age at debut. Group 2 was made up of number of innings, bowling average (wickets/runs), strike-rate (wickets/deliveries), economy-rate (overs/runs), wicket ratio (wickets/innings). Group 3 was ratio of 3, 4 and 5 wicket hauls (relative to the number of innings). Group 4 was number of innings to first 3, 4 and 5 wicket haul. Group 5 was number of innings taken to achieve a sum total of 5, 10, 15 and 20 wickets. When compared to Study 1, the cumulative totals were reduced to 5 wicket increments due to the smaller volume of cricket played at age-group level.

Dependent variables – Batting and bowling. First Class and List A performance statistics that generated a significant relationship with England statistics in Study 1, were carried forward as dependent variables. Adjusted values (as detailed in Study 1), were used when calculating professional batting metrics. Unadjusted statistics were used when generating professional bowling metrics.

Statistical analysis

Statistical analysis was completed in the same fashion as detailed in Study 1.

Results

Test-related batting statistics

The four predictor variables of relevance from Study 1, when examining Test batting, were carried forward for analysis. However, innings taken to achieve a cumulative total of

1000 runs in List A cricket, could not be utilised, because only 10 players had achieved this total, limiting any interpretation of results. Instead, correlational analysis was completed utilising innings taken to achieve 250 and 500 runs as the dependent variable (39 and 23 participants respectively). No significant correlations were revealed.

Significant results were revealed with the other dependent variables (Table 26). Innings (U17) was negatively correlated with innings taken to first score 80 runs (r = -.34), suggesting that those players, who played more U17 innings, took fewer innings in List A cricket to score 80 runs or more. Presumably, the highest potential players, play U17 cricket relatively extensively with this being an important stage of cricket development. In contrast, number of U15 innings was negatively correlated with the number of innings in which 60 runs were scored (r = -.29). Indicating, that players who batted in fewer U15 innings, subsequently scored 60 runs at a greater frequency in 1st Class cricket. It would seem that high potential U15 players may ‘play up’ (U17 cricket) early, receiving exposure to an important development opportunity.

In addition, two other variables elicited significant correlations. Innings taken to achieve a cumulative total of 100 runs in U15 cricket and innings taken to first score 60 runs in U15 cricket correlated significantly with 60 ratio in 1st Class cricket (r = -.44 and -.47 respectively). These correlations indicate that those players who scored more frequently and accumulated runs more quickly, went on to score more frequently (60+ run scores) in 1st Class cricket. Innings taken to first score 60 runs (U15 cricket) also correlated significantly with innings taken to first score 60 runs in 1st Class cricket.

In general, these findings are suggestive that high calibre cricketers, who go on to perform in professional cricket, play U15 cricket for a relatively short period of time but U17 cricket for a longer period of time. In addition, the performances within U15 cricket, even if relatively few, do relate to subsequent 1st Class performance. Finally, it is noteworthy that no 2nd XI variables correlated significantly with the dependent variables.

Table 26

Relationship between performance statistics of England cricket pathway stages and professional cricket, when considering predictors of Test batting

		Innings to 1st 80 (List A, pre Test)	60 ratio (1st Class, Pre T)	Innings to 1st 60 (1st Class, pre Test)
Innings (U15)	Pearson Correlation	-.22	-.29*	-.15
	Sig. (2-tailed)	.15	.05	.32
	N	43	48	44
Innings to 100 runs (U15)	Pearson Correlation	.10	-.44**	.30
	Sig. (2-tailed)	.60	.01	.09
	N	33	37	33
Innings to 1st 60 (U15)	Pearson Correlation	.14	-.47**	.38*
	Sig. (2-tailed)	.47	.01	.04
	N	29	33	29
Innings (U17)	Pearson Correlation	-.34*	-.15	-.23
	Sig. (2-tailed)	.03	.30	.12
	N	44	50	46

Table 27

Relationship between performance statistics of England cricket pathway stages and professional cricket, when considering predictors of ODI batting

		70 ratio (List A, pre ODI)	Innings to 1st 90 (1st Class, pre ODI)
Innings (U17)	Pearson Correlation	-.09	-.40**
	Sig. (2-tailed)	.53	.01
	N	49	42
100 ratio (U17)	Pearson Correlation	.31*	.03
	Sig. (2-tailed)	.03	.83
	N	49	42
Innings to 400 runs (U17)	Pearson Correlation	-.47*	-.19
	Sig. (2-tailed)	.02	.42
	N	24	21

ODI related batting statistics

Ratio of innings in which 100's were scored (U17), and innings taken to accrue 400 runs (U17), were significantly correlated with the ratio of innings in which 70 runs were scored in List A cricket (r = .31 and r = -.47, respectively). These findings support the suggestion, that regularly scoring large innings and amassing runs quickly at U17 is a relevant indicator of subsequent professional performance.

Number of U17 innings was negatively correlated with innings taken to record a score of 90 runs or more in 1st Class cricket (r = -.40). As with Test related batting statistics, players who had batted in more U17 innings, achieved the dependent variable more quickly than those who played less U17 cricket. Again, exposure to the U17 environment is important when considering subsequent achievement. In contrast to Test batting, where U15 statistics were of most relevance, U17 performance statistics were most related to ODI performance.

Test-related bowling statistics

Three predictor variables were carried forward from Study 1 as dependent variables in Study 2. Innings taken to achieve a first five-wicket haul could not be utilised, because only 17 bowlers had achieved this statistic. Significant correlations were revealed between predictor variables and the remaining two dependent variables.

Number of U15 innings was negatively correlated with age at 2nd XI debut. The more innings played at U15, the younger the player was at 2nd XI debut. Given that U15 performance variables did not correlate significantly with age at 2nd XI debut, it would seem that representation, rather than representation and good performance was the primary factor related to 2nd Class debut. Alternatively, it may be that the criteria upon which players are selected, are not captured with performance statistics. It may be that desirable technical characteristics e.g., biomechanic parameters (Worthington, King & Ranson, 2013) are of primary importance.

The second variable to correlate with age at 2nd XI debut was innings taken to accrue 10 wickets in U17 cricket. The negative correlation suggested that players who amassed wickets quickly in U17 cricket, made their 2nd XI debut at an older age.

Table 28

Relationship between performance statistics of England cricket pathway stages and professional cricket, when considering predictors of Test bowling

		Age at 2nd Class debut	Innings to 10 wkts (1st Class, pre Test)
Innings (U15)	Pearson Correlation	-.39*	.28
	Sig. (2-tailed)	.01	.11
	N	42	35
Bowling average (U17)	Pearson Correlation	-.17	-.36*
	Sig. (2-tailed)	.26	.03
	N	44	36
3 wkt haul ratio (U17)	Pearson Correlation	-.24	-.48*
	Sig. (2-tailed)	.15	.01
	N	38	31
Innings to 10 wkts (U17)	Pearson Correlation	-.47*	.21
	Sig. (2-tailed)	.02	.35
	N	26	22
Innings to 1st 4 wkt haul (2nd XI)	Pearson Correlation		.51**
	Sig. (2-tailed)		.00
	N		37

Three variables correlated significantly with innings taken to accrue 10 wickets in 1st Class cricket. Under 17 bowling average and consistency of 3 wicket hauls were negatively correlated (r = -.36 and r = -.48) suggesting that the better the bowling (taking wickets, without conceding runs), the more quickly the bowler amassed wickets in 1st Class cricket. Innings taken to achieve a first four-wicket haul in 2nd XI cricket, was positively correlated with innings taken to accumulate 10 wickets in 1st Class cricket. This suggesting, that the ability to take wickets in a new environment (2nd XI), shortly after debut, was related to subsequent performance in 1st Class cricket. Although not statistically significant, the correlation between strike-rate (U17) and accumulation of 10 wickets (1st Class), approached significance (r = -.33, p = .05).

ODI related bowling statistics

Significant correlations were found between U17 and 2nd XI predictor variables and the dependent variable of economy rate. There were multiple moderate relationships, in the hypothesised direction between predictor variables and economy-rate (Table 29). Economy-rate in 2nd XI cricket generated the largest correlation with economy-rate in 1st Class cricket (r = .65, p = .00). Predictor variables did not correlate significantly with any other dependent variable. Beyond predicting economy-rate, it would seem that ODI bowling performance is difficult to understand through age-group statistics.

Table 29

Relationship between performance statistics of England cricket pathway stages and professional cricket, when considering predictors of ODI bowling

		Innings to 10 wkts (list A, pre ODI)	Strike rate (1st Class, pre ODI)	Economy rate (1st Class, pre ODI)	3 wkt haul ratio (1st Class, pre ODI)
Bowling average (U17)	Pearson Correlation	-.05	-.09	.36*	-.06
	Sig. (2-tailed)	.78	.58	.02	.74
	N	34	42	43	37
Wickets ratio (U17)	Pearson Correlation	.22	-.08	.32*	-.05
	Sig. (2-tailed)	.20	.61	.04	.75
	N	34	42	43	37
Innings to 5 wkts (U17)	Pearson Correlation	-.11	-.13	-.40*	-.14
	Sig. (2-tailed)	.58	.44	.01	.46
	N	29	36	37	31
Economy rate (2nd XI)	Pearson Correlation	.14	-.01	.65**	.02
	Sig. (2-tailed)	.43	.93	.00	.92
	N	37	48	49	43
Innings to 1st 4 wkt haul (2nd XI)	Pearson Correlation	-.08	-.13	-.40**	.06
	Sig. (2-tailed)	.67	.42	.01	.72
	N	33	41	42	37
Innings to 20 wkts (2nd XI)	Pearson Correlation	-.21	.02	-.39*	-.03
	Sig. (2-tailed)	.27	.93	.01	.86
	N	30	38	39	34

Discussion

In order to conduct longitudinal analysis featuring age-group cricket statistics, a two-stage process was adopted. Study 2 examined the relationship between performance statistics in age-group and professional cricket.

Batting

When considering the correlations between age-group and professional statistics, a number of trends were revealed. Firstly, batsmen who played relatively little U15 cricket and relatively greater amounts of U17 cricket went on to perform highly in professional cricket. In addition, it seems that U15 and U17 performance statistics have a positive relationship with Test and ODI related metrics. The statistics of real significance were, in large part, non-traditional metrics. When considering Test-related batting performances, the two performance related metrics that generated significant correlations were, innings taken to accumulate 100 runs (U15) and innings taken to achieve a first total of 60 runs (U15). When considering ODI-related batting metrics, innings taken to accumulate 400 runs (U17) was of most relevance. In this way, Study 2 provides further support for the importance of adaptability-based characteristics (presumably psychological, and, or, skill-based) in progressing through an athlete development pathway. At no point, did traditional metrics e.g., batting average, generate a significant relationship with professional statistics.

It is noteworthy, that at no point were significant correlations revealed between 2nd XI and 1st Class or List A metrics. This was counter to the original hypothesis, in that the authors proposed, the nearer the predictor and dependent variable (temporally), the stronger the relationship. A possible explanation for this would be that the standard of 2nd XI cricket varies so greatly, that performances statistics are relatively meaningless.

Bowling

In contrast to the batting results, the bowling analyses suggested that bowlers who participated in more U15 innings, made their 2nd XI debut at a younger age. In other words, the highest performing professional bowlers participated in more U15 age-group cricket. It may be that high calibre bowlers mature and develop at a later age, and therefore, progressing young bowlers quickly, or at a relatively young age, through the domestic pathway is not desirable.

Also, in contrast to batting statistics, two traditional statistics (bowling average and economy-rate, but not strike-rate) correlated significantly with the dependent variables. In particular, U17 bowling average correlated significantly with the predictors of both Test and ODI bowling. However, as with batting statistics, metrics that address a players adaptability in a new environment e.g., innings taken to achieve a 1st four wicket haul in 2nd XI cricket, hold the greatest degree of predictive validity.

General Discussion

The purpose of Study 1 and 2 was to (a) investigate whether performance statistics provide a tool through which talent identification practices can be informed, and (b) examine whether traditional statistics are the most appropriate metrics through which player potential can be examined. In brief, findings suggest that performance statistics may be a valuable talent identification tool. Moderate correlations were consistently revealed between predictor and outcome variables throughout all stages of analyses. When considering the second objective, results clearly suggest substantial value in ‘new’ performance statistics, in conjunction, with some, traditional bowling metrics.

The most interesting finding of the present research, was the manner in which consistent and repeated relationships were found between adaptability-based statistics and subsequent performance. In both a batting and bowling context, innings taken to achieve landmark scores, or, innings taken to accumulate arbitrary totals, relatively quickly, correlated significantly, and, to a greater extent than traditional metrics. This was the case across Study 1 and 2, signifying that future performance is more closely related to learning and adaptability, than continued performance. Whilst the importance of learning and coachability has regularly been postulated in the talent identification literature (e.g., Williams & Reilly, 2000), there has been very little empirical evidence to support this assertion. Some retrospective and qualitative research (e.g., Gould, Dieffenbach & Moffett, 2002; Hill, 2012) alludes to the importance of such variables; however, it is only relatively recently that quantitative research has begun to underpin such an argument. Other fields of research, such as educational psychology (Ackerman, 1999), have focussed more extensively on ability to learn as a marker of performance and support the argument that higher performing individuals may be better at learning: "interindvidual variances may stay constant or increase over task practice, as those individuals who grasp the optimal solution strategies markedly improve but other individuals are left farther behind" (Ackerman, 2007, p. 236).

Another informative finding of the current research, was the insight into the age at which performance statistics become of predictive relevance. There was very little evidence that U13 performance statistics have any relationship with professional performance, let alone international performance. And, although there was some evidence in support of U15 performance statistics (Test-related batting metrics), the U17 metrics seemed to provide the greatest insight. In examining this finding, the contributing participant numbers provide some insight. Of the 101 professional players included in Study 2 (all aged 25 or under), less than 50% of players featured in U13 cricket. Clearly, this basic, yet fundamental statistic, demonstrates the lack of applicability of conducting talent identification practices at such an age. This finding is in accordance with recent research, Vaeyens, Güllich, Warr and Philippaerts (2009), which suggests that early specialisation (e.g., U13) may be positively correlated with early success, but negatively, or not correlated, with achievement at a senior level.

Whilst there is evidence supporting the importance of some types of performance within U15 and U17 cricket (adaptability), an interesting finding was the manner in which high performing professional batsmen, played less U15 age-group cricket, than their lower performing professional peers. The most parsimonious explanation, being that the highest potential players demonstrate ability early, and progress to higher forms of the game, most likely U17 and 2nd XI cricket which better aids their development. A concern with this lies in the manner in which players are systematically rewarded, e.g., progress to the next level, receiving greater opportunities through early selection, at the detriment of others who possess similar ability that has not yet been expressed. This is particularly relevant given the age (U15) and the likely confound of maturation-related differences (Malina, Reyes, Eisenmann, Horta, Rodrigues & Miller, 2000). Indeed, the bowling findings allude to this confound with higher performing individuals (domestic senior) actually playing more U15 cricket presumably because the high performing, physically mature U15 bowlers have been selected early, but fail to go on and perform over time.

Limitations

A number of limitations were present in the studies. Firstly, the primary aim of this research was to examine the relationship between age-group and England performance statistics. Given the lack of age-group statistics on current England players, a two-stage approach was adopted. Whilst this process allowed longitudinal analysis, Study 2 utilised a player set, which will include a large proportion of players who are unlikely to represent England, essentially a lower ability group. Therefore, the findings of Study 2 may not be representative of how England players perform in age-group and 2nd XI cricket. Whilst this is a limitation, it was unavoidable, and the authors would attest that the exploratory nature and findings of these analyses remain highly insightful.

Secondly, research in golf (Finley & Halsey, 2004), English football (Lago, 2009; Taylor, Mellalieu, James & Shearer, 2008) and within batting in this research, suggests that adjusting performance statistics to account for differences in venue and opposition is worthwhile. However, the adjustments in this research were constrained by the available data and subsequent assumptions. Most pertinently, it was assumed that each batsman faced an equal number of deliveries from the opposing bowlers, and, in a bowling context, that each bowler, bowled an equal number of deliveries to the batsmen. Clearly, this is a crude generalisation and may well have hindered the findings, particularly in the bowling context, where adjustments added little value. Collecting ball-by-ball data across 1st Class, 2nd XI and county age-group cricket would be a progressive step for the ECB, and would allow more refined analysis and understanding of player performance and potential.

Thirdly, whilst longitudinal analysis is repeatedly proposed as a necessity in striving to understand expert performance (Ericsson & Charness, 1994), it is worthwhile noting two caveats. The findings of retrospective, or longitudinal analysis may only be relevant at the time at which performance occurred (O'Donoghue, 2001). Finley and Halsey (2004), in a golf context, do provide some evidence of how the relative importance of golf variables in predicting competition outcome, change over time. Whilst this may be the case, the authors suggest that this analysis (given the extensive longitudinal nature) examines fundamental attributes of future achievement, which are unlikely to alter over time. Further, whilst the authors would maintain that the longitudinal nature of this work will be enlightening, they do not contend that performance statistics will provide *the* answer to talent identification. Rather, combining this approach, with the ECB's scouting and Talent Testing programme, may provide the greatest degree of insight into player potential.

Conclusion

To précis, the current research offers a novel insight on a number of levels. Firstly, this research moves beyond cross-sectional talent identification research that has plagued the extant literature. In doing so, this longitudinal approach, coupled with a rich data set, has allowed exploration of attributes that may be most related to future performance. The research has presented repeated evidence that standard performance metrics are poorly associated (particularly at senior domestic level) with subsequent performance. Instead, the player's ability to learn and adapt on entering a new environment, has a far stronger relationship with subsequent performance. The authors wish to re-iterate that these studies offer an initial insight into performance statistics in a talent identification context and ensuing exploration is required.

Chapter 5

Relative Age Effects throughout a Talent Development Pathway: A Chronological and Biological Analysis of English Cricket[12]

[12] The author wishes to acknowledge the assistance of Chin Wei Ong, a colleague PhD student in data analysis and the write up of this paper. However, the hypotheses tested were the original idea of the author, the data was collected by the author, and the author remains responsible for the ideas expressed in the manuscript.

Research Progression

The first three empirical chapters examined different methodological approaches to talent identification. Each chapter offers an alternate approach, which in itself may account for unique variance in constructing a talent identification model. Chapter 2 examined the reliability and validity of skill-based tests. Chapter 3 analyses a novel scouting based assessment, considering discriminant validity and accuracy of scouting methodologies. Chapter 4 investigated whether (i), performance statistics (a longitudinal data set) could be a tool through which talent identification could be informed, and (ii), examined whether traditional statistics, or theoretically informed statistics (e.g., ability to adapt on entering a new environment) are the most appropriate metrics through which player potential can be examined. In general, non-traditional performance statistics (e.g., ability to adapt in a new environment) were the statistics of most relevance and may have the greatest relationship with future performance.

Chapter 5 presents a pathway analysis of relative age effect (RAE) in cricket, for men and women. Although not a methodological approach (as with the first three empirical chapters) it details biological maturation data that was collected as an integral part of the talent-testing framework and subsequent longitudinal data analysis. The analysis is novel given the systematic analysis of RAE across different stages of athletic development for men and women. Additionally, RAEs have been attributed to selection bias of biologically mature youth athletes, but this has yet to be empirically justified.

To answer these criticisms, RAEs were examined (i) across an entire sport pathway (junior through senior, male and female), (ii) in relation to biological maturity, and (iii) in relation to different cricket disciplines with varying physiological requirements. For males, RAEs were significant in cricketers aged 17 and younger. Analysis of the female data suggested that RAEs are emergent with moderate (compared to small or negligible) effect sizes in more recent years. Measures of skeletal age provide strong evidence that RAEs are the product of advanced biological maturity. Discipline choice moderates the relative age effect; more biologically mature cricketers are favoured in more physiologically demanding disciplines. The results reinforce the importance of studying RAEs through an entire talent development pathway, and suggest that greater emphasis should be placed on considering the role of biological maturity in athlete development.

National governing bodies (NGBs) have employed different strategies to categorise youth sport. As in education, grouping children and adolescents according to chronological age has been deemed an appropriate method to provide a safe environment for athletic development. In addition, youth sport competitions have relied on the annual age-grouping method to ensure level, age-appropriate competition. Whilst the intentions behind annual age categorisation are laudable, research on age-grouping (Cobley, Baker, Wattie & McKenna, 2009) has clearly documented that grouping adolescents across a 12-month period leads to systematic biases, with over-representation of chronologically older players within that period. This phenomenon is referred to as the relative age effect (RAE).

RAEs have been associated with selection biases in various youth sport settings, with players born closer to annual cut-off dates more likely to be selected for school teams (Cobley, Abraham & Baker, 2008), more successful sport teams (Augste & Lames, 2011) and talent selection camps (Sherar, Baxter-Jones, Faulkner & Russell, 2007). Further, significant RAEs have been observed among athletes at the highest youth representation level (e.g., Winter Youth Olympic Games). Whilst there is a growing body of literature that details RAEs across multiple sports and contexts, the extant literature is limited by (i) a failure to examine how RAEs manifest themselves across development pathways (junior through senior, male and female), (ii) a lack of high quality empirical evidence that explains RAEs (e.g., measures of biological maturity), and (iii) a lack of understanding of how RAEs operate within sports across different disciplines. We address these limitations in this study.

RAE across a development pathway

Commonly, RAEs are examined at child, youth *or* senior level, but rarely is this done in a systematic fashion within one sport. As such, it is difficult to generate a conclusive understanding of how RAEs act across progressive pathway stages of a sport. A recent meta-analysis (Cobley et al., 2009) suggests that RAEs tend to be apparent in junior athlete populations (< 11 years of age), increase in magnitude within youth sporting populations (15-18 years of age), before declining at senior ages (> 19 years of age). However, with differential findings across sports (Cobley et al., 2009), it is methodologically inaccurate simply to combine age categories across sports. In seeking to understand RAEs, there is a need to conduct systematic, sport-specific pathway analyses in order to determine how RAEs act across age-groups. In this study, we undertook a systematic analysis of the England and Wales Cricket Board's (ECB) pathway to examine RAEs across developmental stages.

Sex differences.

Examining RAEs across the ECBs development pathway enabled the study of RAE by sex. While RAEs have been examined in men, women have received less attention. In a RAE meta-analysis (Cobley et al., 2009), only 2% of 124,524 participants (sourced from 246 samples) were women. This lack of attention may be due to weaker or non-significant findings that are more common, as documented in women's soccer (Baxter-Jones,1995), rugby league (Till et al., 2010) and elite US developmental programmes (Vincent & Glamser, 2006). These weaker or non-significant findings may be due to the earlier onset of puberty, and hence, lower variability in girls' skeletal age compared to boys during selection phases (Baxter-Jones, 1995). Alternatively, as RAEs have been associated with increasing professionalisation (Musch & Grondin, 2001), female sports, which in a number of instances are still subject to amateur status, may not have been influenced to the same extent. However, with increasing emphasis being placed on women's sport, it is possible that RAEs could become more prominent and hence should be examined systematically.

RAE and biological maturity

RAEs in junior and youth populations have been most commonly attributed to biological maturation differences (Cobley et al., 2009). It has been suggested that chronologically older athletes (i.e., those born early in the selection year) are more physically developed in comparison to those born later in the selection year, subsequently giving them a competitive physiological advantage (Musch & Grondin, 2001). However, while there is evidence supporting increased stature and body mass for sports contingent on power and speed (Malina, 1994; Malina, Bouchard & Bar-Or, 2004), there is no empirical evidence supporting a direct relationship between relative-age and advanced biological maturity.

A number of studies have sought to examine the relationship between RAEs and maturity through the use of peak height velocity estimation (e.g., Deprez et al., 2013; Sherar et al., 2007; Till, Cobley, O'Hara, Cooke & Chapman, 2014). However, this approach lacks reliability and validity (see Malina, Coelho e Silva, Figueiredo, Carling & Beunen, 2012). In contrast, skeletal age estimation derived from a hand /wrist x-ray is considered to be the gold standard of maturation assessment (Malina et al., 2012), but its use is rare. To our knowledge the only exception is work by Hirose (2009) who measured skeletal age of under-10 – under-15 year olds. Counter to current hypotheses, Hirose (2009) found no significant differences in skeletal age between those born in the first and last quarter, although findings may have been limited by the small sample size. Moreover, given the homogeneous sample used (Japanese athletes) there may be a lack of validity (and generalisability) given that the skeletal age estimation used was derived from Caucasian populations. Previous research has revealed that the ethnicity of adolescents is linked to variations in skeletal age (Malina et al., 2004), and more pointedly, Ashizawa et al. (1996) and Tanner et al. (1983) have detailed the manner in which Japanese children attain maturity more rapidly than British children. As such, there is the need for further exploration and validation on British samples.

RAE and cricket disciplines

Despite popular sports such as cricket being most vulnerable to RAEs (Cobley et al., 2009), only three studies have investigated RAE in cricket, with none examining youth cricket. O'Donoghue, Edgar and McLaughlin (2004) and Abernethy and Farrow (2008) found no evidence of a RAE in senior cricket, and whilst Edwards (1994) found a RAE within professional pace bowlers (but not spin bowlers or batsmen), the analysis was somewhat flawed. Edwards adopted a cricket season cut-off date (April – March), rather than the academic and sporting cut-off date (September – August), which is accepted as the influential factor in player retention and/or attrition during athletic development. It is possible that a relative lack of reliance on physical attributes, the fact that cricket is a summer sport, or simply that RAEs have not been widely examined in youth cricket, might explain the lack of occurrence of RAEs. However, until systematic examination of a whole pathway has taken place, the role of relative age in cricket will remain unknown.

The approach adopted by Edwards (1994), analysing RAEs across disciplines (with varying physiological demands), has some merits, in allowing indirect examination of how advanced maturity (RAE) may influence discipline choice. Stuelcken, Pyne and Sinclair (2007) document the anthropometric profile of fast bowlers, which clearly shows an orientation towards height and relatively large somatotypes. As van Rossum (2006) suggests, the interplay between technical and physical factors in either a certain sport, or disciplines within a sport, may impact RAE differently. Consequently, calls to study RAEs in relation to playing positions or disciplines have been sounded (Grondin & Trudeau, 1991), and supported by findings where unique birth quartile distributions were associated with different positions in handball (Schorer, Cobley, Büsch, Bräutigam & Baker, 2009), ice hockey (Grondin & Trudeau, 1991) and soccer (Romann & Fuchslocher, 2013). Thus, the distinctiveness of different disciplines within cricket, and the lack of focus on youth cricket in prior research, lends itself well to the study of RAE.

Present research

This study investigated the incidence of RAEs across the ECB's pathway, from elite-level youth cricketers to senior England representation. In accordance with previous research

(Cobley et al., 2009), we hypothesised that RAE would decline across the youth age-groups (U12 through U19) and would be absent in senior representation. A similar, but less pronounced effect was expected within the England women's cricket pathway. Further, we hypothesised that the incidence of RAE would be closely related with biological maturity with the over-representation of chronologically older players related to advanced biological maturity. With respect to discipline-specific observations, we hypothesised that RAEs would be present and greatest among the most physiologically orientated discipline, pace bowling.

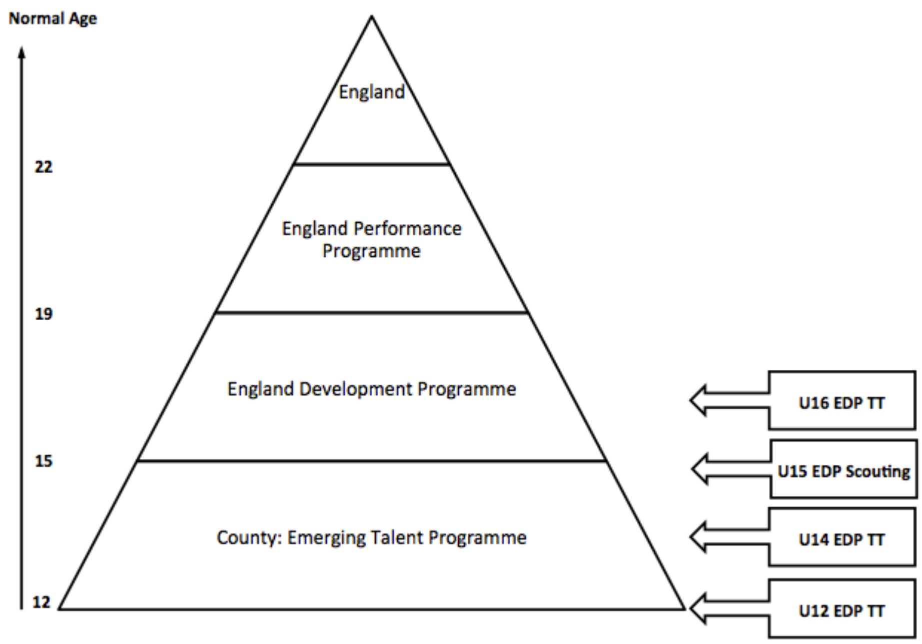
Method

Participants

Relative age effect. Birth dates, collated from internal ECB player records and TASTATS (http://www.tastats.com.au), were collected for male and female players across stages of the respective pathways.

Male development pathway. The male pathway consists of U12, U14 and U16 England Development Programme Talent Testing (EDP TT), under-15 England Development Programme (EDP) scouting, U17 EDP, U19 EDP, England Performance Programme, and England men (Figure 2.1).

Figure 2.1. Development pathway of ECB



EDP TT is a national assessment programme of the highest calibre age-group players in England and Wales (approximately 80 players per age group on an annual basis). EDP TT data was available for 2012 and 2013 at the U12 and U14 age groups, and for two additional years, 2010 and 2011, at the U16 age group. The EDP scouting process observes under-15 players that are being considered for recruitment onto the EDP (2011-2013 data were included). EDP (U17 and U19) is a 4-year national development programme aimed at developing future England players and contains those players who are perceived to be of the greatest potential (2010-2013 data were included). The England Performance Programme is the subsequent stage of the England cricket pathway and these data included players who had been part of the programme between January 2002 and September 2013. The England group included any player that had represented England between January 2001 and September 2013.

Female development pathway. Female participants were categorised as under-15 England Women's Development Programme (EWDP), U19 EWDP, England Women's Academy (EWA), or England Women (representation for England between January 2002 and December 2012). These pathway categories reflect progressive development stages.

This categorisation resulted in a total player list of 1688 cricketers. Birth dates were unavailable for 42 participants and these participants were removed from analysis. In total, 1269 male and 377 female cricketers were evaluated.

Biological maturity. Male U12 and U14 EDP TT participants were assessed for skeletal maturity. Participants consented to take part in the skeletal maturity assessment and, as participants were under the legal age of consent, forms were completed for each participant by a parent or guardian. One hundred and nineteen U12, and 118 U14 EDP TT participants completed the skeletal maturity assessment. Twenty U12 and 23 U14 EDP TT participants did not undergo the skeletal maturity assessment. This was due to non-attendance at EDP TT, lack of availability of the radiography equipment, or, consent being withheld. The ethics committee from the authors' university approved the study.

Procedure

Relative age effect. Birth month of each player was compiled into quarters (Q) relating to the sporting and academic year (1st September - 31st August) in line with standard practice in the RAE literature (Cobley et al., 2009). This resulted in quartiles as follows Q1: September - November, Q2: December - February, Q3: March - May, Q4: June - August.

Skeletal age. The Tanner-Whitehouse 3 (TW3) method (Tanner, Healy, Goldstein & Cameron, 2001) was used to assess skeletal age. An antero-posterior X-ray of the left hand / wrist was taken for each participant. The lead researcher, trained by an author of the TW3 method, examined all radiographs, generating skeletal age estimation for each participant. Chronological age was calculated as the time (years) between date of birth and date of the X-ray examination. The maturity status of each player was established by subtracting skeletal age from chronological age. The TW3 method was deemed most appropriate for the current sample, as it was derived from a reference population of British children.

To provide evidence of reliability and validity, 25 randomly selected radiographs were re-examined for intra-rater reliability three months after initial evaluation. The intraclass correlation (ICC) was .96. In addition, a reliability analysis on the method of skeletal age assessment was conducted on all 2013 radiographs by comparing the manual TW3 method with an automated software methodology (BoneXpert, Visiana, Holte, Denmark, www.BoneXpert.com; Thodberg, 2009; Thodberg, Kreiborg, Juul & Pedersen, 2009; Thodberg, van Rijn, Tanaka, Martin & Kreiborg, 2010). ICCs between manual and automated assessment of skeletal age were .83 for U12's, and .95 for U14's.

Statistical analysis

Relative age effect. To examine whether there were significant differences in birth distribution across quartiles, we used chi-square goodness-of-fit tests across the male and female pathway separately. Birth quarter acted as the independent variable and frequency of births per quarter as the dependent variable.

Recent RAE research has criticised the adoption of an even birth distribution as the expected distribution on the basis that it may increase the likelihood of generating a Type I error (Delorme & Champerly, 2013). Therefore, we sought to establish the uniformity of birth date distribution by accessing census data from the Office for National Statistics (www.ons.gov.uk), for EDP TT and scouting cohorts. Census data revealed a uniform distribution of births, with no birth quarter varying from the expected (25 percent) by more than 1 percent. In fact, for all relevant years of birth, the final birth quarter (June – August) always exceeded 25 percent, meaning that adopting a uniform birth distribution (expected) for chi-square analysis added a degree of conservatism and reduced the chance of generating a Type I error.

Relative age and biological maturity. Separate analyses of variance (ANOVA) were conducted to establish whether there were any significant differences in skeletal age and/or maturity status (dependent variables) across quartiles (independent variable). In total, four ANOVAs were conducted (U12 and U14 for skeletal age and maturity status).

Relative age effect and cricket discipline. In order to establish whether RAEs differed across disciplines, all U12 to U16 players were categorised according to their primary discipline: batsman, pace bowler, spin bowler or wicket keeper. Chi-square analyses were then completed on each discipline, with players grouped according to birth quartile. Due to low numbers, wicket keepers were removed from analyses. As the U17 EDP cohort was relatively small, it was also removed from analysis.

For all chi-square analyses, the magnitude of the RAE was established by computing the effect size (Cohen's *d*). Cohen's *d* was calculated by comparing the observed and expected distribution for the first and second half of the year (cf. Côté, Macdonald, Baker & Abernethy, 2006).

Results

Relative age effect

Male development pathway. The players' distribution across quarters, chi-square statistics and effect sizes are presented in Table 30-32. In male cricketers, a RAE was found in the first five stages of the development pathway (U12, U14 and U16 EDP TT, U15 EDP scouting and U17 EDP). Generally, players born in the first quarter of the year were over-represented compared to players born in the latter quarters (Table 30). No significant RAEs were found beyond the U17 age group.

Female development pathway. The chi-square analyses for the female pathway (Table 31) revealed a significant relative age effect at the EWA stage. For the U15 EWDP, results revealed a trend toward significance (p = .07) and a small effect size (.22). An exploratory analysis was conducted on the U15 and U19 EWDP to examine whether RAEs had become more prevalent in women's cricket in recent years. The U15 and U19 cohort were split into two groups: 2009/2010 and 2011/2012, Chi-square analyses in the U15 cohort approached significance in the more recent years (2011/2012): $\chi^2(3) = 7.21$, $p = .07$ in contrast to preceding years (2009/2010): $\chi^2(3) = 1.87$, $p = .60$. A similar trend was found in the U19 cohort: (2011/2012): $\chi^2(3) = 7.47$, $p = .06$ in comparison to $\chi^2(3) = 1.22$, $p = .75$ for 2009/2010.

Table 30. Relative age effects for different male age-groups across the ECB's development pathway.

Cohort	Q1	(%)	Q2	(%)	Q3	(%)	Q4	(%)	Total	χ^2	*P*	Effect size *(d)*
Male												
U12 EDP TT (2012, 2013)	45	(32.4)	46	(33.1)	29	(20.9)	19	(13.7)	139	14.755	0.002**	0.31
U14 EDP TT (2012, 2013)	62	(44.0)	37	(26.2)	22	(15.6)	20	(14.2)	141	31.965	0.000**	0.40
U15 EDP scout (2011, 2012, 2013)	98	(41.4)	54	(22.8)	54	(22.8)	31	(13.1)	237	39.743	0.000**	0.28
U16 EDP TT (2010, 2011, 2012, 2013)	97	(35.3)	77	(28.2)	57	(20.9)	42	(15.4)	273	25.183	0.000**	0.27
U17 EDP	19	(42.2)	14	(31.1)	7	(15.6)	5	(11.1)	45	11.089	0.011*	0.47
U19 EDP	12	(29.3)	14	(34.1)	7	(17.1)	8	(19.5)	41	4.226	0.238	0.27
England Lions	30	(29.4)	20	(19.6)	26	(25.5)	26	(25.5)	102	2.000	0.572	0.02
England (men)	35	(30.7)	24	(21.1)	33	(28.9)	22	(19.3)	114	4.386	0.223	0.04

Note: ** $p < 0.01$, * $p < 0.05$

Table 31. Relative age effects for different female age-groups across the ECB's development pathway

Cohort	Q1	(%)	Q2	(%)	Q3	(%)	Q4	(%)	Total	χ^2	*P*	Effect size *(d)*
Female												
U15 EWDP (2009, 2010, 2011, 2012)	36	(32.7)	31	(28.2)	26	(23.6)	17	(15.5)	110	7.164	0.067	0.22
U15 EWDP (2009, 2010)	15	(28.3)	14	(26.4)	15	(28.3)	9	(17.0)	53	1.868	0.600	0.09
U15 EWDP (2011, 2012)	21	(36.8)	17	(29.8)	11	(19.3)	8	(14.0)	57	7.211	0.065	0.33
U19 EWDP (2009, 2010, 2011 & 2012)	55	(33.1)	35	(21.1)	42	(25.3)	34	(20.5)	166	6.771	0.080	0.08
U19 EWDP (2009, 2010)	24	(29.6)	17	(21.0)	20	(24.7)	20	(24.7)	81	1.222	0.748	0.01
U19 EWDP (2011, 2012)	31	(36.5)	18	(21.2)	22	(25.9)	14	(16.5)	85	7.471	0.058	0.15
EWA (2010, 2011 & 2012)	19	(34.5)	8	(14.5)	19	(34.5)	9	(16.4)	55	8.055	0.045*	0.02
England (women)	13	(28.3)	13	(28.3)	15	(32.6)	5	(10.9)	46	5.130	0.162	0.13

Note: * $p < 0.05$

Table 32. Relative age effects according to cricket discipline for different male age-groups across the ECB's development pathway

Cohort	Q1	(%)	Q2	(%)	Q3	(%)	Q4	(%)	Total	χ^2	*P*	Effect size *(d)*
U12 EDP TT (2012, 2013)												
Batsmen	9	(28.1)	13	(40.6)	5	(15.6)	5	(15.6)	32	5.500	0.139	0.38
Pace bowler	20	(37.0)	20	(37.0)	12	(22.2)	2	(3.7)	54	16.222	0.001*	0.48
Spin bowler	9	(25.7)	10	(28.6)	7	(20.0)	9	(25.7)	35	0.543	0.909	0.09
U14 EDP TT (2012, 2013)												
Batsmen	13	(52.0)	5	(20.0)	3	(12.0)	4	(16.0)	25	10.040	0.018	0.44
Pace bowler	27	(52.9)	14	(27.5)	6	(11.8)	4	(7.8)	51	25.627	0.000*	0.61
Spin bowler	16	(33.3)	13	(27.1)	11	(22.9)	8	(16.7)	48	2.833	0.418	0.21
U15 EDP scout (2011, 2012, 2013)												
Batsmen	29	(33.3)	25	(28.7)	22	(25.3)	11	(12.6)	91	8.218	0.042	0.24
Pace bowler	42	(51.9)	18	(22.2)	13	(16.0)	8	(9.9)	85	33.617	0.000*	0.48
Spin bowler	17	(37.8)	8	(17.8)	13	(28.9)	7	(15.6)	47	5.756	0.124	0.11
U16 EDP TT (2010, 2011, 2012, 2013)												
Batsmen	19	(42.2)	12	(26.7)	10	(22.2)	4	(8.9)	46	10.200	0.017	0.38
Pace bowler	18	(26.5)	28	(41.2)	7	(10.3)	15	(22.1)	68	13.294	0.004*	0.35
Spin bowler	16	(39.0)	12	(29.3)	9	(22.0)	4	(9.8)	41	7.488	0.058	0.37

Note: * $p < 0.017$

Relative age effect and cricket discipline

Chi-square analyses for cricket discipline (Table 32) revealed RAEs in pace bowlers (U12, U14, U16 EDP TT and U15 EDP scouting) as indicated by the moderate effect sizes and significant chi-square statistics. In addition, RAEs in batsmen (U14, U16 EDP TT) were indicated by predominantly moderate effect sizes and significant or trending towards significant chi-square statistics. No significant RAEs were revealed in spin bowlers.

Relative age effect and biological maturity

Skeletal age. The ANOVA on U12 and U14 players revealed significant effects for skeletal age (F (3, 115) = 3.87, p = .01, η_p^2 = .09 and F (3, 114) = 4.14, p = .01, η_p^2 = .10 respectively). Bonferroni-corrected follow-up tests showed that U12 and U14 players born in Q1 (11.8 and 14.9 years) were significantly older (skeletally) than those born in Q4 (10.9 and 13.8 years).

Whilst Q1 players were skeletally older, these analyses say nothing about the *maturity status* of players across quartiles. In order to understand the influence of maturity, relative to age, differences in chronological age need to be accounted for. By establishing each player's maturity status (chronological age – skeletal age), we were able to examine the relationship between quartile and maturity status. ANOVAs conducted on each age-group revealed no significant effects at U12s and U14s.

Biological maturity and cricket discipline: Skeletal age and maturity status. In order to examine the influence of cricket discipline (independent variable) on skeletal age (dependent variable) an ANOVA was conducted on each age group (U12 and U14 EDP TT). The ANOVAs revealed significant effects for U12s and U14s, F (2, 99) = 7.04, p = .00, η_p^2 = .12, and F (2, 100) = 4.94, p = .01, η_p^2 = .09, respectively. Bonferroni-corrected follow-up tests on the U12s revealed that pace bowlers were significantly older (skeletally) than spin bowlers and batsmen (11.9, 11.0, and 11.2, respectively). Follow-up tests on the U14s detailed a significant difference between pace bowlers and spin bowlers (skeletal age of 15.0 and 14.1 years, respectively).

The analysis was repeated, with the dependent variable altered to maturity status. A significant effect was found within both the U12 and U14 EDP TT cohort, F (2, 99) = 4.88, p = .01, η_p^2 = .09, and F (2, 100) = 3.69, p = .03, η_p^2 = .07 respectively. Follow-up tests revealed that U12 and U14 pace bowlers were significantly more advanced in their maturity status than spin bowlers.

Discussion

The purpose of this study was to examine: (i) RAEs in a quasi-longitudinal fashion across the ECB's cricket pathway (male and female); (ii) the relationship between biological maturity and RAE; and (iii) the relationship between biological maturity and cricket discipline.

Across the male cricket pathway, significant RAEs were found in the first five stages of the development pathway (U12, U14 and U16 EDP TT, U15 EDP scouting and U17 EDP). No RAEs were found at U19 and above. These findings were in accordance with a number of other studies that have focused on British samples (Dudink, 1994; Simmons & Paull, 2001) and team sports (Cobley et al., 2009). The senior player findings replicated previous findings in cricket by O'Donoghue et al. (2004) and Abernethy and Farrow (2008). More recent research, documents concordant findings with relative age effects being positively related to selection / involvement in development programmes, but negatively related to graduation or progression within such programmes to senior status (Gibbs, Jarvis & Dufur, 2012; McCarthy & Collins, 2014).

A unique approach within this research was the pathway specific analysis. Whilst others have made an effort to analyse data in this fashion (Jimenez & Pain, 2008; Mujika et al., 2009; van den Honert, 2012), to our knowledge, the only other study to have specifically examined the full developmental pathway of an NGB is Till et al. (2010), who generated similar findings. The evidence presented here provides the first conclusive evidence that RAEs are embedded within the cricket development pathway, before becoming non-significant at senior levels.

In relation to the female pathway, there was some evidence of an emergent RAE when comparing 2009/2010 to 2011/2012 data. We believe that this emergent RAE may be the product of increasing professionalisation in women's cricket and unless strategies are implemented to counteract RAEs, it may only be a matter of time before they become commonplace. Suggestions on how to counteract the RAE have been discussed elsewhere (see Cobley et al., 2009; Musch & Grondin, 2001).

The pathway structure of this analysis clearly documents the manner in which RAEs are minimised, and eventually negated, as athletes' progress towards senior status. This consistent finding in decreasing RAE across the ages clearly reflects a relatively higher proportion of Q1/Q2 players dropping as they become older. Conversely, a relatively higher proportion of Q3/Q4 players are *retained* in the pathway as they progress towards senior status. As such, it seems that during the developmental stages of youth participation, the Q3/Q4 players who are within the pathway are in an *advantageous* position. From a long-term athlete development perspective, Q3/Q4 players may benefit from continually being exposed to relatively higher levels of training, competition and challenge – relative to their age – than their Q1/Q2 counterparts (Ashworth & Heyndels, 2007). This positive developmental outcome of creating a more challenging sporting environment is in contrast to the more commonly asserted view that RAEs are detrimental to many athletes' development (Cobley et al., 2009).

The biological maturity findings revealed that Q1 players were significantly older (skeletally) than Q4 players at both the U12 and U14 age group. As hypothesised, there were no significant differences between players' maturity status. In other words, players throughout Q1-Q4 were equally late or advanced in their maturity. The causative factor in RAEs seems to be the advanced biological maturity, which is solely a product of chronological age (being 6 -12 months older).

The discipline-specific analysis provides further insight into biological maturity and RAE. The largest RAEs were found in pace bowlers for the U12, U14 and U15 cohorts, relative to batsmen and spin bowlers. In addition, pace bowlers were not only older (skeletally) than spin bowlers in both the U12 and U14 cohort; they were also more advanced in their maturity status (i.e., early maturers) in comparison to spin bowlers. These findings highlight a failing in the ECB's recruitment system, with pre-adolescent boys directed (implicitly or explicitly) towards disciplines that suit their current capabilities (e.g., pace bowling because they are more biologically mature) rather than towards disciplines where they may be suited post-adolescence. From an applied perspective, it would be beneficial to avoid early specialisation of discipline, and ensure that players are not selected to programmes based on discipline ability pre-adolescence.

Conclusion

In the present study we demonstrated the differential impact of RAE across age and sex within a cricket development pathway. The effective reversal of RAEs within the cricket pathway implies that relatively young athletes are in an advantageous position, with their subsequent over-representation at older ages. This suggests that adequate challenge is a crucial component of effective talent development. Additionally, our findings on biological maturity suggest that RAEs are a direct product of biological maturity differences that result from differences in chronological age, which supports the notion of talent selectors' preference towards physical attributes in youth sport. The analysis of biological maturity with respect to cricket discipline further supports this notion, as more biologically mature athletes were selected for (or chose) those disciplines that are more reliant on physiological attributes. Whilst this research adopted a quasi-longitudinal structure, further progression would be marked by the longitudinal observation of one or multiple age groups over a number of years. The current research also focused predominantly on the relationship between RAE and biological maturity; a more detailed and extensive examination of maturity drawing on cognitive and psychosocial measures (Greenberger, Josselson, Knerr & Knerr, 1975; Weinberger & Schwartz, 1990) would be a worthwhile future direction.

Chapter 6

General Discussion

The final chapter aims to remind the reader of the nature of the thesis (collaborative and longitudinal research project), summarise the specific questions and findings that have been addressed in each of the four empirical research chapters, consider the implications (theoretical and applied), and detail the limitations of the research. The chapter concludes with future research directions.

A 10 year-longitudinal project

As detailed in the introduction, the research was initiated by the ECB with a realisation that worthwhile talent identification research (establishing predictive factors, or dispelling talent identification methodologies) would require significant and lengthy research (circa 10 years of data collection). As such, this Ph.D. was undertaken as the first stage of a longitudinal research project. Research has progressed on this premise, and, whilst the breadth of the research has expanded (in a meaningful and justifiable fashion) the fundamental objective has remained the same. Indeed, the ECB's commitment to this research continues, and is demonstrated with the instigation of a subsequent Ph.D. studentship in 2014 to continue the research. A further three years of data collection, will build on the current thesis and longitudinal analysis will allow the research to progress, with predictive talent identification questions thoroughly examined. Specific areas that would be worthwhile addressing in the ensuing years are documented in 'future directions'.

Summary of results

Chapter 2 examined the reliability and validity of five batting and two bowling tests. Two pilot tests were conducted which revealed varying levels of discriminant validity and reliability. From a batting perspective, the greatest degree and consistency of discrimination was found in the batting against pace test, with concordant results across Pilot Test 1 and 2. The batting against spin test was the most reliable, however it failed to generate significant discriminatory effects in Pilot Test 1 or 2. Interestingly, there was some evidence within the batting against pace test, that skill-based differences become more pronounced after greater degrees of familiarisation and / or learning.

The second area of interest with regard to batting from Chapter 2 was the examination of simple underlying attributes (specifically, quality of bat-ball contact within the thin bat test) versus more complex, skill-based and ecologically valid attributes (e.g., the Match Performance scenarios). It was interesting that crude measures of interceptive action (quality of bat-ball contact) consistently discriminated between batsmen of varying standard, as has previously been documented by Müller and Abernethy (2008) and Houghton, Dawson and Rubenson (2011).

The pace bowling tests used in Chapter 2 drew on core constructs of accuracy and speed of delivery. Whilst the target-based scores did not discriminant between ability groups within Pilot Test 2, they did within Pilot Test 1 for the accumulation test. Bowling speed generated high levels of reliability and discriminant validity. However, this is likely to have been significantly influenced by anthropometrics, physiological parameters and advanced maturity, which over time will be negated given the adolescent age of participants. The skeletal and biological maturity findings from Chapter 5 support this, with pace bowlers being significantly older (skeletal age) and significantly more advanced in maturity status (skeletal age – chronological age) than spin bowlers at under-12 and under-14 ages. To date, the reliability and validity of spin bowling assessments has not been systematically examined.

Chapter 3 examined the discriminant validity of a novel talent identification methodology, scouting. The study examined scouting reports over a two-year period (Study 1 and 2), where athletes were observed and concurrently evaluated against pre-defined criteria (skill, physiological and psychological). Data was examined in relation to (i) the discriminant validity of scouting reports, and (ii) the parameters through which scouting could be conducted most effectively (e.g., indoor versus outdoor, single versus multiple observations and single versus multiple scouts). Results suggest that scouting has substantial discriminant validity. More specifically, skill-based parameters differentiated between short and long-listed players. Study 1 findings alluded to the importance of tactical awareness, over and above performance and technical abilities. In Study 2, most skill-based variables discriminated with similar effect sizes, suggesting variables discriminated to an equal extent.

Skill-based variables failed to discriminate between short-list and selected players, suggesting that the importance of skill-based attributes decreases at subsequent selection stages. However, the most significant finding from Chapter 3, was the manner in which a psychological variable (inner drive, continued self-motivation and perseverance) discriminated between short-list and selected players. With no skill-based or physiological variables discriminating at this stage of selection, it would seem that psychological variables may be of the greatest importance when identifying the highest potential athletes. In addition, it is noteworthy that different psychological variables differentiated between groups at different stages of selection. Fight, resilience and coping with emotions, discriminated between long-list and short-list players, whereas, inner drive, was the attribute that differentiated at the later stage of selection. Psychological markers of future success are discussed in more detail within theoretical implications.

Analysis of the scouting process, suggested that outdoor scouting (over indoor scouting) was a more effective mechanism through which to gain accurate scouting appraisal. Although speculative, it seems likely that a highly ecologically valid environment (outdoor) assists in generating accurate appraisals of player ability. Unsurprisingly, multiple reports (averaged) generate a more accurate appraisal than single reports. Finally, utilising different scouts, rather than the same scout to generate multiple reports is most effective. It would seem that this appraisal technique (combining multiple opinions), which is not new to psychological literature (Einhorn, Hogarth & Klempner, 1997), is a valuable approach.

Chapter 4 accessed a longitudinal data set, performance statistics. Study 1 focused on the relationship between England Cricketer's performance in domestic cricket (pre international debut) and subsequent international performance. Study 2 focused on the relationship between age-group statistics and professional statistics of relevance from Study 1. In examining the relationship, focus was placed on utilising traditional statistics (e.g., batting average and number of 50 run scores) as well as non-traditional statistics that may act as markers of adaptability or learning (e.g., innings taken to achieve a landmark score on exposure to a new environment).

In Study 1, similar predictor variables (innings taken to achieve 80/90 runs, and the number of 60/70 run scores as a ratio of number of innings) correlated with international statistics in both forms of the game (ODI and Test). When considering ODI bowling, traditional statistics (strike rate, economy rate and 3-wicket haul ratio in 1st Class cricket), and non-traditional statistics (innings to accumulate 10 wickets in List A cricket), correlated significantly with ODI performance statistics. In relation to Test bowling, age at 2nd Class debut correlated significantly with players' highest world ranking; the younger the player at 2nd Class debut, the better the subsequent world ranking. Innings taken to accumulate 10 wickets and innings to first 5-wicket haul (1st Class) correlated significantly with Test bowling average and economy rate. However, these correlations were counter to the hypothesised direction. The fewer games taken to achieve the first 5-wicket haul and to accumulate 10 wickets, the worse the international bowling average and economy rate in Test cricket.

In Study 2, when examining the correlations between age-group and professional statistics, a number of trends were revealed. Firstly, to a greater extent than Study 1, the statistics of real significance were, in large part, non-traditional metrics (innings taken to accumulate 100 runs in U15 cricket, and innings taken to achieve a first total of 60 runs in U15 cricket when considering Test related statistics; innings taken to accumulate 400 runs in U17 cricket when considering ODI related statistics). Also, batsmen who played less U15 cricket and greater amounts of U17 cricket went on to perform higher in professional cricket. As such, Study 2 provides further support for the importance of adaptability-based characteristics. No 'traditional' batting metrics generated a significant relationship with professional performance statistics. What is particularly interesting is the manner in which learning / adaptability seems most important during the relatively early developmental stages. At present, it would be remise to suggest that this relates to a psychological, over skill acquisition attribute or vice versa. However, with the repeated findings relating to learning / adaptability (e.g., Chapter 2), it is clearly a metric which should receive greater levels of attention from a talent identification perspective. As an emergent theme, learning is discussed in theoretical implications.

Chapter 5 reports relative age effect (RAE) findings across a talent development pathway (male and female), investigates the relationship between RAE and biological maturity, and, examines RAE in relation to different cricket disciplines. In the male pathway, RAEs were significant at young ages, U12 to U17. RAEs declined to become non-significant at U19 and older ages. Perhaps the most interesting finding of this paper was the manner in which RAEs diminish through the pathway. In other words, a relatively higher proportion of Q3/Q4 players are retained, whilst a higher proportion of Q1/Q2 players, who were previously overrepresented, drop out. It would seem that Q3/Q4 players who do feature in the pathway are actually in an advantageous position, as demonstrated by their overrepresentation at later stages. It may be that Q3/Q4 players who are in the pathway are exposed to relatively higher levels of training, competition and challenge, and, if they remain in the system are actually in an advantageous position (Gibbs, Jarvis & Dufur, 2012; McCarthy & Collins, 2014).

Non-significant effects were found within the female pathway; however, there was some evidence of an emergent effect when comparing more recent (2011/2012) with older (2009/2010) data. It would seem likely that increasing professionalisation attached to women's cricket might be influencing the occurrence of RAEs.

Analysis of biological maturity data (skeletal age and maturity status) suggested that RAE are the product of advanced biological maturity. In addition, there was clear evidence that discipline choice is compounded by biological maturity, with pre-adolescent bowlers significantly more mature than spin bowlers (relative to their age).

Implications

The collective theoretical and applied implications that are derived from the research (Chapter 2 – 5) are addressed in the following section. From a theoretical perspective, key themes:

learning and adaptability, psychological markers of future success and maturation are discussed. The applied implications follow, and are listed for ease and simplicity.

Theoretical implications

Learning and adaptability

The most significant theoretical implication from the research relates to the repeated findings for learning / adaptability. As van Rossum and Gagné (2005) suggest, it may be that potential is most aptly assessed / recognised through rate of learning, rather than level of ability. The evidence from Chapter 2, where increasing consistency in discrimination between high and low ability groups were found in the retest, alludes to a learning effect.

It would seem that familiarisation and practice allowed higher skilled batsmen to improve by more than lower skilled batsmen. As a standalone finding, the argument would be unconvincing. However, the findings from Chapter 4 concur, where learning / adaptability-based performance statistics significantly correlated with future performance, particularly between adolescent and senior levels. This, in conjunction with research conducted by Phillips, Portus, Davids and Renshaw (2012), which provides supporting evidence for the notion that higher skilled individuals are better able to 'learn' and modify their bowling actions in order to improve accuracy, presents a compelling argument. In addition to the research detailed, some retrospective and qualitative research (Gould, Dieffenbach & Moffett, 2002; Hill, 2012) provides further evidence for the importance of ability to learn and coachability.

The extant literature outside of sport provides further evidence that learning, as a construct, should receive greater attention. In studying 120 composers, Simonton (1991) found that the most eminent composers, when compared to their less eminent counterparts, had less formal training before embarking on composition, and, had less compositional practice before they made significant contributions to music. In contrast to the Theory of Deliberate Practice (Ericsson, Krampe & Tesch-Römer, 1993), it would seem that eminence was marked by mastering skills, materials and techniques at a quicker rate than their colleagues, not by a monotonic relationship between deliberate practice and performance. Furthermore, Baltes (1998) in a memory task and Rowe (1998) in motor skill acquisition have demonstrated how intense training on a given task *extenuates* pre-task individual differences. It would seem that 'ability to learn' may be a decisive factor in the achievement of expert performance.

In contrast to the sport and exercise literature, educational research has placed significant emphasis on learning. In comparison to the view depicted above, something of a trait conceptualisation, educational literature offers an alternate position. Sanders and Rivers (1996) examined 3 million records of achievement for Tenessee's student population. The research revealed that there were significant differences in how much students learned and that this was a direct product of the *teachers* they were exposed to. For example, an average student who started second-grade in the 50th percentile of achievement would end up in the 90th percentile of achievement under a high-performing teacher, but in the 37th percentile under a low-performing teacher. More recent research (Rivkin, Hanushek, & Kain, 2005; Rockoff, 2004) provides further evidence for the link between teacher quality and student attainment. The reason for presenting an alternate position (teacher derived learning) is to avoid the atypical and narrow talent identification interpretation that could be taken from the findings. Clearly, learning is a complex interaction between multiple factors (Davids, Button, & Bennett, 2008) the task, the individual (their learning ability) and the environment (the quality of teaching), and, as such, it would be naïve to draw overly simplistic conclusions from the novel findings. Regardless, it would seem that placing greater emphasis (applied and theoretical) on rate of learning would be worthwhile. The researches maintain that further empirical work examining the differing learning ability of more, and less 'talented' performers, would be a valid avenue of future research.

Psychological markers of future success.

A growing body of research suggests that psychological characteristics of elite athletes may be a key determinant of the senior success (Collins & MacNamara, 2012; Durrand-Bush & Salmela, 2002; Gould, Dieffenbach & Moffett, 2002; MacNamara & Collins, 2013). Bloom (1982), in an extensive study of elite performers, found that the majority of senior elite abilities were not evident during adolescence. This was supported by more recent work by Barreiros, Côte, and Fonseca (2014), Gulbin, Weissensteiner, Oldenziel, and Gagné (2013), and Güllich and Emrich (2014) who have documented the lack of relationship between adolescent performance and senior success. However, Bloom (1982) suggests senior capabilities that translate back to adolescence may be psychologically-based.

Motivation. Current research suggests that the most successful senior athletes display higher levels of general motivation (Bush & Salmela, 2002; Connaughton, Hanton, & Jones, 2010; Connaughton, Wadey, Hanton, & Jones, 2008; Gould, Dieffenbach, & Moffett, 2002; Gould, Eklund, & Jackson, 1993; Orlick & Lee-Gartner, 1995). In conjunction, and related to the psychological scouting findings, there is research suggesting that the highest caliber athletes display high levels of conscientiousness (Bush & Salmela, 2002; Gould et al., 2002). Whilst the majority of the research detailed above relates to studies of senior athletes, it is difficult to comprehend how adolescent athletes would progress to elite status without exceptionally high levels of motivation and conscientiousness. It is particularly informative that 'inner drive' (continued self-motivation and perseverance) was the only variable in Chapter 3 (scouting) that differentiated between very high and high potential athletes. Whilst there is a general dearth of research in sport examining the predictive validity of such variables, possibly due to social desirability and self-presentation confounds that are inherent with self-report and interview data collection methods, Duckworth, Peterson, Matthews and Kelly (2007) has demonstrated how 'grit' (perseverance and passion for long-term goals) accounts for significant incremental variance in attainment. It would seem that the analysis of these scouting variables in a longitudinal fashion could be enlightening and informative for talent identification research.

Challenge. Research (e.g., Sarkar, Fletcher & Brown, 2014) has established a link between elite performance and resilience / the ability to overcome challenge. Additionally, Collins and MacNamara (2012) have presented qualitative evidence, from athlete biographies, of the manner in which elite athletes have overcome challenging circumstances (often referred to as trauma), which may stand them in good stead for future challenges. Van Yperen (2009), in one of the only longitudinal and multifaceted talent identification papers, highlighted how those footballers who went on to play in the highest senior level, experienced higher levels of traumatic experiences (parental divorce rate) than those that did not. It would seem that the overcoming of challenges, obstacles or traumatic events might be an important component of developing mental toughness, resilience, and / or a mindset for achievement at the highest level. Although this was not directly tested within the thesis, there were some intriguing results within Chapter 5. In studying RAE, those athletes who are youngest (within the academic / sporting year) and underrepresented at early stages of the pathway, seem to be in an advantageous position as they become over-represented at later stages. It would seem that the relatively greater challenge (training and competition) that these 'young' athletes are exposed to, equips them with attributes that allows them to progress / develop to a greater extent than their relatively 'older' counterparts. In a British context, this effect has also been documented within rugby (McCarthy & Collins, 2014). More detailed and theoretical examination of this would be worthwhile.

Maturation

There is a burgeoning body of talent identification and development research that documents the influence and importance of understanding the role of maturation. Empirical studies in football, gymnastics and ice hockey (Carling, Le Gall & Malina, 2012; Malina et al., 2005; Mirwald et al., 2002; Sherar et al., 2007) have documented how talent identification and selection practices are confounded by maturation status. From an academic and applied perspective, the challenge is exacerbated by relatively poor and unreliable maturation assessment methodologies (see Malina et al., 2012). Robust measures of skeletal maturity must be used to generate reliable and valid data. Although only dealt with simplistically within Chapter 5, extensive work was completed in implementing a skeletal maturity assessment. Over 350 athletes were examined for skeletal maturity (hand-wrist x-ray and analysed via the TW3 method), with pilot work (not presented in the thesis) conducted. The real significance of the maturation data will come to light when used as a covariate in multivariate analysis. However, the documented work in Chapter 5 provides conclusive evidence of impact of advanced maturity, with young athletes clearly directed towards disciplines that are commensurate with their current, rather than future, capabilities. It would seem that the performance advantages associated with being more physically mature dictate an orientation towards pace bowling.

Applied implications

Applied implications from Chapter 2 – 5 are detailed below. These have been listed, primarily for ease of interpretation by the ECB.

England Development Programme Talent Testing (EDP TT)

- The batting against spin test did not generate discriminant validity and should be removed from the EDP TT assessment inventory.
- Batting against pace should be retained and adequate emphasis should be placed on familiarisation prior to attending assessment.
- All skill-based test protocols should be distributed to participants in advance of assessment. This has the added benefit of including an indirect behavioral measure of motivation.
- The thin bat test should be retained with delivery numbers increased in order to improve reliability and potentially discriminatory power. Analysis suggests that quality of bat-ball contact, rather than shot accuracy, may the metric of most relevance.
- Match Performance Setting scenario should be removed with Match Performance chasing retained. This has the added benefit of retaining an element of batting against spin.
- A measure of anticipatory ability should be included within the EDP TT inventory.
- Both bowling assessments should be retained.

Scouting

The applied recommendations for scouting are largely procedural. With no longitudinal analysis completed on scouting data, it would be remiss to place applied recommendations on discriminatory findings (even though they align with the extant literature and are intuitively justifiable).

- Given the findings of this research, emphasis should be placed on scouting in the outdoor environment. If indoor scouting is imperative, effort should be made to create as much ecologically validity as possible.
- Further research should examine the discriminant and predictive validity of scenario-based assessment in an indoor scouting environment. In other words, scenarios that focus on specific attributes (e.g., ability to learn or resilience) could be facilitated within an indoor scouting environment.
- Multiple reports by different scouts should be filed on players to achieve the greatest degree of reliability and discriminatory validity.
- The discriminatory results provide strong evidence for the importance of psychological variables in talent identification practices. Given the complexity and difficulty in observing psychological variables, the ECB should continue to place significant emphasis on up-skilling scouts, particularly around the inter- and intra-rater reliability of psychological constructs.

Performance Statistics

Applied implications of the performance statistic analysis are documented below:

- When considering future batting performance in international cricket, multiple variables should be considered. It would be pertinent to consider innings taken to achieve a landmark score of 80 / 90 runs, and the number of 60 / 70 run scores, as a ratio of innings batted in.

- List A and 1st Class variables should be considered when considering future international performance of batsmen.
- When considering future bowling performance in international cricket, greatest emphasis should be placed on traditional metrics from 1st Class cricket: strike rate, economy rate and number of 3-wicket hauls, as a ratio of innings bowled in.
- When considering future bowling performance in international cricket, some consideration can be given to the age of debut in 2nd XI cricket – this may give an indirect measure of the perceived potential of the player.
- It would seem that 1st Class bowling statistics (not List A) are of most relevance when considering future performance in international cricket, regardless of whether this is ODI or Test cricket.
- Emphasis should be placed on examining non-traditional age-group performance statistics when considering early (U15 / U17) talent identification. Within an age-group setting, selectors should avoid using traditional metrics (e.g., average) when considering the potential / performance of batsmen.
- 2nd XI performance statistics should not be utilised when considering the potential / performance of young batsmen.
- In contrast to batting, traditional bowling metrics (bowling average and economy rate) in U17 cricket may have some value. They should be used in conjunction with adaptability-based variables (e.g., innings taken to achieve 1st four wicket haul in 2nd XI cricket).
- There is no evidence supporting the use of performance statistics (as correlates of future performance) at young ages (U13). There is some evidence from a batting perspective that U15 statistics may be of relevance. There is good evidence that certain U17 statistics are correlated with future performance.

Relative Age Effect

Specific recommendations in relation to the RAE have been covered in detail elsewhere (Cobley, Baker, Wattie, & McKenna, 2009; Musch & Grondin, 2001). The following suggestions relate specifically to maturation and the cricket context.

- The RAE findings suggest that Q3/Q4 players who do feature in the younger stages of the pathway are in an advantageous position, demonstrated by their effective over-representation at later stages of the pathway. Presumably, this is a product of the relatively greater challenge (training and competition) that they are exposed to. Consideration should be given to how relatively older (Q1/Q2) players can be challenged to a greater extent at earlier stages of the development pathway.
- There is evidence of an emerging RAE in women's cricket. This should be monitored on a year-by-year basis.
- The more physiologically orientated disciplines are particularly susceptible to RAEs. In addition, maturation analysis revealed that discipline choice at young ages (U12 and U14) is unduly influenced by skeletal age and maturation status. In other words, at a young age, pace bowlers are likely to be those that were born early in the year *and* are advanced biologically. The ECB should avoid selection practices at a young age and consider applied interventions to circumvent early specialisation in disciplines. Other work in team sport (Güllich, 2014; Güllich & Emrich, 2014) would strongly support the rationale behind early participation, late specialisation.

Limitations

The specific limitations of the empirical studies have been dealt with in the respective chapters. The following section deals with the general limitations of the thesis. The first and most significant limitation is the requirement for longitudinal data in talent identification research. Meaningful research must address the characteristics of adolescent performance (if any) that are predictive of elite performance (Morris, 2000), and this will only be completed through analysis of longitudinal data. Whilst Chapter 4 (and in part, Chapter 5) adopted such an approach, the talent testing and scouting analysis (Chapter 2 and 3) were limited by cross-sectional research. Whilst this is the case, it was always expected, and a product of the need to initiate meaningful longitudinal data collection.

Secondly, and linked to the data requirements for worthwhile talent identification research, there was a necessity to adopt a multifaceted approach to data collection. Whilst this was achieved through the extensive data collection within England Development Programme Talent Testing (EDP TT), Scouting and Performance Statistics, there is a significant amount of data captured that is yet to be analysed and / or written up. This reflects the capacity of a single Ph.D. student. In addition, it is worth noting that the scope of the project could have consumed a thesis in any one of many areas (performance statistics and maturation, amongst others). In contrast to this research, other talent projects have seen significant investment (financial and personnel) to ensure that the broad and complex nature of talent related research could be fully addressed (e.g., the Study of Mathematically Precocious Youth; Lubinski & Benbow, 2006). Given the longitudinal premise on which the project was initiated, it was important that the thesis set the framework through which effective longitudinal work could be conducted. However, this has meant that certain areas haven't been addressed in the level of detail that may be desirable.

Thirdly, the thesis has failed to combine different methodologies of data collection in multivariate analysis. For example, at no point were scouting and EDP TT sufficiently aligned to conduct analysis examining the unique contribution of different data collection / assessment methodologies. Clearly, accounting for unique variance through different methodologies would add a significant component to the research; this is the intention within future research. This specific limitation reflects the applied nature of the work and the lack of control over whom scouting and talent testing was conducted with. It is worth noting, that whilst these are limitations, they were always expected and a reflection of the collaborative relationship between a university and a National Governing Body.

Finally, and as discussed in theoretical implications, current research strongly supports the assertion that the achievement of expertise may be closely related to psychological factors (Collins & MacNamara, 2012, Durrand-Bush & Salmela, 2002; Gould, Dieffenbach & Moffett, 2002; Van Yperen, 2009). Whilst there are some direct measures (that have not been addressed in the thesis, coach-rated mental toughness, emotional attachment, vision – support – challenge), significant emphasis should have been placed on these / other psychological constructs. In conjunction, the thesis relies almost exclusively (with the exception of some data that has not been detailed within scouting) on quantitative data. Whilst quantitative data collection is often seen as factual and reliable (Steckler, McLeroy, Goodman, Bird, & McCormick, 1992), it may be that qualitative work, focusing on the psychosocial experiences of young athletes (including important relationships, contextual factors etc.) may be enlightening for talent identification purposes.

Future directions

Given the longitudinal premise on which the research was initiated, there are a number of outstanding questions to be addressed. Future questions worthy of further consideration have been categorised in three areas: (i) longitudinal data questions which fall out of the current, and initially intended research direction; (ii) additional data considerations, which relate to areas that are not specifically addressed within the present research; and (iii) conceptual / theoretical talent identification questions that have been generated through reading and critical thinking whilst conducting the Ph.D. The section concludes with a brief discussion of a data analysis methodology that may hold substantial utility for future analyses.

Longitudinal data questions

1. Significant work in this thesis focussed on developing a longitudinal framework for talent identification analysis. Future analysis should examine how combinations of testing, scouting, and performance statistics can generate the greatest degree of predictive validity.

2. Some research (Bartmus et al., 1987; Christensen, 2009; Thomas & Thomas, 1999) suggests that coaches are best placed to make informed and educated decisions regarding ‘talent’. Does the analysis of scouting data, in comparison to testing and performance statistics data reinforce this? What unique variance is accounted for, across the three data sets? At what age do talent identification methodologies offer empirical value? Between what groups (e.g., very high and high performers, or, high performers and low performers) does talent identification methodology hold value?

Testing

3. The testing framework includes a significant proportion of data, which has not been systematically examined. For example, some preliminary pilot work, not presented in the thesis has been conducted on anticipation, alluding to findings that are representative of current cross-sectional work (see Müller, Abernethy & Farrow, 2006). Given the breadth of data collection methodologies, cross-sectional and longitudinal analysis should be conducted on anticipation, anthropometric data (particularly in relation to post adolescent disciplines), coach-rated mental toughness data (Hardy, Bell & Beatie, 2014) and skill-based assessments that have not been documented in this thesis.

Scouting

4. The scouting form includes qualitative text data entry. As yet, no analysis has focussed on this. Qualitative methodologies should be used to examine the predictive value of this data.
5. A limitation of the scouting analysis is the manner in which the independent (scouting data) and dependent variable (selection) were not completely independent of each other. It would be meaningful to examine scouting data in relation to a dependent variable such as performance statistics (a number of years after scouting had taken place). This would give a clearer representation of the scouting variables that are predictive.

Performance statistics

6. Significant bodies of work have focussed on resilience as an important attribute in the achievement of elite performance (e.g., Galli & Vealey, 2008). However, there is little high quality quantitative research that underpins the extensive body of retrospective and qualitative research. Extending the performance statistics analysis to focus on such attributes would be insightful.

Additional data considerations

7. Adaptability / the ability to learn emerged as a significant theme within the thesis. What direct assessments of adaptability / ability to learn (qualitative or quantitative) could be implemented in talent identification practice?
8. Psychological variables have consistently been documented as a key determinant of elite success (Durrand-Bush & Salmela, 2002; Gould, Dieffenbach & Moffett, 2002; MacNamara & Collins, 2013; Mahoney &Avener, 1977; Orlick & Partington, 1988). Only modest emphasis has been placed on psychological variables within this thesis. What is the role of commitment and motivation? What part do more complex psychological traits (e.g., resilience) play in the achievement of expert performance? How and what are the mechanisms that leads to people with challenging or traumatic childhood experiences (Collins & MacNamara, 2012) becoming overrepresented? Are the psychological variables that are predictive of future success about learning, ‘performing’, or about the ability to cope with the ancillary demands of performing?
9. A strength of the current testing framework was the inclusion of a skeletal maturity assessment. However, what is the relationship between physical and psychosocial measures of maturity (Greenberger, Josselson, Knerr & Knerr, 1975; Weinberger & Schwartz, 1990)?

Conceptual / theoretical talent identification questions

10. Investment theories (Cattell, 1987) suggest that individual differences in abilities and knowledge are the product of inherited and developed motivational drivers that lead people towards or away from different learning. To what extent can investment theories underpin our understanding of talent identification?
11. Why are empirical talent identification practices necessary? Humans are susceptible to many errors in judgment (Gard, 1998; Kahneman, Slovic, & Tversky, 1982). These include ignoring base rates, confirmation bias, assigning non-optimal weights to cues, and failure to properly assess co-variation (e.g., the role of maturation). What biases are most influential in the subjective assessment of talent? And, therefore, what (if any) talent identification practices are most meaningful?

Future data analysis

Detailing future analysis intentions may be informative for subsequent researchers, and will provide greater insight to the thesis examiner of the intended direction of the research programme. As discussed earlier in the thesis, there are a number of specific challenges when conducting talent identification research. Specifically, if talent identification research is to have meaningful impact, it must differentiate between relatively synonymous groups. By this, analysis must discriminate between super-elite and elite, or those that ‘make-it’ and those that just fail to make-it, rather than using polemic player groups. This presents a statistical challenge with the relatively small participant numbers that ‘make it’ to the highest levels of achievement. Standard statistical processes (e.g., discriminant function analyses) struggle where there are a high number of variables and relatively low number of participants, as will be the case with future analysis. The intention with the present research would be to conduct pattern recognition analyses, which have been developed in bioinformatics to address the challenge of classifying groups (in this case, of athletes) on the basis of extensive data sets. Essentially, bioinformatics uses modern computational power and Bayesian statistics to analyse whether a large number of variables differentiate between two groups (e.g., those that make it, and those that just fail to make it)[13].

Using a software programme such as WEKA (http://www.cs.waikato.ac.nz/ml/weka/ (Hall, et al., 2009), the researcher can select variables which classify the group that the athlete belongs to, without this classification being the product of over-fitting. The more different criteria agree on the most discriminating features, the more confidence one can have in the results. To the author's knowledge, this would be the first time that state of the art pattern recognition has been conducted in prospective talent identification research. It would be a highly pertinent methodology, which would overcome the challenge of an extremely wide data set (EDP TT, scouting and performance statistics), with relatively low participant numbers. The researcher foresees this being a valid and highly applicable methodology to tackle subsequent analysis.

[13] It is worthwhile noting that the thesis student is not an expert in the methodology. The student has a basic appreciation of the statistical analysis, and is aware of the significant potential (given his in-depth knowledge of the data set on which it would be applicable).

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Appendix 1: Pilot Test 1 and Pilot Test 2 test administration order

Pilot Test 1 test administration order

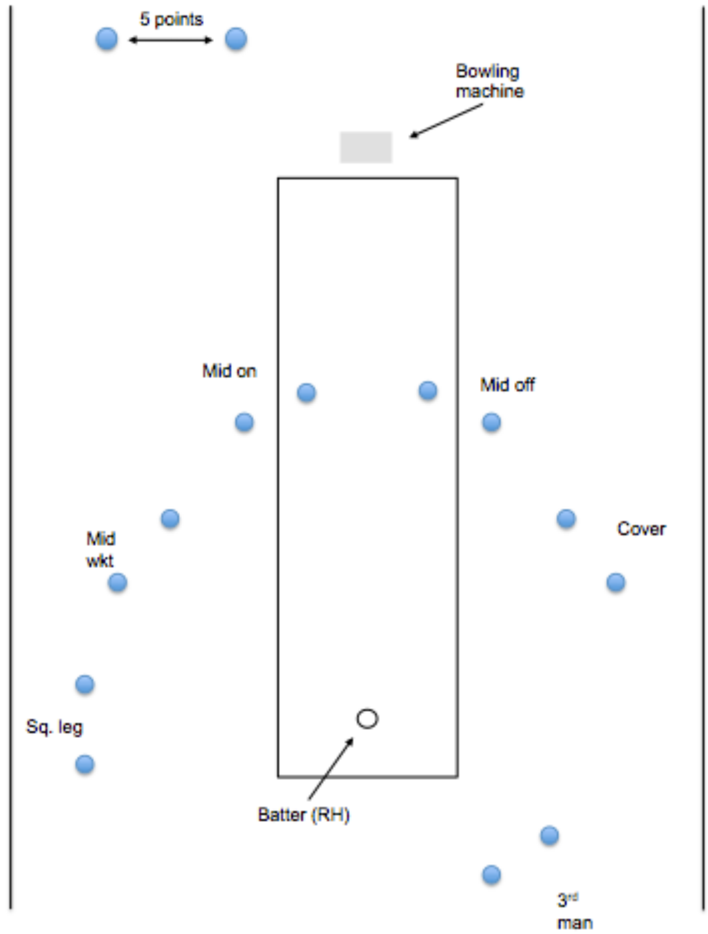
Test number	**Test**	**Length**	**Speed**	**Spin type**
1	Pace	½ volley	70 mph	
2	Spin	½ volley	49 mph	Off spin
3	Pace	Short	70 mph	
4	Spin	Good length	49 mph	Off spin

Pilot Test 2 test administration order

Test number	**Test**	**Length**	**Speed**	**Spin type**
1	Pace	½ volley	65 mph	
2	Spin	½ volley	45 mph	Off spin
3	Pace	½ volley	75 mph	
4	Spin	½ volley	45 mph	Leg spin
5	Pace	Short	65 mph	
6	Spin	Short	45 mph	Off spin
7	Pace	Short	75 mph	
8	Spin	Short	45 mph	Leg spin
9	MPS	Short	75 mph	
10	MPS	Short	75 mph	
11	MPC	Full	45 mph	Off spin
12	MPC	Full	45 mph	Off spin
13	Thin bat	½ volley	65 mph	
14	Thin bat	½ volley	75 mph	
15	Thin bat	Short	65 mph	
16	Thin bat	Short	75 mph	

Appendix 2: Batting against pace, Pilot Test 1 iteration

Target positions[14]:



	Distance from centre stump (to front of cone)	
	Left cone (m)	Right cone (m)
Mid off	19.1	19.3
Cover	10.0	9.5
3rd man	5.0	4.3
Sq. leg/deep sq. leg	5.1	5.9
Mid wicket	9.5	10.0
Mid on	19.3	19.1

Line and length:

- ½ volley delivery pitching 3.5m from stump and 1m from edge of cut wicket
- Short delivery pitching 8.4m from stumps and 0.9m from edge of cut wicket

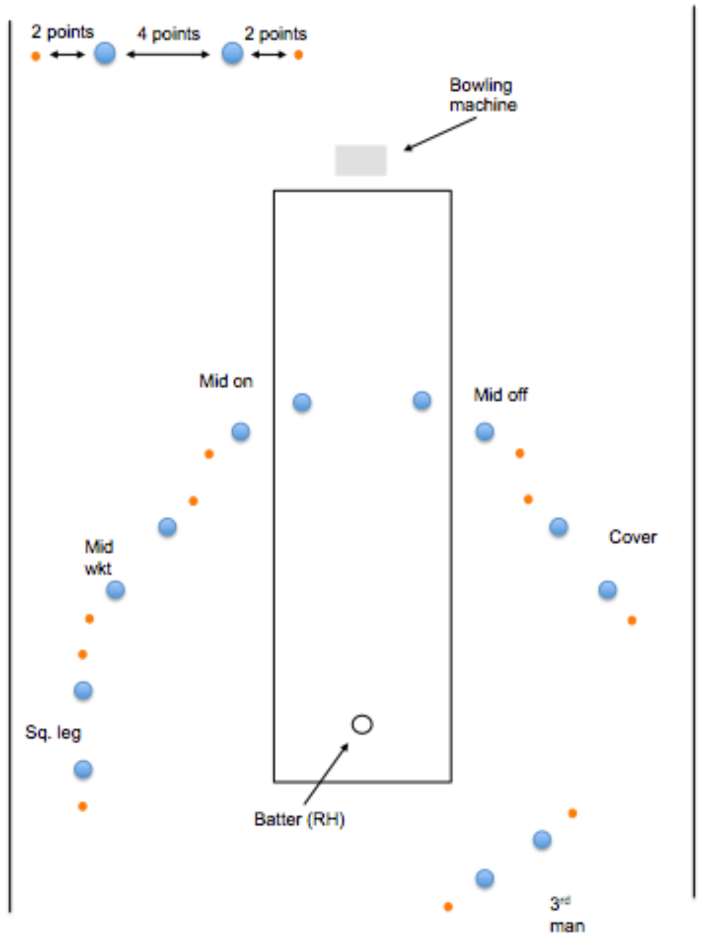
[14] As the cone position was dictated by one measurement taken from centre stump there was substantial variation in the position of cones (target size was maintained). In order to ensure a replicable protocol in 2011 'latitude' and 'longitude' measurements were implemented.

Order of deliveries

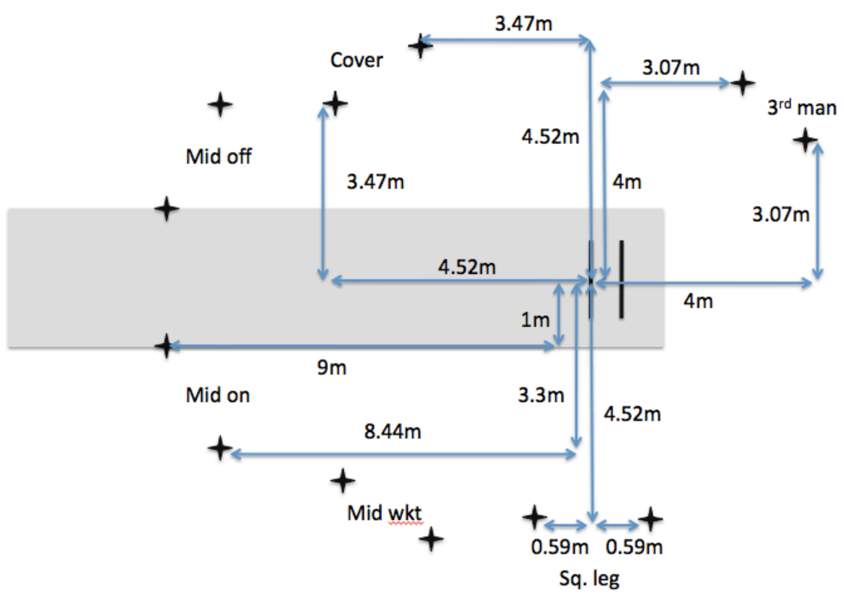
Delivery number	Length	Target
1	Full	Mid off
2	Full	Mid off
3	Full	Cover
4	Full	Cover
5	Full	3rd man
6	Full	3rd man
7	Full	Sq. leg
8	Full	Sq. leg
9	Full	Mid wicket
10	Full	Mid wicket
11	Full	Mid on
12	Full	Mid on
13	Short	Mid off
14	Short	Mid off
15	Short	Cover
16	Short	Cover
17	Short	3rd man
18	Short	3rd man
19	Short	Sq. leg
20	Short	Sq. leg
21	Short	Mid wicket
22	Short	Mid wicket
23	Short	Mid on
24	Short	Mid on

Appendix 3: Batting against pace, Pilot Test 2 iteration

Target position



Target positions: All measurements taken from the batsman's centre guard



Line and length

- ½ volley delivery pitching 3.5m from stump and 1m from edge of cut wicket
- Short delivery pitching 8.4m from stumps and 0.9m from edge of cut wicket

Appendix 4: Batting against spin, Pilot Test 1 and Pilot Test 2 iteration

Spin settings

Leg spin settings				Off spin settings			
RHB		LHB		RHB		LHB	
Top spin	Side spin	Top spin	Side spin	Top spin	Side spin	Top spin	Side spin
				+4	-R8	+4	+L8

Line and length:

<u>Off spin:</u>

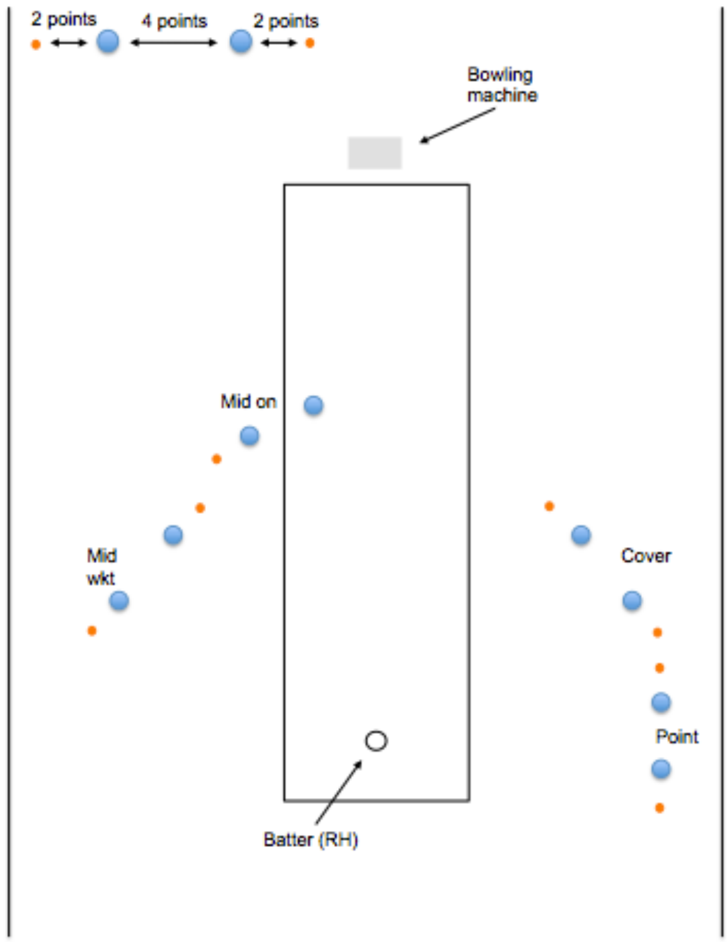
- ½ volley delivery pitching 2.9m from stump and 0.6m from edge of cut wicket
- Short delivery pitching 6.6m from stumps and 0.6m from edge of cut wicket

<u>Leg spin:</u>

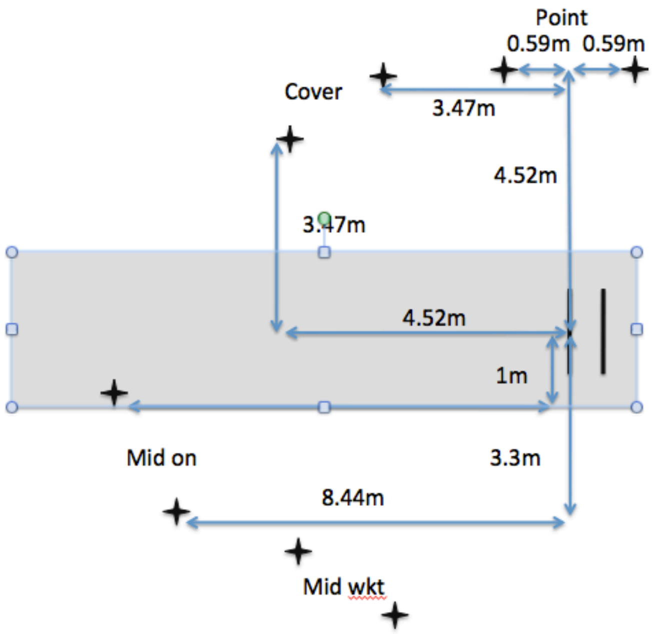
- ½ volley delivery pitching 2.9m from stump and 1.2m from edge of cut wicket
- Short delivery pitching 6.6m from stumps and 1.2m from edge of cut wicket

Appendix 5: Batting with a thin bat against pace, Pilot Test 2 iteration

Target positions

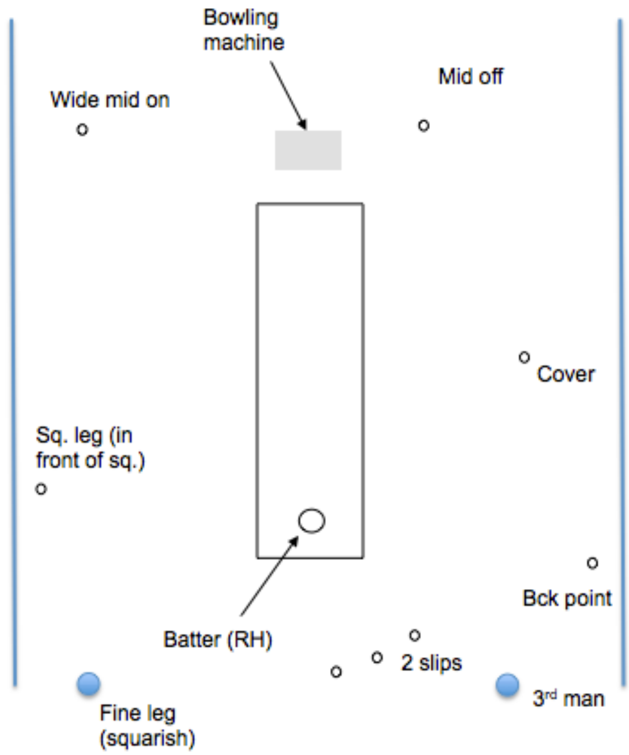


Target positions: All measurements taken from the batsman's centre guard



Appendix 6: Match Performance Setting, Pilot Test 1 and Pilot Test 2 iteration

Target positions



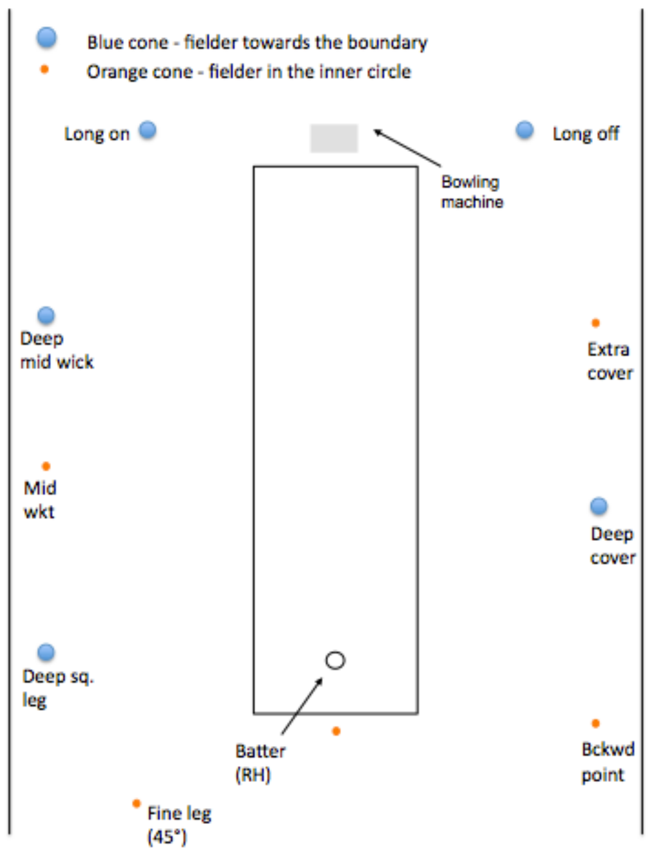
Appendix 7: Match Performance Chasing, Pilot Test 1 & Pilot Test 2 iteration

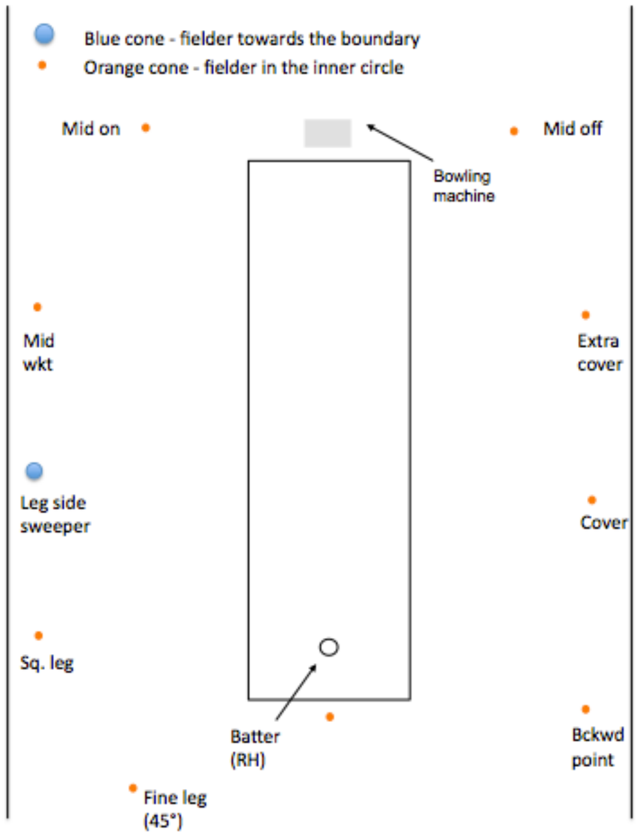
Target positions

Initial field setting		**After 3 balls - OUT**		**IN**
Backward point		Backward point		Backward point
Deep cover	→	Cover	↔	Cover
Extra cover		Extra cover		Extra cover
Long off		Long off	↔	Mid off
Long on		Long on	↔	Mid on
Deep mid wicket		Deep mid wicket	↔	Mid wicket
Mid wicket		Mid wicket	↔	Leg side sweeper
Deep square leg		Deep square leg	↔	Square leg
Fine leg (in the circle)		Fine leg (in the circle)		Fine leg (in the circle)

Compulsory field change after 3 balls to field 'OUT': Deep cover → cover

Administrator can alternate between field 'IN' and 'OUT' in final 6 balls




Blue cone - fielder towards the boundary
Orange cone - fielder in the inner circle
Mid on
Mid off
Bowling machine
Mid wkt
Extra cover
Leg side sweeper
Cover
Sq. leg
Batter (RH)
Bckwd point
Fine leg (45°)

Appendix 8: Test of multivariate and between-subject effects when batting against spin

		Test			Retest		
		1-12	**13-24**	**1-24**	**1-12**	**13-24**	**1-24**
Hotelling's T^2		0.329	0.305	0.427	0.070	0.202	0.103
Multivariate test statistic		$F(4, 20) = 1.647, p = 0.202$	$F(4, 20) = 1.525, p = 0.233$	$F(4, 20) = 2.136, p = 0.114$	$F(4, 20) = 0.350, p = 0.841$	$F(4, 20) = 1.008, p = 0.427$	$F(4, 20) = 0.513, p = 0.727$
Spin (off)	**Half volley**	$F(1, 23) = 0.380, p = 0.544$	$F(1, 23) = 0.752, p = 0.395$	$F(1, 23) = 0.994, p = 0.329$	$F(1, 23) = 0.066, p = 0.800$	$F(1, 23) = 1.117, p = 0.302$	$F(1, 23) = 0.208, p = 0.653$
	Short	$F(1, 23) = 1.437, p = 0.243$	$F(1, 23) = 0.429, p = 0.519$	$F(1, 23) = 1.106, p = 0.304$	$F(1, 23) = 0.974, p = 0.334$	$F(1, 23) = 2.605, p = 0.120$	$F(1, 23) = 2.073, p = 0.163$
Spin (leg)	**Half volley**	$F(1, 23) = 3.633, p = 0.069$	$F(1, 23) = 0.289, p = 0.596$	$F(1, 23) = 0.770, p = 0.389$	$F(1, 23) = 0.001, p = 0.982$	$F(1, 23) = 0.014, p = 0.907$	$F(1, 23) = 0.004, p = 0.949$
	Short	$F(1, 23) = 0.603, p = 0.445$	$F(1, 23) = 5.631, p = 0.026$	$F(1, 23) = 4.265, p = 0.050$	$F(1, 23) = 1.021, p = 0.323$	$F(1, 23) = 0.026, p = 0.873$	$F(1, 23) = 0.510, p = 0.482$

Appendix 9: Test of multivariate and between-subject effects when batting against pace with a thin bat

		Test			Retest		
		1-8	**9-16**	**1-16**	**1-8**	**9-16**	**1-16**
Hotelling's T^2		0.124	0.618	0.184	0.624	0.168	0.301
Multivariate test statistic		$F(4, 20) = 0.619$, $p = 0.654$	$F(4, 20) = 3.089$, $p = 0.039$	$F(4, 20) = 0.920$, $p = 0.472$	$F(4, 20) = 2.965$, $p = 0.384$	$F(4, 20) = 0.798$, $p = 0.541$	$F(4, 20) = 1.429$, $p = 0.231$
Speed 1 (slow)	**Half volley**	$F(1, 23) = 1.016$, $p = 0.324$	$F(1, 23) = 1.643$, $p = 0.213$	$F(1, 23) = 0.055$, $p = 0.816$	$F(1, 23) = 2.424$, $p = 0.134$	$F(1, 23) = 0.167$, $p = 0.686$	$F(1, 23) = 0.588$, $p = 0.451$
	Short	$F(1, 23) = 0.668$, $p = 0.422$	$F(1, 23) = 4.209$, $p = 0.052$	$F(1, 23) = 2.627$, $p = 0.119$	$F(1, 23) = 0.656$, $p = 0.427$	$F(1, 23) = 0.228$, $p = 0.638$	$F(1, 23) = 0.789$, $p = 0.384$
Speed 2 (fast)	**Half volley**	$F(1, 23) = 0.219$, $p = 0.644$	$F(1, 23) = 0.724$, $p = 0.404$	$F(1, 23) = 0.018$, $p = 0.895$	$F(1, 23) = 9.321$, $p = 0.006$	$F(1, 23) = 1.529$, $p = 0.229$	$F(1, 23) = 5.459$, $p = 0.029$
	Short	$F(1, 23) = 0.012$, $p = 0.915$	$F(1, 23) = 0.563$, $p = 0.461$	$F(1, 23) = 0.350$, $p = 0.560$	$F(1, 23) = 0.002$, $p = 0.967$	$F(1, 23) = 2.404$, $p = 0.135$	$F(1, 23) = 0.816$, $p = 0.376$

Appendix 10

Pearson's correlations (r) for test - retest and differing delivery breakdowns: Batting against pace

		Test vs. Retest					
		1-12 vs. 1-12	13-24 vs. 13-24	1-24 vs. 1-24	1-48 vs. 1-48	1-96 vs. 1-96	1-12 vs. 13-24
Speed 1 (slow)	Half volley	0.51	0.33	0.60	0.54		0.54
	Short	0.08	0.33	0.30			0.51
						0.50	
Speed 2 (fast)	Half volley	0.08	0.24	0.48	0.42		0.00
	Short	0.02	0.16	0.35			0.40

		Test vs. Test			Retest vs. Retest		
		1-12 vs. 13-24	1-12 vs. 1-24	13-24 vs. 1-24	1-12 vs. 13-24	1-12 vs. 1-24	13-24 vs. 1-24
Speed 1 (slow)	Half volley	0.42	0.84	0.85	0.32	0.78	0.84
	Short	0.27	0.82	0.77	0.65	0.92	0.90
Speed 2 (fast)	Half volley	0.32	0.87	0.74	0.49	0.88	0.84
	Short	0.26	0.77	0.81	0.47	0.83	0.88

Appendix 11

Pearson’s correlations (r) for test - retest and differing delivery breakdowns: Batting against spin

<table>
<tr><th></th><th></th><th colspan="6">Test vs. Retest</th></tr>
<tr><th></th><th></th><th>1-12 vs. 1-12</th><th>13-24 vs. 13-24</th><th>1-24 vs. 1-24</th><th>1-48 vs. 1-48</th><th>1-96 vs. 1-96</th><th>1-12 vs. 13-24</th></tr>
<tr><td rowspan="2">Off spin</td><td>Half volley</td><td>0.40</td><td>0.25</td><td>0.28</td><td rowspan="2">0.35</td><td rowspan="4">0.70</td><td>-0.11</td></tr>
<tr><td>Short</td><td>0.20</td><td>0.27</td><td>0.37</td><td>0.40</td></tr>
<tr><td rowspan="2">Leg spin</td><td>Half volley</td><td>0.36</td><td>-0.04</td><td>0.37</td><td rowspan="2">0.73</td><td>0.12</td></tr>
<tr><td>Short</td><td>0.53</td><td>0.51</td><td>0.64</td><td>0.10</td></tr>
</table>

<table>
<tr><th></th><th></th><th colspan="3">Test vs. Test</th><th colspan="3">Retest vs. Retest</th></tr>
<tr><th></th><th></th><th>1-12 vs. 13-24</th><th>1-12 vs. 1-24</th><th>13-24 vs. 1-24</th><th>1-12 vs. 13-24</th><th>1-12 vs. 1-24</th><th>13-24 vs. 1-24</th></tr>
<tr><td rowspan="2">Off spin</td><td>Half volley</td><td>-0.02</td><td>0.85</td><td>0.51</td><td>-0.02</td><td>0.77</td><td>0.62</td></tr>
<tr><td>Short</td><td>0.44</td><td>0.81</td><td>0.89</td><td>0.53</td><td>0.91</td><td>0.83</td></tr>
<tr><td rowspan="2">Leg spin</td><td>Half volley</td><td>0.19</td><td>0.79</td><td>0.75</td><td>-0.14</td><td>0.72</td><td>0.59</td></tr>
<tr><td>Short</td><td>0.22</td><td>0.75</td><td>0.81</td><td>0.54</td><td>0.91</td><td>0.85</td></tr>
</table>

Appendix 12

Pearson's correlations (r) for test - retest and differing delivery breakdowns: Batting against pace with a thin bat

		Test vs. Retest					
		1-8 vs. 1-8	9 - 16 vs. 9 - 16	1-16 vs. 1-16	1-32 vs. 1-32	1-64 vs. 1-64	1-8 vs. 9-16
Speed 1 (slow)	Half volley	-0.56	0.39	0.29	0.18	0.20	-0.44
	Short	0.30	0.24	0.48			-0.05
Speed 2 (fast)	Half volley	0.14	0.26	0.23	0.09		0.54
	Short	-0.13	0.24	-0.10			0.05

		Test vs. Test			Retest vs. Retest		
		1-8 vs. 9 - 16	1-8 vs. 1-16	9 - 16 vs. 1-16	1-8 vs. 9-16	1-8 vs. 1-16	9 - 16 vs. 1-16
Speed 1 (slow)	Half volley	-0.20	0.61	0.65	0.12	0.77	0.73
	Short	0.40	0.89	0.62	0.52	0.82	0.67
Speed 2 (fast)	Half volley	0.18	0.88	0.79	0.12	0.85	0.89
	Short	0.14	0.72	0.79	0.13	0.79	0.71

Appendix 13: Independent t tests assessing discriminant validity of Match Performance Chasing

		Mean	
		University	School
Test – block 1	t(23) = -0.01, p = 0.990	9.91	9.86
Test – block 2	t(23) = -1.73, p = 0.098	16.64	13.29
Retest – block 1	t(23) = -0.79, p = 0.437	14.73	12.79
Retest – block 2	t(23) = -1.47, p = 0.155	15.55	11.64

Scouting appendices

Appendix 14

		All data				Outdoor				1st outdoor report			
		Long list	Short list	T value	η_p^2	Long list	Short list	T value	η_p^2	Long list	Short list	T value	η_p^2
Batting (1st discipline)	Defends v pace	2.35	2.50	$t_{(12)}$ 0.52	.02	2.32	2.50	$t_{(12)}$ 0.64	.03	2.20	2.50	$t_{(12)}$ 1.09	.09
	Attack v pace	2.23	2.70	$t_{(12)}$ 1.95	.24	2.24	2.75	$t_{(12)}$ 2.04	.26	2.10	2.75	$t_{(12)}$ 2.96*	.42
	Defend v spin	2.33	2.75	$t_{(12)}$ 1.58	.17	2.32	2.75	$t_{(12)}$ 1.60	.18	2.20	2.75	$t_{(12)}$ 2.10	.27
	Attack v spin	2.02	2.70	$t_{(12)}$ 2.68*	.37	2.00	2.68	$t_{(12)}$ 2.64*	.37	1.90	2.75	$t_{(12)}$ 3.88**	.56
Pace bowling	Pace & bounce	1.94	2.53	$t_{(16)}$ 1.99	.20	1.89	2.53	$t_{(16)}$ 2.15*	.22	1.78	2.56	$t_{(16)}$ 2.37	.26
	Control	2.51	2.61	$t_{(16)}$ 0.39	.01	2.44	2.56	$t_{(16)}$ 0.39	.01	2.44	2.56	$t_{(16)}$ 0.37	.01
	Lateral movement	1.98	2.43	$t_{(16)}$ 1.90	.18	1.94	2.43	$t_{(16)}$ 1.81	.17	2.00	2.44	$t_{(16)}$ 1.51*	.13
	Variation	2.26	2.82	$t_{(16)}$ 2.49*	.28	2.22	2.81	$t_{(16)}$ 2.23*	.24	2.11	2.78	$t_{(16)}$ 2.68*	.31
Spin bowling	Spin	1.99	3.05	$t_{(12)}$ 2.29*	.30	2.04	3.00	$t_{(12)}$ 2.01	.25	2.13	3.00	$t_{(12)}$ 1.88	.23
	Variation	2.25	2.93	$t_{(12)}$ 2.04	.26	2.34	2.88	$t_{(12)}$ 1.52	.16	2.25	2.83	$t_{(12)}$ 1.49	.16
	Control	2.24	2.83	$t_{(12)}$ 1.90	.23	2.23	2.75	$t_{(12)}$ 1.73	.20	2.25	2.67	$t_{(12)}$ 1.22	.11
Fielding	Catches	2.89	3.07	$t_{(48)}$ 1.68	.06	2.89	3.07	$t_{(48)}$ 1.73	.06	2.93	2.95	$t_{(48)}$ 0.14	.00
	Throws	2.50	3.01	$t_{(46)}$ 4.13**	.25	2.51	3.01	$t_{(47)}$ 3.77**	.23	2.53	3.05	$t_{(44)}$ 3.78**	.21
	Stops	2.80	3.05	$t_{(48)}$ 2.19*	.09	2.81	3.05	$t_{(48)}$ 2.10*	.08	2.87	3.10	$t_{(48)}$ 1.84	.07
	Athletic movement	2.71	3.05	$t_{(48)}$ 2.59*	.12	2.70	3.10	$t_{(48)}$ 2.70*	.13	2.73	3.10	$t_{(48)}$ 2.38*	.11

Note: ** $p < .01$, * $p < .05$

Performance Stats Appendices

Appendix 15

Batting	**Definition**
Innings	The number of innings in which a batsmen batted
Not outs	The number of times the batsman was not out at the conclusion of an innings in which they were batting
Runs	The number of runs scored
Maximum score	The highest score made by the batsman
Batting average	The total number of runs scored (across innings) divided by the total number of innings in which the batsman was out
Strike rate	The average number of runs scored per 100 balls faced
Bowling	
Overs	The number of overs bowled
Runs	The number of runs conceded
Wickets	The number of wickets taken
Bowling average	The number of runs conceded divided by the number of wickets taken
Strike rate	The number of balls bowled divided by the number of wickets taken
Economy rate	The number of runs conceded divided by the number of overs bowled
Five wickets in an innings	The number of innings in which the bowler took at least 5 wickets