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1. Introduction

1.1 Background of Cricket

Cricket has been played for over five centuries and is established in almost 100 different countries (Justham, West & Cork, 2008). It is a field-based sport contested by teams of eleven players; each possessing a set of specific skills which define their role and contribute to team performance (Stuelcken, Pyne & Sinclair, 2007).

Cricket archives and statistics date back to the sixteenth century, with the first laws drafted in 1744 and the Marylebone Cricket Club taking governance of the sport from the late eighteenth century (Dellor & Lamb, 2006). The overriding principles of these first laws still regulate the sport today, where put simply, to win a match you have to score more runs than the opposition before losing all your wickets or finishing your allotted overs (Boardman, 2010). Since these early beginnings, cricket has changed radically to conform to modern society and its faster way of life. For example, the introduction of single innings matches came during the 1960's, with the first major one-day tournament being played in England. This type of match proved to be hugely popular and crickets' first one-day international (ODI) was contested in 1971. Since its inception, one-day cricket has grown in importance. A catalyst for this success was the introduction of a breakaway World Series competition by Australian entrepreneur Kerry Packer in 1977 (Dawson, Morley, Paton & Thomas, 2009). Packer purchased the world's best cricketers and televised the matches; establishing cricket as a profitable enterprise alongside the development of coloured clothing, day-night matches and branded team names (Boardman, 2010).

The introduction of a Twenty20 competition in England in the early 2000’s provided another new exciting format of cricket which unlocked a fresh audience and target market. However, this led to the re-assessment of the appeal of one-day cricket due to speculation that it was too predictable (Boardman, 2010; Brown, 2003). Consequently, in 2005, in an effort to increase the appeal of the sport and extend the dramatic periods beyond the culmination of an innings (Boardman, 2010), the International Cricket Council (ICC) introduced powerplays in ODIs. Subsequently, powerplays were soon adopted in English county cricket and during the 2012 season powerplays were used in both the List A and Twenty20 competitions.

Powerplays occur at the start of an innings for a varying number of overs dependent on the competition and the length of a match. Moreover, in List A cricket in 2012, an additional batting and bowling powerplay occurred under the instruction of the batting or fielding captains respectively. During powerplay overs further fielding restrictions are imposed, requiring a minimum of fielders in close proximity to the batsman, of which two are in catching positions (Boardman, 2010). Further and more detailed information on fielding restrictions during non powerplay and powerplay overs in List A cricket in 2012 is available in Appendix 1. Combined with increasing the appeal of the sport, powerplays, and the associated fielding restrictions and tactical timings of additional powerplays, are designed to provide an opportunity for a batting team to score more runs. However, powerplays can also increase the risks taken by batsmen and consequently increase the chances of a fielding team taking wickets and winning a match.

During the 2012 season, English county cricket comprised of eighteen counties competing in three forms of cricket: first-class, List A and Twenty20. The County Championship is the domestic first-class competition. All eighteen counties compete in a two-division league format, with matches contested over four days and two innings per side. A diminishing scale of points are awarded for a win, tie, draw, abandonment or loss, with bonus points available to reward batting and bowling performances in the first innings of a match. In the Twenty20 counties are divided into three regionalised divisions of six teams. Matches are limited to 20 overs per side with an emphasis on fast action. The top two from each division, plus the two best third-placed teams across all the divisions qualify for the quarter-finals. In the event of two or more teams finishing on equal points; net run-rate and then head to head records are used to establish who qualifies for the quarter-finals. If teams still can’t be separated then the quarter-finalists are decided by drawing lots (ECB, 2012a).

The Clydesdale Bank 40 over competition is the List A competition. The eighteen counties, joined by Scotland, Netherlands and the Unicorns, are split into three groups of seven teams. The Unicorns are a team formed in 2010 specifically to play in the List A competition. Members of the squad are players without a current full-time professional contract with one of the first-class counties. The squad consists of former professionals alongside young players aspiring to play first-class cricket (Unicorns, 2013). The top team from each league plus the best second-placed team across all three divisions then compete in semi-finals. In the event of two or more teams finishing on equal points; teams are separated using similar criteria to that used in the Twenty20 (ECB, 2012b).

1.2 Rationale

Much of the published literature relating to cricket has primarily focused on the physiological (Devlin, Fraser, Barras & Hawley, 2001; Gore, Bourdon, Woolford & Pederson, 1993; Noakes & Durandt, 2000), biomechanical (Bartlett, Stockill, Elliott & Burnett, 1996; Elliott, Davis, Khangure, Hardcastle & Foster, 1993; Glazier, Paradisis & Cooper, 2000; Pyne, Duthie, Saunders, Petersen & Portus, 2006) and psychological (McLeod & Jenkins, 1991; Totterdell & Leach, 2001; Totterdell 2000) aspects of the sport. More recently research has extended to the discipline of performance and notational analysis (NA; Douglas & Tam, 2010; Moore, Turner & Johnstone, 2012; Najdan, 2011; Petersen, Pyne, Portus, Cordy & Dawson, 2008a; Petersen, Pyne, Portus & Dawson, 2008b); however research in this area is still sparse in comparison. Najdan (2011) suggests that this is due to a concentration on technical elements and the innate conservatism of the sport. Although the outlined research is vital in helping us understand the sport and the demands and pressures on players, its findings cannot have an immediate impact upon team performances during a match. However, an objective analysis and quantification of the key performance indicators (KPIs) that correlate with successful performance in List A matches would allow coaches and players to develop tactics which interact with a match situation. Therefore, the findings of this study will contribute to the growing level of research focusing on performance analysis (PA) in cricket, and the KPIs that are associated with successful performances in List A matches.

1.3 Aims of the Research Study

Consequently, the aims of this study are to:

i) Preliminarily investigate and quantify the magnitude of differences between key performance indicators of winning and losing teams in a selection of English List A matches.

ii) Preliminarily investigate pitch-level analysis data, including the line and length of wickets taken and boundaries scored, and its impact on winning or losing in a selection of English List A matches.

2. Literature Review

2.1 Performance Analysis

PA of sport is the investigation of sports performance or performance during training (O'Donoghue, 2010). It can be divided into two disciplines; sports biomechanics and NA. Both disciplines involve the analysis and improvement of performance, making extensive use of video analysis and video-based technology (Hughes & Bartlett, 2008). They differ in that biomechanics is grounded in the science of mechanics and anatomy, analysing individual sports techniques in fine detail (Hughes & Bartlett, 2008). NA, however, concentrates on gross movements or movement patterns in sports with a primary focus on strategy and tactics (Hughes & Bartlett, 2008). The principal aims of NA are to develop an understanding of a sport that can inform decision-making and enhance performance, whilst overcoming the limitations of subjective observation and providing objective information in a consistent and reliable manner (Hughes & Bartlett, 2008; O'Donoghue, 2010).

With well-chosen performance indicators (PIs), PA can highlight both good and bad techniques or team performances, alongside facilitating comparative analysis of individuals or teams (Hughes & Bartlett, 2008). PIs are a selection or combination of action variables relating to a successful performance or outcome that aim to define an aspect of performance (Hughes & Bartlett, 2002). PIs fall into one of three classifications; biomechanical, technical or tactical (Hughes & Bartlett, 2002). Out of these classifications, Hughes and Bartlett (2002) suggest that coaches have previously identified the strategic and tactical aspect of performance, through the analysis of KPIs, as the most adaptable during match situations. A strategy can be defined as a plan that is established prior to competition that will make the best of a team's strengths whilst limiting the effects of any weaknesses (O'Donoghue, 2010). Strategies also seek to exploit any known weaknesses of an opponent whilst minimising situations where opponent's strengths can be utilised (O'Donoghue, 2010). Tactics, however, are the moment-to-moment decisions made during a competition by players based on predetermined strategies, the options available to them and the perceived risks and opportunities associated with each (Alderson, Fuller, & Treadwell, 1990; Yiannakos & Armatas, 2006). Consequently, NA allows coaches to objectively assess the success of any strategies and tactics employed within a match (Jenkins, Morgan & O'Donoghue, 2007), and to develop new strategies and tactics for future opponents and matches (Hughes & Franks, 2005).

2.1.1 Performance Indicators

PIs are derived from flowcharts for NA (Hughes & Franks, 2004) and hierarchical technique models for biomechanics (Hay & Reid, 1988). Dependant on the research question being asked or a coaches' request; PIs are used to define a performance against some form of outcome or in a comparative way with opponents or peer groups of athletes or teams (Hughes & Bartlett, 2004; Hughes et al., 2012b). PIs are also often used in isolation as a measure of the performance of a team or individual (Hughes et al., 2012b).

PIs can vary from coach to coach and sport to sport (Hughes et al., 2012a), and are regularly normalised to a total of a PI, for example, aggregated data from performances or to a maximum value (Hughes & Bartlett, 2004). Examples of normalisation in cricket are PIs normalised by an over, innings, match or season. Moreover, PIs can be normalised in relation to opponents, players or teams of a similar standard, or to profiles of previous performances (Hughes & Bartlett, 2004). However, caution is required when presenting PIs in isolation as a single set of data can give a distorted impression of a performance (Hughes et al., 2012b). For example, a rugby player could kick five out of five kicks resulting in 100% conversion-rate. However, questions on the meaning and context of the data need to be asked. How difficult were the kicks? What were the pitch positions? How much pressure was there? How crucial was each kick to the game state? At what time in the match were the kicks taken? Moreover, in cricket, the interaction between the bowlers and batman must be considered. For example, a bowler having an outstanding performance can make an excellent batsman appear ordinary, and vice versa (Hughes & Bartlett, 2004).

O'Donoghue (2010) suggests that, due to time constraints in undergraduate and postgraduate research projects; PIs are typically selected and justified based on surveying coaching and PA literature, or by undertaking preliminary qualitative research to elicit PIs from expert coach opinion. This is in comparison to the more time-consuming method of quantitatively investigating the validity of the PIs to be used within a research study. Subsequently, it is suggested that students should consider which PIs are important to their research and also the feasibility of possible methods for collecting raw data, and the reliability of the possible systems to be used to record data (O'Donoghue, 2010). Moreover, the correct identification and definition of PIs is crucial before designing a coding system or research project in PA (Hughes et al., 2012a; 2012b). It has also recently been suggested that identifying a universal set of PIs with clear operational definitions for a sport would have significant benefits for PA research and consultancy (Hughes et al., 2012a; 2012b).

2.2 Research in Cricket

Early research in cricket focused upon sport and exercise biomechanics, in particular injury identification and prevention in fast bowlers (Elliott et al.. 1993; Elliott, Foster & Gray, 1986; Foster, John, Elliott, Ackland & Fitch, 1989). More recently, research progressed to investigating the impact of technique on bowling accuracy (Burnett, Elliott & Marshall, 1995; Portus, Sinclair, Burke, Moore & Farhart, 2000) and the determinants of ball-release speed (Glazier et al., 2000; Loram et al., 2005; Pyne et al., 2006). Comparatively, batting has received less attention with the major studies investigating dehydration (Gore et al., 1993), eye movements (Land & McLeod, 2000), and the ergonomics of batting equipment (Stretch, 2000). Other research included investigations on injury types and incidences (Stretch, 2001a; 2001b), decision making processes (McLeod & Jenkins, 1991) and the impact of mood on performance (Totterdell & Leach, 2001; Totterdell 2000).

More contemporary research has shifted attention to examining the physiological demands of match-play with a number of time-motion (Duffield & Drinkwater, 2008; Rudkin & O'Donoghue, 2008) and global positioning system (GPS) technology based studies being completed (Petersen, Pyne, Dawson, Portus & Kellett, 2010; Petersen, Pyne, Portus & Dawson, 2009). Duffield and Drinkwater (2008) conducted time-motion analyses on test and one-day batting innings with the aim of developing training protocols to simulate scoring a century. Results showed that the activity of both test and one-day innings is predominantly low-intensity with similar amounts of high-intensity activity (Duffield & Drinkwater, 2008). However, test innings are performed over a greater period of time with longer periods of standing and walking (Duffield & Drinkwater, 2008).

In a similar study, Rudkin and O'Donoghue (2008) investigated the demands of English first-class county fielding with the aim of creating a movement database from which specific training programmes could be devised. Players were observed for the first ten overs of each of the morning, afternoon and evening sessions using a computerised time-motion analysis system (Rudkin & O'Donoghue, 2008). Results identified large periods of rest with a lower proportion of high-intensity activity compared to most team invasion sports (Rudkin & O'Donoghue, 2008). Rudkin and O'Donoghue (2008) concluded that their data upheld the view that cricket fielding is 'un-demanding' before suggesting that further research is required on different fielding positions and one-day cricket.

Petersen et al. (2009) investigated the time-motion characteristics during four Twenty20 matches. GPS analysis of eighteen players was completed with the aim of quantifying movement demands and determining the amount of physical preparation and recovery required for Twenty20 matches (Petersen et al., 2009). Results indicated that fast bowling is the most physically demanding discipline with bowlers covering the most distance with the highest number of high-intensity efforts and the shortest recovery periods (Petersen et al., 2009). In comparison with Rudkin and O'Donoghue, (2008) Twenty20 fielders covered two and a half times more distance per hour than in first-class matches (Petersen et al., 2009). Moreover, in comparison with test and one-day centuries (Duffield & Drinkwater, 2008), Twenty20 batsmen spent a greater proportion of time in high-intensity activity (Petersen et al., 2009). It was concluded that coaches dealing with players participating in all three formats of cricket must reconcile the differences by devising match- and discipline-specific training sessions (Petersen et al., 2009).

In a subsequent study, Petersen et al. (2010) examined both discipline and match format differences using 24 Cricket Australia tour matches (seven Twenty20, sixteen one-day and one multi-day match). Results indicated that the physiological demands of cricket vary substantially between both discipline and match format, with Twenty20 cricket the most intense for all disciplines (Petersen et al., 2010). Similarly to Petersen et al. (2009), fast bowling was recognised as the most demanding discipline with fast bowlers covering the greatest total distance, distance in high-intensity activity and having the lowest work-to-rest ratio across all formats (Petersen et al., 2010). Batsmen performed at a similar intensity during Twenty20 and one-day matches covering a total distance of ~2.6 $km \cdot h^{-1}$, compared to multi-day cricket where batsmen covered 0.4 km less distance per hour (Petersen et al., 2010). However, the volume of work completed by a batsman is directly proportional to the time they spend at the crease.

2.3 Performance Analysis in Cricket

Cricket is a sport in which statistics feature heavily and can influence match strategy and tactics throughout (Petersen et al., 2008b). For example, how quickly to chase a total or whether a bowler should look to take wickets or restrict runs. Factors such as the manipulation of field placements, an innings tempo, and skill execution can also influence a match outcome (Petersen et al., 2008b). Consequently, some of the statistical and analytical research in cricket dates back to the 1980's focusing on batting strategies (Clarke, 1988; Preston & Thomas, 2000), arriving at a fair conclusion during prematurely ended matches (Duckworth & Lewis, 1988), the impact of the coin toss (De Silva & Swartz, 1997; Morley & Thomas, 2005) and weather (Forrest & Dorsey, 2008) on match outcomes, and the development of player-specific performance ranking systems (Damodaran, 2006; Lemmer, 2011; 2008; 2006; 2004; 2002).

One of the first of these studies was undertaken by Clarke (1988) who used dynamic programming formulation to calculate the optimal scoring rate during a batting innings. For example, the total number of runs needed to set a good target or the tempo required to successfully chase a target. The findings conflicted with the then current approach to batting of scoring slowly at first before increasing the run-rate if wickets were not lost. Results suggested that teams should try to score slightly faster than the expected average run-rate and if, or when, wickets are lost reduce the run-rate and the risk of losing more wickets and being bowled out prematurely (Clarke, 1988). Clarke (1988) concluded that this method should be adopted for both first and second innings and suggested that there was evidence that teams should bat first to increase their chances of winning a match.

Twelve years later, Preston and Thomas (2000) completed a similar study using English county limited-overs matches with the aim of increasing the understanding of batting strategy and the ability to judge how to set or chase a target. Findings differed quite dramatically to Clarke (1988) with Preston and Thomas (2000) concluding that optimal strategies differ fundamentally between first and second innings. Preston and Thomas (2000) identified that when setting a target a team should look to increase the run-rate throughout an innings. For example, take it slow and preserve wickets to begin with, before increasing the run-rate later in the innings (Preston & Thomas, 2000). However, when chasing a target, results were in agreement with the findings of Clarke (1988) suggesting that the run-rate should decline over the course of an innings. For example, score quickly to start with, therefore reducing the required run-rate for the latter overs (Preston & Thomas, 2000).

Throughout the twentieth century various different methods were used to decide rain-affected cricket matches. These included using an average run-rate, counting back to the score that the team batting first had achieved at the same point in their innings, and using targets derived by totaling the best scoring overs from the first innings. However, all these methods had easily exploitable flaws. For example, run-rate ratios don't account for how many wickets the team batting second has lost and simply reflect how quickly they were scoring when the interruption occurred. Therefore, if a team suspected an interruption was likely they could attempt to increase the run-rate without regard for the loss of wickets, consequently skewing the comparison between scores. Subsequently Duckworth and Lewis (1988) designed a method claimed to offer no advantage to either team, based on a simple model involving a two-factor relationship giving the number of runs which can be scored on average in the remainder of an innings, as a function of the number of overs remaining and the number of wickets fallen (Duckworth & Lewis, 1988). The method was first adopted in international and domestic one-day competitions in 1997 (Duckworth & Lewis, 1988), and after a couple of minor adjustments is still being used today.

In conjunction with the statistically focused research, topics such as the impact of the toss on match outcome and home advantage in cricket have also been examined. De Silva and Swartz (1997) investigated the coin toss and the influence of being able to decide whether to bat first or second, citing three beliefs surrounding the coin toss in cricket. Firstly, some believe that batting first is an advantage, enabling a team to establish a number of runs and produce a psychological hurdle for the team batting second (De Silva & Swartz, 1997). Others believe that batting second has the advantage of knowing what your target is and being able to pace your pursuit accordingly (De Silva & Swartz, 1997). Finally, some believe it should depend on variables such as the weather, pitch, and opposition (De Silva & Swartz, 1997). 427 ODIs from the 1990's were analysed with results showing that winning the toss has no impact on the outcome of a match (De Silva & Swartz, 1997). Results also identified that the average win percentage of international teams increased from 50 to 63% when only considering matches played at home; yet it is hypothesised that home advantage is more pronounced in international cricket, so these findings may not be applicable to matches played in English domestic cricket.

There is a wealth of literature that indicates a clear and historically stable home-field advantage in sport, although its magnitude varies between sports, and to an extent between competitions and performance levels (Morley & Thomas, 2005). However, until Morley and Thomas (2005) investigated home advantage in English county one-day matches, none of this research had focused on cricket. It was hypothesised that winning the toss is advantageous to a team due to allowing strategic preference on whether to bat or bowl first (Morley & Thomas, 2005). Moreover, it was suggested that this advantage is increased if the home team wins the toss, as it is expected that they would have more familiarity and experience with the pitch and local weather conditions (Morley & Thomas, 2005). Results confirmed these theories with 57% of matches being won by the home team (Morley & Thomas, 2005). When also considering the impact of the toss on match outcome, results showed that 51% of matches were won when a team won the toss. Moreover, when the home team won the toss the win percentage increased to 56%, again confirming a slight home advantage. However, it was concluded that team quality and overall match importance nullifies the impact of winning the toss. In particular, a team is more likely to win a match due to greater quality and form, and a greater importance of a match in the context of a league (Morley & Thomas, 2005).

More contemporary research in cricket has focused on the PA of match-play and the identification of KPIs which can be used to objectively assess individual and team performances, and determine strengths and areas for improvement (Douglas & Tam 2010; Moore et al., 2012; Petersen et al., 2008a; Petersen et al., 2008b). Research of this kind emphasises the importance of determining which KPIs are correlated with, and increase the likelihood for success, and should consequently underpin both team selection and strategy (Petersen et al., 2008b). Additionally, with recent changes regarding the laws and timings of powerplays and fielding restrictions in limited overs cricket (Douglas & Tam, 2010); the identification of KPIs that are associated with winning is paramount so that coaches can develop, implement and exploit detailed batting, bowling and fielding strategies (Najdan, 2011; Petersen et al., 2008a).

The first of these studies analysed 47 ODI matches from the round-robin and super-eights phases of the ICC 2007 World Cup (Petersen et al., 2008a). Magnitude-based inferences were used to characterise differences between selected batting and bowling variables (Petersen et al., 2008a). The effect size (ES) statistic was then applied to assess the magnitude of differences between winning and losing team performances. Overall results showed that winning teams scored a higher percentage of runs from boundaries and had more 50+ run partnerships (Petersen et al., 2008a). During the super-eights phase, winning teams captured more wickets and maintained a higher run-rate primarily through hitting a higher percentage of boundaries (Petersen et al., 2008a). It was also noted that losing teams scored more runs via singles. Petersen et al. (2008a) concluded that specialist bowlers capable of taking wickets and not just restricting runs should be utilised. However, it was highlighted that forcing the opposition to score a high percentage of runs in singles, and bowling maidens to restrict the run-rate, also enhances chances of success. In terms of batting, it was recommended that batsmen retained wickets and built partnerships, whilst keeping the run-rate high through a high proportion of boundaries (Petersen et al., 2008a).

In a similar study, Petersen et al. (2008b) analysed 56 Twenty20 matches from the 2008 Indian Premier League using online ball-by-ball data and match scorecards. Again magnitude-based inferences were used to characterise differences between selected batting and bowling variables (Petersen et al., 2008b). Similarly the ES statistic was applied to assess the magnitude of differences between winning and losing teams. Results identified that winning teams took more wickets and maintained a higher run-rate; whilst losing teams once again scored a higher proportion of singles (Petersen et al., 2008b). Petersen et al. (2008b) concluded that specialist bowlers capable of taking wickets should be employed in the first and last six overs of an innings, with more defensive bowlers, focusing on the restriction of runs, used throughout the middle overs (Petersen et al., 2008b). Field placements should also reflect bowling tactics, with aggressive wicket-taking and defensive run-restrictive field placements utilised during the respective phases of play. In terms of batting it is recommended that batsmen proficient at preserving wickets and keeping the run-rate high through scoring boundaries should be selected (Petersen et al., 2008b). Conversely, in the middle eight overs batsmen need to accumulate runs whilst still having the primary focus of scoring boundaries (Petersen et al., 2008b).

Subsequently in 2010, 27 matches from the ICC 2009 Twenty20 World Cup were used to compare the magnitude of differences between winning and losing performances (Douglas & Tam, 2010). Student t-tests were applied to calculate any significant differences, with Cohen's d-test determining the magnitude of the ES between the two groups. Top indicators for success were losing fewer wickets (in particular during the powerplay), maintaining a higher run-rate, scoring more runs in the middle eight overs and bowling more dot balls (Douglas & Tam 2010). Douglas and Tam (2010) concluded in agreement with Petersen et al. (2008b) that specialist bowlers should be utilised during specific phases of a match; whereas batmen should aim to maintain wickets whilst keeping the run-rate high during powerplays using 'risk free' cricket focusing on boundaries fours and the rotation of strike.

More recently, team performances in English Twenty20 cricket have been investigated using seven matches from the 2010 season (Moore et al., 2012). Selected batting and bowling KPIs were analysed as well as additional pitch-level analysis of where the ball pitched when a wicket was taken or a boundary scored. T-tests and the ES statistic were used to assess the importance of the contribution of KPIs to a winning performance. Chi square tests were also used to analyse the distribution of the pitch-level data. Fundamental results showed that winning teams took more wickets, particularly in the first six overs, scored a higher percentage of runs through boundaries, faced less dot balls and maintained a higher run-rate. Moore et al. (2012) were again in agreement with previous research (Douglas & Tam, 2010; Petersen et al., 2008b), concluding that the timing and utilisation of specialist wicket-taking and run-restricting bowlers is paramount, whilst batmen should aim to preserve wickets whilst keeping the run-rate high during powerplays, primarily through boundary fours and strike rotation.

The pitch-level analyses were less conclusive with no clear trends in boundary destination or the line and length of where boundaries are hit from. However, results did suggest that losing teams bowled too full in the early overs and too short in the latter overs. In terms of performance, bowling too full in the early overs can increase the chances of the batting team scoring runs; whilst successful full-pitched bowling during the final overs is acknowledged as being more difficult to score runs from. Similarly, short-pitched bowling in the latter overs can again increases the number of opportunities for a batting team to score runs. Consequently, Moore et al. (2012) attributed skill-based and tactical inadequacies as the differences between winning and losing teams bowling performances, recommending that bowlers develop detailed roles for different phases of a match with an emphasis on individual skill execution.

Finally, in a similar study, Najdan (2011) analysed 29 winning and 30 losing team performances from the 2010 English domestic Twenty20 competition. Selected batting and bowling KPIs were analysed alongside similar additional pitch-level analysis to Moore et al. (2012). Medians and the ES statistic were used to assess the importance of selected KPIs to successful performance (Najdan, 2011). Results showed that winning teams achieved more 50+ run partnerships and had individual batsmen contributing 50 to 74 or 75+ runs more often than losing teams (Najdan, 2011). Winning teams also lost fewer wickets during the powerplay overs (overs 1-6) and during overs 7-10, whilst scoring more boundary fours in the last six overs of an innings. Winning teams also outscored the opposition throughout overs 11-14 and had more bowlers taking two or more wickets during a match (Najdan, 2011).

The pitch-level analysis revealed that winning teams bowled a higher percentage of full deliveries and a lower percentage of length deliveries compared to losing teams (Najdan, 2011). No differences were evident between the lengths of wicket-taking deliveries with both winning and losing teams taking wickets using a full length compared to a short length. In particular, the most wickets were taken when bowling yorker, full or good length deliveries (Najdan, 2011). Finally, winning teams scored more runs through long off and through the off-side in general, with Najdan (2011) suggesting that losing teams bowled too wide.

Najdan (2011) went on to conclude that retaining wickets during the powerplay and overs 7-10, along with outscoring the opposition in the final ten overs, are critical to success in English Twenty20. Consequently, team selection should focus on batsmen capable of preserving wickets during the initial overs whilst still scoring boundary fours. Batsmen with high boundary percentages should also be selected with the aim them of batting during the final ten overs, and at least one batsman should score 50+ runs with a focus on scoring runs through the off-side and in particular long-off (Najdan, 2011). A successful team should include bowlers who take early wickets, accompanied by attacking fields throughout the first ten overs (Najdan, 2011). These bowlers should aim to bowl a majority of full and yorker deliveries but alongside some short and good length deliveries for variation. During the final ten overs, teams should select bowlers with good economy-rates who are less likely to concede boundaries. Finally, unpredictability and variation of bowling styles is crucial, and bowlers should build a repertoire of deliveries including slower balls, yorkers and bouncers alongside other variations (Najdan, 2011). These findings are comparable to those of previous research (Douglas & Tam, 2010;

Petersen et al., 2008b) but suggest a longer period (overs 1-10) of retaining wickets without necessarily outscoring the opposition. This discrepancy may be due to authors using different phases of play in their respective research. For example, Najdan, (2011) used the phases of play of overs 1-6, 7-10, 11-14 and 15-20, instead of overs 1-6, 7-14 and 15-20 used by Petersen et al. (2008b) and Douglas and Tam (2010).

While there has been a clear increase in the frequency of research investigating the KPIs in cricket, it has been highlighted that limited-overs cricket is constantly evolving and so analyses of this type frequently need updating (Douglas & Tam, 2010; Moore et al., 2012). It is also acknowledged that although statistics can potentially play a major role in cricket and represent a determining factor for match strategies; research into KPIs in cricket is still sparse compared to other sports and areas of sports science in cricket (Moore et al., 2012). Moreover, with the exception of Moore et al. (2012) and Najdan (2011) no research has included any pitch-level analysis and has either limited information on the origin of data used (Petersen et al., 2008a), or have used basic scorecard data from online sources (Douglas & Tam, 2010; Petersen et al., 2008b). Consequently, it is suggested that these studies only provided a general overview of the most effective strategies (Najdan, 2011), identifying only embryonic KPIs related to success that most coaches would have anticipated (Moore et al., 2012; Najdan, 2011). Likewise, the use of one-off international tournaments with matches played in the same locations within a small time-frame may have resulted in findings not being representative of cricket played throughout a season and at varying standards. Furthermore, no research has focused on List A matches in English county cricket, and in particular 40-over matches. Finally, alongside the limitations of the origins of the data used in many of the studies, and the associated validity and reliability issues, some studies provided only a limited description of the analysis systems and procedures used. Moreover, there were also inadequate details on the methods and statistical tests used to test the reliability of the data collection processes. For example, Moore et al. (2012) tested only 84 randomly selected clips to examine the inter- and intra-reliability of seven Twenty20 matches using a Pearson's Moment Product Correlation.

2.4 Reliability in Performance Analysis

Reliability is the amount of measurement error deemed acceptable for the effective practical use of an analysis system (Cooper, Hughes, O'Donoghue & Nevill, 2007). More specifically, the reliability of a variable in PA is the consistency with which the measurement procedure can be used by independent operators to measure the same performances (O'Donoghue, 2010). There are two types of reliability: intra- (same operator) and inter-reliability (two different operators). Intra-reliability indicates that a particular operator of a system can consistently identify and classify KPIs of a performance (O'Donoghue, 2010). Inter-reliability demonstrates that a system can be used consistently, recording data that are independent of individual operator perceptions (O'Donoghue, 2010).

Any variable that is not measured reliably cannot be valid no matter how relevant it is to an analysis project or understanding a sports performance (O'Donoghue, 2010). If coaches and players are making important decisions about how they prepare for competition, it is paramount that any data is gathered reliably (O'Donoghue, 2007). In the past, many research papers in PA have presented no reliability tests whatsoever (Hughes, 2008); however, it is fast becoming a major feature of PA research to investigate the reliability of data entered into an analysis system, and to provide confirmatory statistics in any subsequent report (Cooper et al., 2007). In the rare cases where reliability has been reported, Hughes (2008) suggests that inappropriate data-processing techniques and statistical procedures had been applied. Moreover, it has been common practice to identify the KPIs that a research study is interested in, and then treat these indicators collectively by reporting a summary statistic such as Pearson's correlation coefficient or percentage errors (Cooper et al., 2007). However, when using these methods there is a danger that poor reliability of KPIs could be masked (Cooper et al., 2007). Consequently, each KPI identified as being important should be treated as an independent variable, and a reliability coefficient should be reported for each (Cooper et al., 2007). Data should also retain its sequentiality and be cross-checked item against item (Hughes, 2008). For more information, Cooper et al. (2007) outlined a simple but effective method for performance analysts to check reliability with great simplicity.

3. Method

3.1 Participants & Study Design

Data was collected from fourteen English List A matches played during the 2012 cricket season. In accordance with previous literature, any matches that were abandoned or shortened, and decided by the Duckworth-Lewis system, were excluded from analysis (Douglas & Tam, 2010; Moore et al., 2012). This led to four matches being excluded; resulting in ten matches being used for data analysis. All procedures and protocols were approved by the Faculty of Applied and Health Sciences Research Ethics Committee of the University of Chester prior to any data collection (Appendix 2), and informed consent was obtained to film and code matches and the use of any associated match data (Appendix 3).

All matches were coded live using bespoke analysis software (Feedback Cricket™, Feedback Sport Ltd, Christchurch, New Zealand) linked to a fixed camera, or set of cameras (Canon XM2 Camcorder, Canon (UK) Ltd, Surrey, UK), positioned directly behind the bowler's arm on a camera gantry. Match footage was recorded on to a laptop (Lenovo Think Pad W510, Lenovo Technology UK Ltd, Hook, UK) preloaded with the analysis software. Before the coding process began, training in the use of the system from the England and Wales Cricket Board (ECB) was undertaken before establishing operational definitions for all PIs (Appendix 4).

Prior to a match beginning, a game file was set up and the following information entered: the teams competing (in batting order and identifying the captains and wicketkeepers), the date, type of match, umpires officiating, venue and outcome of the toss. Each delivery was then coded using a specific analysis sequence. First, the location of the ball landing on the pitch was coded using a pitch map (Figure 1). Second, the outcome of the delivery was then coded using the following criteria: runs scored and extras scored. For example, a ball hit to the boundary for four runs would be coded as a ‘boundary 4’ and ‘no extra’; whilst a ball hit into the outfield, not reaching the boundary, where the batsmen ran two runs would be coded as a ‘2’ and ‘no extra’. Also, if a wide was bowled then this would be coded as ‘0’ runs and a ‘wide’. Finally, the destination of the ball was coded using a map of the playing field (Figure 2). The timings of the powerplay overs (Appendix 5) were also recorded as and when they occurred during a match.

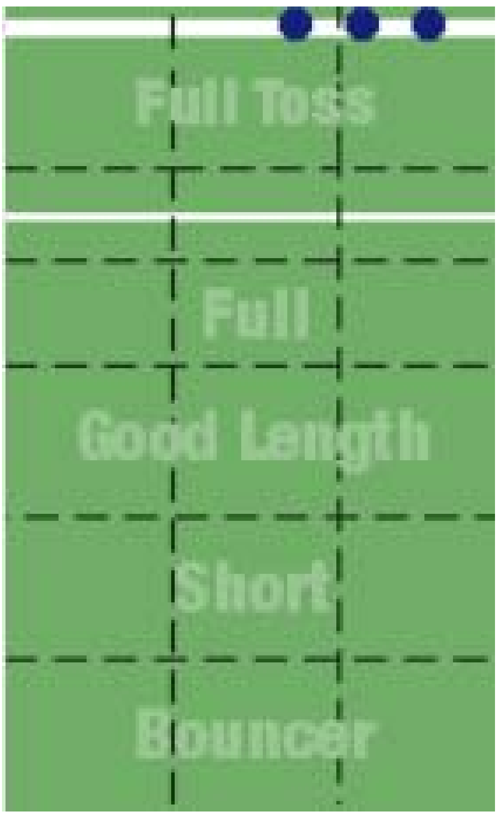

Figure 1. The pitch map used to notate the geographical location of deliveries

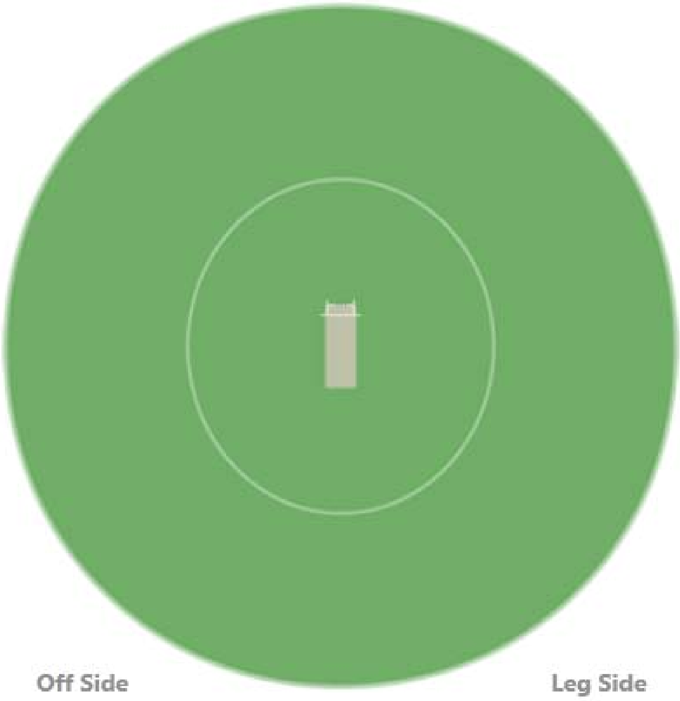

Figure 2. The boundary destination map used to notate the destination of the ball

Upon completing the coding process, data on all of the KPIs were extracted for further analysis. The general, batting and bowling KPIs analysed in this study are displayed and defined in Tables 1, 2 and 3. These KPIs were selected based on previous literature (Douglas & Tam, 2010; Moore et al., 2012; Petersen et al., 2008a; 2008b), the data capturing capacity of the analysis software and the researchers' knowledge of the KPIs used in elite cricket.

Table 1. General key performance indicators quantified for winning and losing teams

Performance Indicator	Definition
Total runs scored in the 1st-10th wicket partnerships	The total amount of runs scored for the 1st, 2nd, 3rd, 4th, 5th, 6th, 7th, 8th, 9th and 10th wicket partnerships
Number of 25+ run partnerships	The number of partnerships where 25 or more runs are scored
Number of 50+ run partnerships	The number of partnerships where 50 or more runs are scored
Number of 100+ run partnerships	The number of partnerships where 100 or more runs are scored
Number of batsmen scoring 25+ runs	The number of batsmen scoring 25 or more runs
Number of batsmen scoring 50+ runs	The number of batsmen scoring 50 or more runs
Number of batsmen scoring 100+ runs	The number of batsmen scoring 100 or more runs
Number of bowlers taking 3+ wickets	The number of bowlers taking 3 or more wickets
Number of bowlers taking 4+ wickets	The number of bowlers taking 4 or more wickets

Table 2. Batting key performance indicators quantified for winning and losing teams

Performance Indicator	Definition
Runs scored per over*	The number of runs scored per over
Wickets lost per over *	The number of wickets lost per over
Dot balls faced per over *	The number of dot balls faced per over
Number of 1's scored per over *	The number of 1's scored per over
Number of 2's scored per over *	The number of 2's scored per over
Number of 3's scored per over *	The number of 3's scored per over
Number of 4's scored per over *	The number of boundary 4's scored per over
Number of 5's scored per over *	The number of 5's scored per over
Number of 6's scored per over *	The number of boundary 6's scored per over

*each performance indicator is applied separately to the following phases of play: an innings, overs 1-8, 9-16, 17-24, 25-32, 33-40, and the mandatory, batting and bowling powerplays

Table 3. Bowling key performance indicators quantified for winning and losing teams

Performance Indicator	Definition
Total number of maiden overs	The total number of maiden overs bowled
Number of Wides bowled per over *	The number of wides bowled per over
Number of No Balls bowled per over *	The number of no balls bowled per over

*each performance indicator is applied separately to the following phases of play: an innings, overs 1-8, 9-16, 17-24, 25-32, 33-40, and the mandatory, batting and bowling powerplays

In addition to the general, batting and bowling KPIs, secondary in-depth pitch-level analysis data was collected on the geographical location of where the ball pitched when a wicket was taken and a boundary was scored (Figure 1). Additionally, ball destination data was gathered for when a boundary was scored (Figure 2). All data was exported into Microsoft Excel™ for further analysis.

Based upon previous research (Moore et al., 2012; Najdan, 2011) all batting and bowling KPIs were also cross-referenced with the following phases of play: an innings, overs 1-8, 9-16, 17-24, 25-32, and 33-40. All variables were further cross-referenced with the three powerplays. These included the mandatory powerplay (overs 1-8) and the batting and bowling powerplays; the timing of which are chosen by the respective captains, both lasting four overs. Cross-referencing of the KPIs allowed for comparisons between different phases of an innings. It also enabled the identification of not only the KPIs correlated with overall success but also any specific timings of when a KPI correlates with success throughout a match. For example, if taking wickets during overs 17-24 or scoring boundaries fours during the bowling powerplay correlates with successful performance.

3.2 Reliability

To ensure objectively and reliability of the data collection process, intra-operator reliability analysis was conducted. Firstly, match scorecards obtained from the official match scorers were used to check the external validity of the coded scorecard data for all matches. Secondly, the intra-reliability of the coding and pitch-level data collection processes was assessed with a randomly selected match being re-coded by the researcher. More specifically, the entire match was coded on two occasions separated by a two-month period to negate any learning effects. Reliability analysis was conducted using the simple statistical method for assessing the reliability of data entered into sport PA systems as outlined by Cooper et al. (2007). Coded match data were split into 40 reference cells, each containing data on the line and length of deliveries bowled and the destination of where the ball was hit to from two over sections of the match. The agreement between test and retest recorded frequencies was quantified for each PI by simply calculating the differences between frequencies recorded on the two occasions (Appendix 6). Each of the eighteen line and length categories were treated as separate PIs. For example, full toss/off, full toss/line and full toss/leg were all treated as separate PIs. Moreover, the sequence of PIs notated within ten of the 40 reference cells were also recorded (Appendix 6).

As recommended by Cooper et al. (2007) a reference value with respect to the type, frequency and context in which the data will be used was selected of ±1 for the line and length data. This was based on an unofficial guideline from the ECB of 95% coding accuracy and also the researchers' knowledge of how the data is used within elite cricket. For example, during a standard full 40-over match there are 480 deliveries. A reference value of ±1 for every two over reference cell totals 40 deliveries, which was a simple and even reference value thought to have no practical importance within an applied setting; and only fractionally higher than the unofficial ECB guidelines. For the ball destination data a reference value of ±2 was selected due to the increased potential value of each delivery. For example, for each delivery only one line and length combination (Figure 1) can be selected but for the ball destination data any number of runs between one and six could be scored off each delivery and consequently recorded onto the map of the playing field (Figure 2).

Good levels of agreement were observed for all line and length PIs except length/line and length/leg (Table 3). Most of these PIs (full toss/off, full toss/line, full toss/leg, yorker/off, yorker/line, yorker/leg, full/off, length/off, short/off, bouncer/off, bouncer/line and bouncer/leg) are considered to be relatively infrequent PIs (Cooper et al., 2007) in cricket, so these results were to be expected. However, selected more frequently occurring PIs also reported good reliability agreements (full/line, full/leg, short/line and short/leg; Table 3). Moreover, good levels of agreement were observed for the ball destination data (Table 4) with the majority of results comparable to the expert or gold standard recommendations of 95% of differences being within the selected reference value (Cooper et al., 2007).

Table 4. The percentage agreement within a ±1 reference value between test and retest analyses for line and length data

Percentage Agreement (%) within a ±1 reference value		
Line & Length	**Yes**	**No**
Full Toss/Off	100	0
Full Toss/Line	97.50	2.50
Full Toss/Leg	100	0
Yorker/Off	100	0
Yorker/Line	100	0
Yorker/Leg	100	0
Full/Off	97.50	2.50
Full/Line	90.00	10.00
Full/Leg	95.00	5.00
Length/Off	97.50	2.50
Length/Line	78.50	21.50
Length/Leg	67.50	32.50
Short/Off	100	0
Short/Line	95.00	5.00
Short/Leg	92.50	7.50
Bouncer/Off	100	0
Bouncer/Line	100	0
Bouncer/Leg	97.50	2.50

Table 5. The percentage agreement within a ±2 reference value between test and retest analyses for ball destination data

Percentage Agreement (%) within a ±2 reference value		
Area of Ball Destination	**Yes**	**No**
Fine-Leg	97.50	2.50
Third-Man	97.50	2.50
Mid-Off	90.00	10.00
Mid-On	95.00	5.00

Despite the modest results for the PIs of line/length and line/leg, the overall reliability of the data collection process was deemed acceptable for the purposes of this research study. A potential limitation to the agreements observed between some PIs could be due to a combination of the method of coding and the analysis system used. For example, the way in which the system processes and assigns line and length. The method of coding used was to attempt to replicate exactly where the ball had pitched during a match onto the pitch map (Figure 1). Figures 3a and 3b demonstrate that, when coding the length of a delivery, the system user can click on the pitch map in two very similar positions (yellow squares) but the line and length assigned to that delivery can vary (red squares). For example, in Figure 3a the delivery is assigned as 'full' and in Figure 3b the delivery is assigned as 'length', even though there are only fractional differences between the locations of the coded red circle on the pitch map.

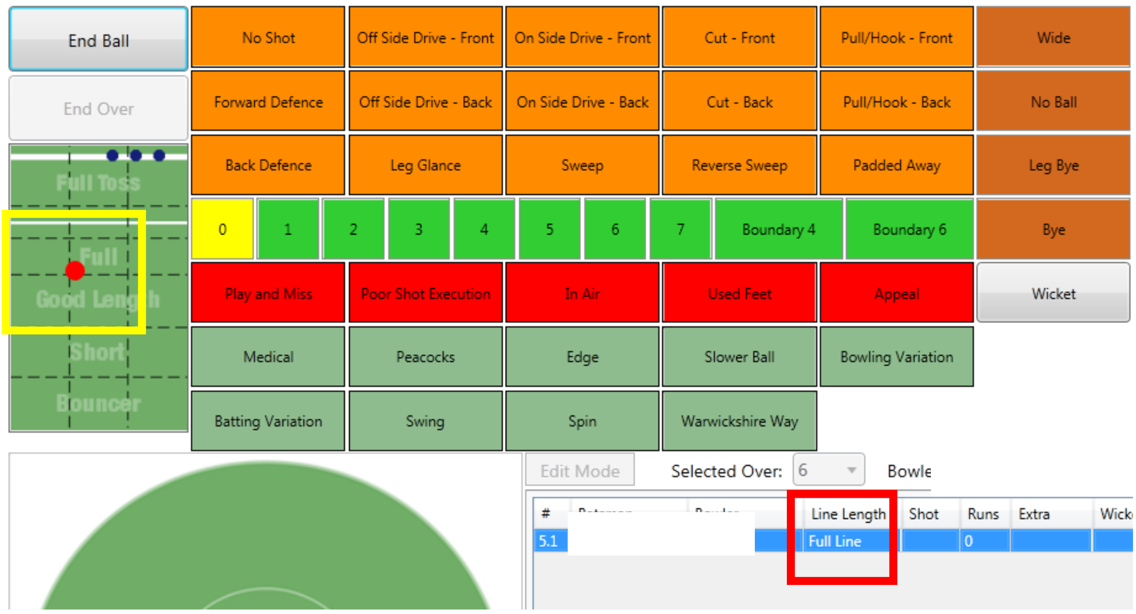

Figure 3a. Example print screen of the limitations of coding the length of a delivery

Figure 3b. Example print screen of the limitations of coding the length of a delivery

Figures 4a and 4b demonstrate the same issue when coding the line of a delivery. For example, in Figure 4a the delivery is assigned as ‘line’ and in Figure 4b the delivery is assigned as ‘leg’, even though there are again only fractional differences between the locations of the coded red circle on the pitch map.

Figure 4a. Example print screen of the limitations of coding the line of a delivery

Figure 4b. Example print screen of the limitations of coding the line of a delivery

Table 6. Sequence of actions percentage agreement of line, length and ball destination data recorded into ten selected two-over reference cells

Percentage Agreement (%) of the Sequence of Coded Data		
Type of Data	**Yes**	**No**
Line	83.06	16.94
Length	79.84	20.16
Ball Destination	83.87	16.13

Finally, good levels of agreement were also observed for the percentage agreement of sequential coded data. The results are comparable to results observed by an experienced analyst when testing the reliability of coding an international rugby match (Cooper et al., 2007).

3.3 Statistical Analysis

All KPIs were expressed as a ‘per over’ rate owing to the fact that some matches, and consequently selected phases of a match, were not fully completed. For example, a team could have been bowled out or have reached the required target in the 33rd over of a match and therefore not completed the overs 33-40 phase of the match.

Shapiro-Wilk tests of normality revealed predominantly non-normally distributed dependent variables, rendering the use of non-parametric statistical tests appropriate. All statistical analyses were completed using the Statistical Package for Social Sciences version 20.0 programme. For the main analysis, Mann-Whitney U tests were used to compare the winning and losing teams’ KPIs, along with the ES statistic (+/- 95% confidence level). Likewise, the winning and losing teams' pitch-level data were assessed using Mann-Whitney U tests. The alpha level was adjusted to a reduced $p < 0.005$ in an attempt to offset the increased risk of a type I error as a result of conducting multiple hypothesis tests (Field, 2013). Moreover, due to a limited sample size and data set on boundaries scored and wickets taken (less frequently occurring KPIs), pitch-level data were merged from the eighteen possible categories of line and length (Figure 2) to six categories of: full/off, full/line, full/leg, short/off, short/line and short/leg. The ES statistic allowed the relative importance of the different KPIs to be assessed in terms of their contribution to a successful match outcome (Field & Miles, 2010) and was calculated using the following formula (Field, 2013):

$$r = \frac{z}{\sqrt{N}}$$

Due to the use of different statistical tests and procedures, for example, the use of non-parametric tests and the comparison of medians instead of means; the criteria for the interpretation of ES was 0.1-0.3 small, 0.3-0.5 moderate and > 0.5 large (Field, 2013). This was in contrast to previous literature (Douglas & Tam, 2010; Moore, et al., 2012; Najdan, 2011; Petersen et al., 2008a; 2008b) who interpreted ES as < 0.2 trivial, 0.2-0.6 small, 0.6-1.2 moderate, 1.2-2.0 large and > 2.0 very large. Therefore, comparisons to previous research were made using the ES classifications, rather than their numerical value as demonstrated below (Table 7).

Table 7. Differences in classifications of the ES statistic used in previous research

Classification	Cohen (Field, 2013)	Hopkins (Hopkins, 2004)
Trivial		< 0.2
Small	0.1 - 0.3	0.2 - 0.6
Moderate	0.3 - 0.5	0.6 - 1.2
Large	> 0.5	1.2 - 2.0
Very Large		> 2.0

4. Results

Selected results, based on relative importance to successful performances, for all general, batting and bowling KPIs along with pitch-level analysis are reported below. Comprehensive results for all KPIs and pitch-level analysis can be found in Appendix 7. No significant differences ($p < 0.005$) between winning and losing team performances were identified. Consequently, the relative importance of KPIs to winning and losing team performances were compared using the ES statistic.

4.1 General

The mean ranks and ES for selected general KPIs are displayed in Tables 8 and 9.

Table 8. Selected results for general key performance indicators of winning teams

Performance Indicator	Mean Rank – Winning Team	Mean Rank – Losing Team	Effect Size	Rating
Number of bowlers taking 3+ wickets	14.00	7.00	-0.63	Large
Number of bowlers taking 4+ wickets	13.00	8.00	-0.56	Large
Number of batsman scoring 50+ runs	13.25	7.75	-0.52	Large
Number of 100+ run partnerships	12.50	8.50	-0.49	Moderate
Number of 50+ run partnerships	12.90	8.10	-0.43	Moderate
Number of runs scored for the 5th wicket partnership	11.36	7.35	-0.3*6	Moderate
Number of batsman scoring 100+ runs	11.50	9.05	-0.32	Moderate
Number of runs scored for the 2nd wicket partnership	12.30	8.70	-0.30	Moderate
Number of runs scored for the 1st wicket partnership	12.25	8.75	-0.30	Moderate
Number of batsman scoring 25+ runs	11.95	9.05	-0.25	Small

The biggest differences identified between winning and losing teams were the number of bowlers taking 3+ (U = 15.0, p = .007, ES = -63.) and 4+ (U = 25.0, p = .063, ES = -.56) wickets (Table 8). Differences were also observed between the number of batsman scoring 50+ runs (U = 22.5, p = .035, ES = -.52) and the number of 100+ (U = 30.0, p = .143, ES = -.49) and 50+ run (U = 26.0 p = .075, ES = -.43) partnerships (Table 8). Also, trends indicated that winning teams scored more runs for the 5th (U = 18.5, p = .109, ES = -.36), 1st (U = 32.5, p = .190, ES = -.30) and 2nd (U = 32.0, p = .190, ES = -.30) wicket partnerships, and had a higher number of batsman scoring 100+ runs (U = 40.0, p = .481, ES = -.32; Table 8).

Table 9. Selected results for general key performance indicators of losing teams

Performance Indicator	Mean Rank – Winning Team	Mean Rank – Losing Team	Effect Size	Rating
Number of runs scored for the 6th wicket partnership	4.60	9.70	-0.47	Moderate
Number of runs scored for the 10th wicket partnership	1.50	6.00	-0.46	Moderate

Conversely, results suggested that losing teams scored more runs for the 6th (U = 8.0, p = .040, ES = -.47) and 10th (U = 0.0, p = .056, ES = -.46) wicket partnerships (Table 9).

4.2 Batting

Tables 10 and 11 display the mean ranks and ES for selected batting KPIs.

Table 10. Selected results for batting key performance indicators of winning teams

Performance Indicator	Mean Rank – Winning Team	Mean Rank – Losing Team	Effect Size	Rating
Number of 4s scored per over (Innings)	14.15	6.85	-0.62	Large
Number of 4s scored per over (Overs 1-8/ Mandatory Powerplay)	14.00	7.00	-0.60	Large
Runs scored per over (Innings)	13.35	7.65	-0.48	Moderate
Runs scored per over (Overs 1-8/ Mandatory Powerplay)	12.70	8.30	-0.37	Moderate
Runs scored per over (Overs 25-32)	12.70	8.30	-0.37	Moderate
Number of 2s scored per over (Innings)	12.55	8.45	-0.35	Moderate
Number of 4s scored per over (Overs 25-32)	12.30	8.70	-0.31	Moderate
Number of 6s scored per over (Overs 33-40)	12.00	9.00	-0.30	Moderate
Number of 6s scored per over (Batting Powerplay)	11.80	9.20	-0.29	Small
Number of 2s scored per over (Overs 25-32)	12.10	8.90	-0.27	Small
Runs scored per over (Overs 17-24)	12.10	8.90	-0.27	Small
Runs scored per over (Overs 9-16)	12.05	8.95	-0.26	Small
Number of 1s scored per over (Overs 25-32)	12.00	9.00	-0.25	Small

The key differences identified between batting KPIs of winning and losing performances included the number of boundary fours scored by winning teams during the overall innings (U = 13.5, p = .004, ES = -.62) and in particular during the mandatory powerplay (Overs 1-8; U = 15.0, p = .007, ES = -.60) and overs 25-32 (U = 32.0, p = .190, ES = -.31; Table 10). Results also indicated that winning teams scored more runs per over throughout an innings (U = 21.5, p = .029, ES = -.48) but more importantly revealed that winning teams outscored losing teams during the mandatory powerplay (*U* =28.0, *p* = .105, ES = -.37) and overs 25-32 (*U* = 28.0, *p* = .105, ES = -.37; Table 10).

Table 11. Selected results for batting key performance indicators of losing teams

Performance Indicator	Mean Rank – Winning Team	Mean Rank – Losing Team	Effect Size	Rating
Wickets lost per over (Innings)	6.40	14.60	-0.70	Large
Dot balls faced per over (Overs 25-32)	6.85	14.15	-0.62	Large
Wickets lost per over (Overs 25-32)	7.05	13.95	-0.59	Large
Number of 6s scored per over (Overs 25-32)	7.35	13.65	-0.59	Large
Wickets lost per over (Overs 17-24)	7.60	13.40	-0.50	Large
Wickets lost per over (Overs 9-16)	8.10	12.90	-0.43	Moderate
Wickets lost per over (Overs 1-8/ Mandatory Powerplay)	8.10	12.90	-0.41	Moderate
Number of 3s scored per over (Overs 33-40)	9.00	12.00	-0.41	Moderate
Dot balls faced per over (Innings)	8.45	12.55	-0.35	Moderate
Dot balls faced per over (Overs 33-40)	8.50	12.50	-0.34	Moderate
Dot balls faced per over (Overs 17-24)	8.55	12.45	-0.33	Moderate
Wickets lost per over (Overs 33-40)	8.65	12.35	-0.32	Moderate
Wickets lost per over (Bowling Powerplay)	9.20	11.80	-0.26	Small

However, the biggest differences identified between batting KPIs of winning and losing teams were the number of wickets lost by losing teams throughout an innings (*U* = 9.0, *p* = .001, ES = -.70; Table 11). Additionally, results indicated a hierarchy of the specific timings of when wickets were lost of: overs 25-32 (*U* = 15.5, *p* = .007, ES = -.59), 17-24 (*U* = 21.0, *p* = .029, ES = -.50), 9-16 (*U* = 26.0, *p* = .075, ES = -.43), 1-8 (*U* = 26.0, *p* = .075, ES = -.41) and 33-40 (*U* = 31.5, *p* = .165, ES = -.32; Table 11).

Furthermore, losing teams faced more dot balls throughout an innings (*U* = 29.5, *p* = .123, ES = -.35) and in particular during overs 25-32 (*U* = 13.5, *p* = .004, ES = -.62) and 33-40 (*U* = 30.0, *p* = .143, ES = -.34; Table 11). Finally, results also revealed that losing teams scored a higher number of 6s per over during overs 25-32 (*U* = 18.5, *p* = .015, ES = -.59; Table 11).

4.3 Bowling

The mean ranks and ES for selected bowling KPIs are displayed in Tables 12 and 13.

Table 12. Selected results for bowling key performance indicators of winning teams

Performance Indicator	Mean Rank – Winning Team	Mean Rank – Losing Team	Effect Size	Rating
Number of no balls bowled per over (Overs 17-24)	11.50	9.50	-0.32	Moderate
Number of wides bowled per over (Batting Powerplay)	11.55	9.45	-0.25	Small

Minimal differences were identified between the bowling KPIs of winning and losing team performances. However, results indicated that winning teams bowled more no balls per over during overs 17-24 (*U* =40.0, *p* = .481, ES = -.32; Table 12) and losing teams bowled more wides per over throughout an innings (*U* = 26.5, *p* = .075, ES = -.40) and during the bowling powerplay (*U* = 23.5, *p* = .043, ES = -.53; Table 13).

Table 13. Selected results for bowling key performance indicators of losing teams

Performance Indicator	Mean Rank – Winning Team	Mean Rank – Losing Team	Effect Size	Rating
Number of wides bowled per over (Bowling Powerplay)	7.85	13.15	-0.53	Large
Number of wides bowled per over (Innings)	8.15	12.85	-0.40	Moderate
Number of wides bowled per over (Overs 9-16)	9.00	12.00	-0.27	Small

4.4 Pitch Level Data

Tables 14 and 15 demonstrate the mean ranks and ES for selected pitch-level data.

Table 14. Selected results for pitch-level data of winning teams

Performance Indicator	Mean Rank – Winning Team	Mean Rank – Losing Team	Effect Size	Rating
Number of boundaries scored from a Full/Off delivery	12.05	8.95	-0.34	Moderate
Number of wickets lost from a Short/Off delivery	11.11	9.00	-0.34	Moderate
Number of runs scored from boundaries through Mid-off	12.15	8.85	-0.28	Small
Number of boundaries scored from a Short/Line delivery	12.10	8.90	-0.27	Small

Pitch-level data identified limited differences between winning and losing teams. However, results revealed that winning teams scored more runs from boundaries from full/off deliveries (U = 34.5, p = .247, ES = -.34; Table 14 & Figure 5) and scored more runs from boundaries through mid-off (U = 33.5, p = .218, ES = -.28; Table 14 &

Figure 7). Winning teams also lost more wickets from short/off deliveries compared to losing teams (U = 35.0, p = .447, ES = -.34; Table 14 & Figure 6).

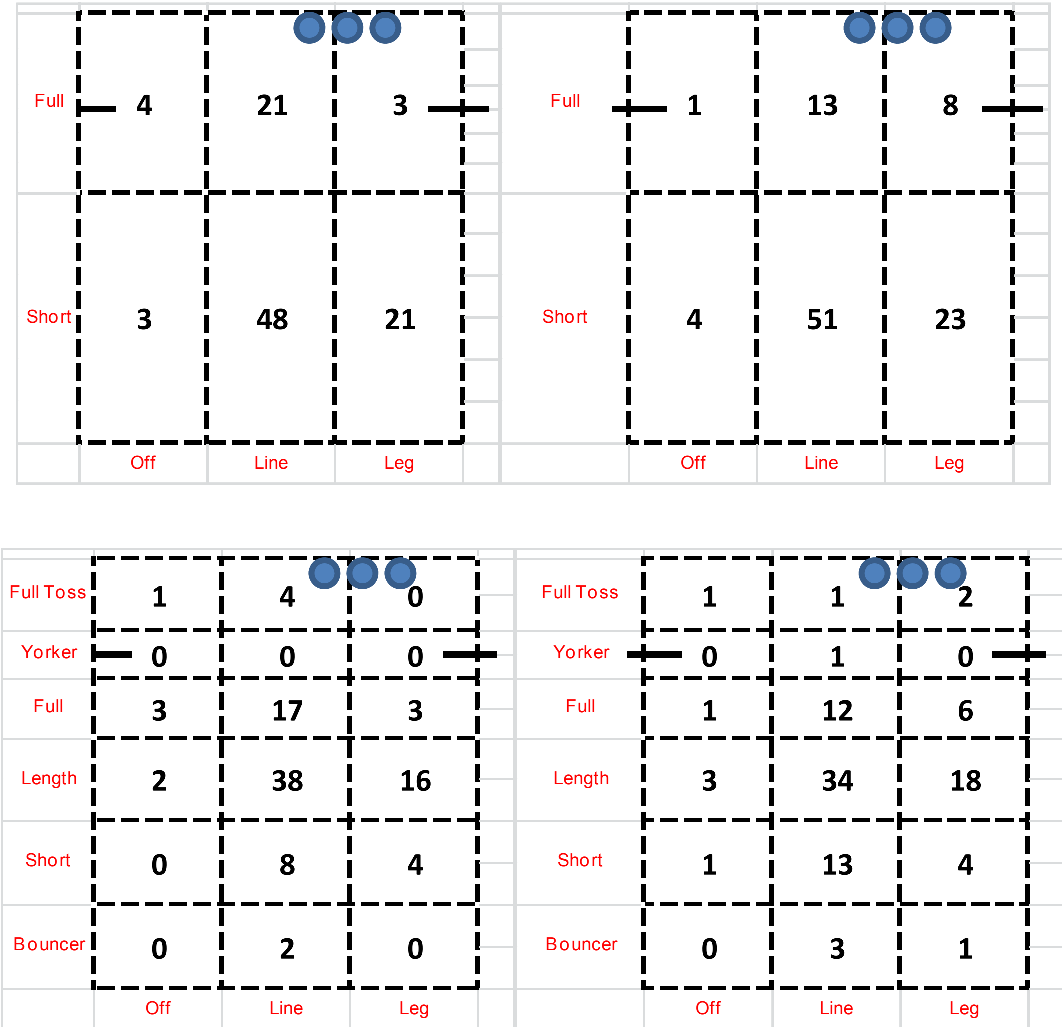

Figure 5. Pitch-level data (%) of deliveries when boundaries were scored by winning (left) and losing (right) teams

Table 15. Selected results for pitch-level data of losing teams

Performance Indicator	Mean Rank – Winning Team	Mean Rank – Losing Team	Effect Size	Rating
Number of wickets lost from a Short/Line delivery	7.22	12.50	-0.46	Moderate
Number of wickets lost from a Full/Leg delivery	8.00	11.80	-0.40	Moderate
Number of wickets lost from a Short/Leg delivery	7.67	12.10	-0.40	Moderate

Finally, pitch-level data also revealed that losing teams lost more wickets from short/line (U = 20.0, p = .043, ES = -.46), full/leg (U = 27.0, p = .156, ES = -.40) and short/leg (U = 24.0, p = .095, ES = -.40) deliveries (Table 15 & Figure 6).

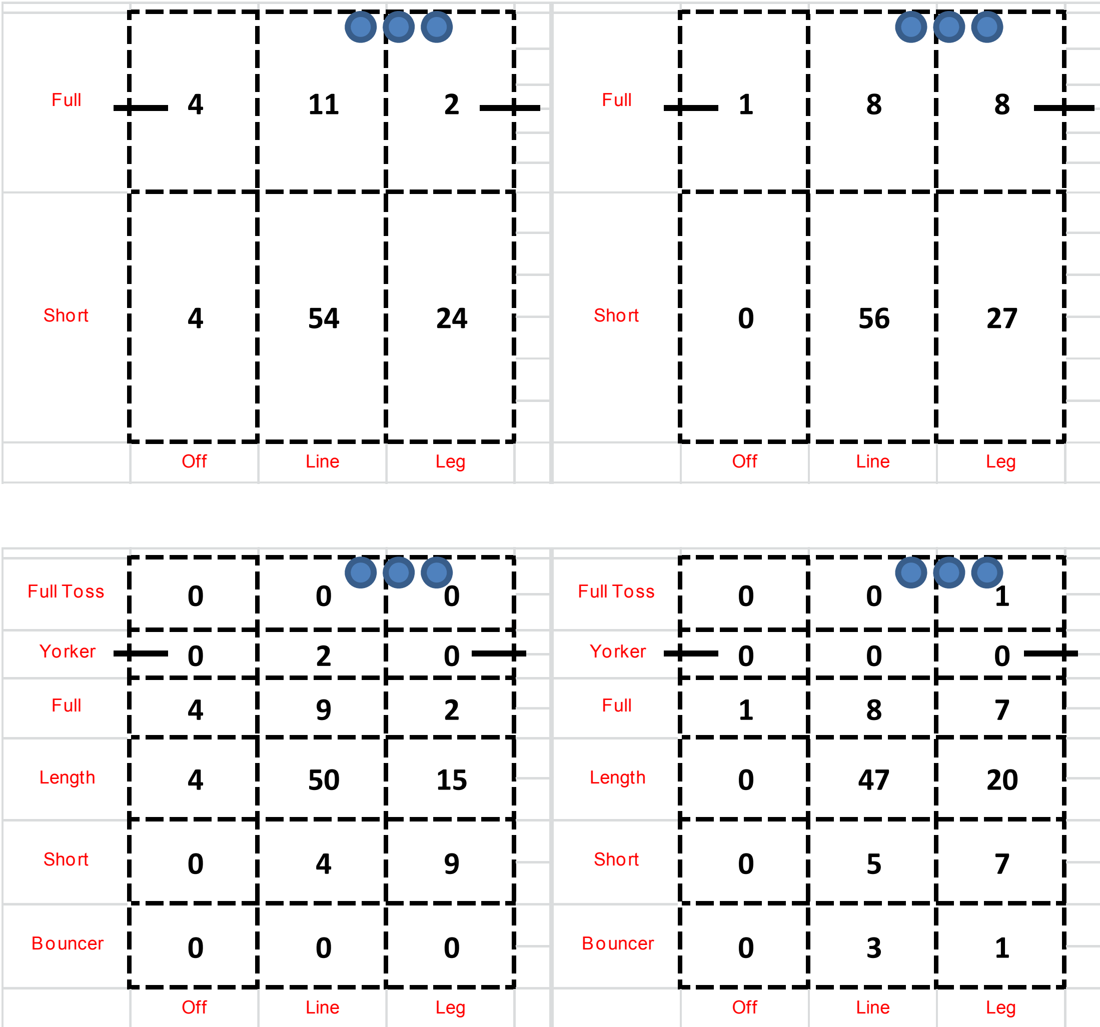

Figure 6. Pitch-level data (%) of deliveries when wickets were lost by winning (left) and losing (right) teams

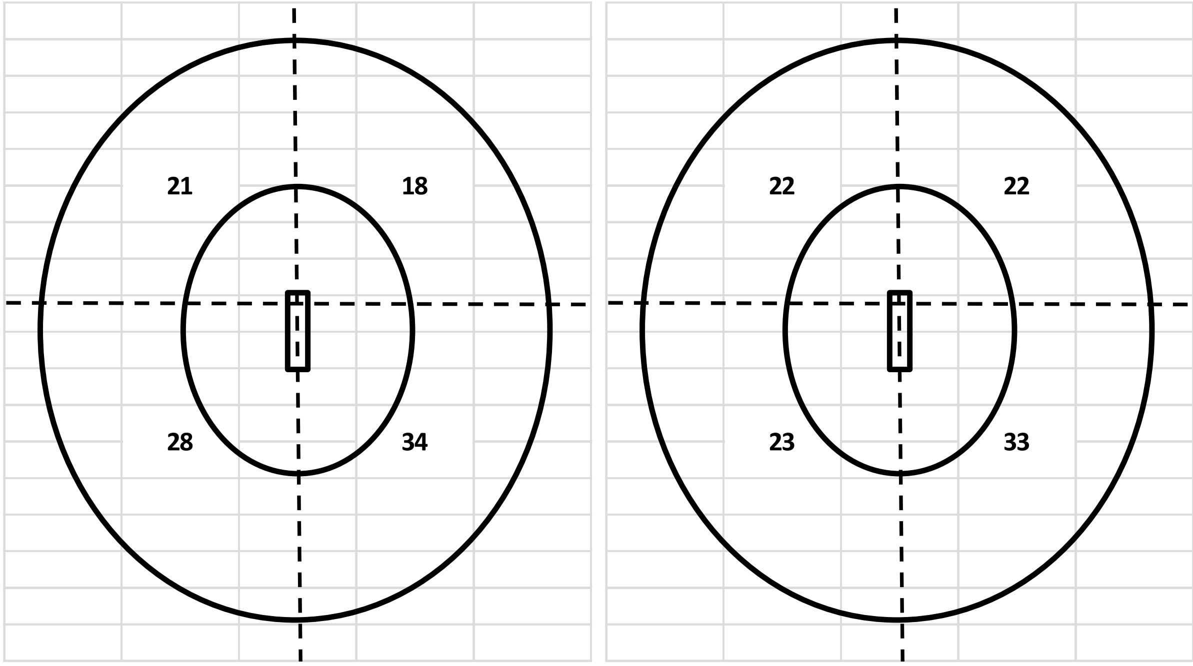

Figure 7. Pitch-level data (%) of the boundary destinations of winning (left) and losing (right) teams

5. Discussion

5.1 General

From a general KPI perspective, the main findings of this study suggest that the differences between winning and losing teams in English List A matches are the number of bowlers taking 3 to 4+ wickets, and the number of batsmen scoring 50 to 100+ runs. This is in agreement with Najdan (2011) who reported that the number of bowlers taking 2+ wickets and the number of batsmen contributing 50 to 75+ runs are moderately correlated with success in English Twenty20. The differences observed between match format and bowlers taking 2+ or 3 to 4+ wickets are undoubtedly due to the longer bowling spells permitted in List A matches providing an extended opportunity to take wickets and influence a match's outcome. Equally, the differences between batsmen's scores are due to the increased time to bat, alongside a potential decrease in the requirement for a high run-rate. However, it can be concluded that the impact of having individual batsmen and bowlers score 50 to 100+ runs and take multiple wickets is advantageous to success in English domestic limited-overs cricket, and in particular List A matches.

Other key differences between winning and losing teams included the number of 50 to 100+ run partnerships and the amount of runs scored for each individual wicket partnership. These results reinforce those of previous research with Petersen et al. (2008a) reporting large and moderate ES for the number of 50+ run partnerships during the round-robin and super-eights phases of the 2007 World Cup. Additionally, in Twenty20 Najdan (2011) reported moderate correlations for 50+ run partnerships in English domestic matches, and Douglas and Tam (2010) reported significant correlations for 50+ run partnerships during the ICC World Cup. Further investigation into the influence of batting partnerships on success in List A matches revealed that winning teams scored more runs for the fifth, first and second wicket partnerships, and that losing teams scored more runs for the sixth and tenth wicket partnerships. No previous research has reported on the impact of individual wicket partnerships, though Moore et al. (2012) and Najdan (2011) suggested that higher opening partnerships had a small correlation with success in Twenty20.

These findings highlight the importance of having a 50 to 100+ run partnership for the first or second wicket, and ideally, one or two of the top three batsmen scoring 50 to 100+ runs. A large first or second wicket partnership would also set an ideal platform for middle/lower order batsmen to bat with more freedom and increase the run-rate during the latter stages of an innings. Conversely, the finding that losing teams score more runs for the sixth and tenth wicket partnerships reflects a need to rebuild after losing early wickets, or a failure to construct big partnerships and a reliance on lower-order batsmen to improve a total. Information on partnerships is crucial for coaches and captains when considering the intended tempo of an innings. It is also helpful when configuring a batting order and deciding when individual batsmen's strengths should be exploited. However, the findings of this study differ from tactics outlined by Clarke (1988) who suggested that, whether setting or chasing a target, teams should look to score slightly faster than the expected average run-rate to begin with and if, or when, wickets are lost reduce the run-rate and consequently the risk of losing more wickets. This in contrast to the findings of Preston and Thomas (2000) and the results of this study which suggest that, when setting a target, teams should score slowly to begin with, building partnerships and having individual batsmen contribute scores of 50 to 100+ runs, before allowing the middle/lower order batsmen to increase the run-rate later in the innings. Despite this, Preston and Thomas (2000) went on to support the findings of Clarke (1988), suggesting that when chasing a target, teams should look to score quickly at first, therefore reducing the required run-rate for later in the innings. Consequently, future studies should seek to investigate the impact of partnerships on both setting and chasing targets during winning and losing performances in List A matches.

5.2 Batting

Examination of the batting KPIs revealed that the biggest differences between winning and losing performances were the number of wickets lost throughout an innings, which concurs with previous literature investigating an ODI World Cup (Petersen et al., 2008a) and a range of international and domestic Twenty20 tournaments played around the world (Douglas & Tam, 2010; Moore et al., 2012; Najdan, 2011). Consequently, wickets, and the associated tactics and strategies, can be considered as the most important KPI in limited-overs cricket. This is comparable to goals in football, which has previously been identified as the most important KPI, with a wealth of subsequent research focusing upon the associated tactics and strategies to scoring goals (Jinshan, Xiaoke, Yamanaka & Matsumoto, 1993; Michailidis, Michailidis, Papaiakovou & Papaiakovou, 2004; Redwood-Brown, 2008; Yamanka, Hughes & Lott, 1993).

An additional aim of this study was to identify any specific phases of an innings where KPIs correlated with success. Subsequently, a hierarchy of timings of when taking wickets is important was identified of: overs 25-32, 17-24, 9-16, 1-8 and 33-40. Previous research in Twenty20 report a range of results with the first six overs, also known as the powerplay overs, identified as the most important phase to take wickets (Petersen et al., 2008b), followed by the final six overs of an innings (Douglas & Tam, 2010; Petersen et al., 2008b). Moore et al. (2012) also suggest that taking wickets throughout the middle overs is crucial to success, and Najdan (2011) proposes an extension of the importance of taking wickets to the first ten overs of an innings compared to the first six. Collectively, these findings emphasise the importance of taking wickets a regular intervals throughout limited-overs matches. However, in English List A matches, taking wickets during overs 25-32, a phase of the innings when teams are potentially increasing the run-rate to set or chase a competitive target, is particularly important. Moreover, due to the highlighted impact of large first and second wicket partnerships, it is also recommended that teams aim to take wickets during the mandatory powerplay overs (overs 1-8). Team captains should therefore utilise destructive wicket taking bowlers during the mandatory powerplay and overs 25-32. This is in contrast to the traditional tactic of saving wicket taking bowlers until the latter overs of an innings, for example, overs 33-40.

From a run scoring perspective, results indicated that winning teams scored more runs per over compared to losing teams, which is comparable to previous research from the 2007 World Cup (Petersen et al., 2008a). The present study also revealed that winning teams outscored losing teams during the mandatory powerplay and overs 25-32. This is again consistent with previous research in Twenty20 which identified the powerplay overs as a key phase to outscore the opposition (Moore et al., 2012; Petersen et al., 2008b; Douglas & Tam, 2012). Winning teams' superior run-rate can be explained by a higher number of boundary fours scored throughout an innings and again during the mandatory powerplay and overs 25-32. These results are similar to those reported for the super-eights phase, but in contrast to the round-robin phase of the 2007 World Cup, where winning performances were characterised by a higher proportion of boundary sixes compared to boundary fours (Petersen et al., 2008a). This disparity may be a consequence of the wider range of talent participating in the round-robin phase and therefore a greater number of opportunities to hit sixes. However, during the next phase, the range in ability decreases and batsmen are competing against better-quality bowlers, so opportunities to hit sixes are less frequent and the importance of boundary fours increases.

In contrast to previous results, the findings of this study indicated that losing teams scored a higher number of boundary sixes throughout overs 25-32. This may be representative of a belated attempt to set an appropriate target or to keep up with an ever increasing required run-rate. Moreover, the increased risks associated with boundary sixes compared to boundary fours provides an explanation to why losing teams lost more wickets during that phase of an innings. In agreement with previous research, it is therefore concluded that boundary fours should be considered more crucial to success in List A matches due to a decreased amount of risk associated with boundary fours compared to sixes (Petersen et al., 2008b; Douglas & Tam, 2010; Najdan, 2011).

Losing team performances were also characterised by facing a higher proportion of dot balls throughout an innings and during overs 25-32 and 33-40. No additional correlations between the number of ones (singles) scored and winning or losing performances were found in this study; though previous research reported correlations between a higher percentage of singles and losing Twenty20 matches (Douglas & Tam, 2010; Moore et al., 2012; Petersen et al., 2008b). Consequently, the ability of batsmen to minimise the amount of dot balls faced by rotating the strike, alongside scoring a high proportion of boundary fours, cannot be underestimated.

Batting strategy in List A matches should therefore focus upon retaining wickets and building partnerships during early overs, with the secondary aim of outscoring the opposition primarily through scoring boundary fours. A new key phase was identified of overs 25-32 and batsmen should again aim to outscore the opposition primarily through scoring a higher number of boundary fours. Teams should also seek to retain wickets during this phase to enable the associated increase in run-rate to be continued into the latter overs. These findings indicate a shift from the traditional tactic of delaying an increase in run-rate until the final phase of an innings. Teams should also attempt to minimise the amount of dot balls faced; placing an importance on strike rotation alongside a high percentage of boundary fours compared to the riskier option of boundary sixes. Team selection should concentrate on top-order batsmen who can build partnerships and retain wickets during the early overs whilst maintaining a high run-rate. Additionally, batsmen with high strike-rates and boundary four percentages should be included within the middle/lower order, with the aim of them batting during overs 25-32.

5.3 Pitch Level Data

5.3.1 Boundaries Scored

The secondary aim of this study was to examine the pitch-level data of winning and losing performances in List A matches. With the limited previous research investigating pitch-level analysis focusing exclusively on Twenty20, the current study's findings suggest that winning teams scored more runs in boundaries from full/off deliveries and through the mid-off area of the pitch. These results demonstrate a logical relationship between losing teams bowling too full and wide and winning teams taking advantage by scoring a high proportion of runs through mid-off. This theory has previously been supported in English Twenty20 with Najdan (2011) revealing that winning teams scored more runs through mid-off, before proposing that losing teams bowled a wider line of delivery. In a similar study, Moore et al. (2012) reported no differences in boundary destinations, but using descriptive results suggested a contrasting theory of winning teams scoring more boundaries from a leg-stump line compared to an off-stump line. This conflict may reflect the different samples used, including matches from a range of the three regionalised divisions. Consequently, variations in players, tactics and pitch-conditions could account for the observed disparities. However, collectively the results further demonstrate the need for research of this type to constantly be updated and conducted on a range of competitions played around the world, and even within different regions of a country. However, combined with previous research (Moore et al., 2012; Najdan, 2011), the findings of this study highlight the need to bowl a tight off-stump line, widely recognised in coaching literature as the 'corridor of uncertainty' (Woolmer, Noakes & Moffett, 2008), and minimise any wide of off stump or leg-stump line bowling.

5.3.2 Wickets Taken

Pitch-level analysis of wicket taking deliveries revealed that winning teams lost more wickets from short/off deliveries compared to losing teams. These findings provide evidence that aggressive short-pitched bowling was successful in English List A matches in 2012. The success of short-pitched bowling is emphasised further by losing teams losing more wickets from short/line and short/leg deliveries compared to winning teams. The observed differences between the short-pitched bowling are due to the line of delivery. For example, winning teams bowled a straighter line, consequently forcing batsmen to play a shot and increasing the chances of taking wickets. However, the results are in contrast to Twenty20 matches with Najdan (2011) reporting that short-pitched deliveries were less likely to take wickets. The disparity between match formats may be explained by a difference in the approach of the batsmen. For example, during a Twenty20 innings a batsman may adopt a more attacking approach, anticipating a wider variety of deliveries with the main aim of maximising the amount of runs scored from each. This is compared to a List A innings, when a batsman may adopt a less attacking approach, due to increased time available to bat, and anticipate a smaller variety of deliveries. Consequently, the effectiveness of aggressive short-pitched bowling is increased, along with the likelihood of taking wickets, due to the element of surprise.

Finally, losing teams lost more wickets from full/leg deliveries, which is indicative of successful 'death' (yorker or full length) bowling which is widely recognised as difficult to score off and more likely to take wickets (Woolmer et al., 2008). These results are similar to Najdan (2011) who identified that both winning and losing teams lost wickets to full and yorker length deliveries during Twenty20 matches. Moore et al. (2012) also reported in agreement with this study, concluding that during the latter overs winning teams took more wickets by bowling a full-length compared to the shorter-length bowled by losing teams. From a performance perspective, it is therefore recommended that bowlers develop a repertoire of deliveries including yorkers and bouncers, alongside the more traditional length delivery. In particular, in List A cricket, bowlers proficient at short-pitched bowling should be utilised within the early overs and bowlers proficient at 'death' (yorker or full length) bowling employed during the latter overs.

5.4 Bowling

Minimal differences were identified between the bowling KPIs of winning and losing performances. However, winning teams did bowl more no balls per over during overs 17-24 and losing teams bowled more wides per over throughout the innings and during the bowling powerplay. The results provide further evidence to the conclusion that losing teams bowled a wider line of delivery, but are in contrast to previous literature reporting that losing teams bowled more no balls (Douglas & Tam, 2010; Moore et al., 2012; Najdan, 2011). Bowling wides and no balls indicates a lack of skill execution and poor tactics. For example, bowling a bouncer that bounces too high and conceding a wide. In conclusion, although findings suggest a negligible influence on success in List A matches; the amount of no balls and wides bowled should be minimised. Specifically, bowlers should work on their run-ups and front-foot landing to minimise any front-foot no balls and the associated more stringent consequences (Appendix 4). Moreover, bowlers should regularly practice the execution of a repertoire of bowling variations, such as the yorker or bouncer, to minimise the risk of conceding wides and no balls.

5.5 Limitations & Future Directions

5.5.1 Reliability of Coding

The difficulty and subjectivity involved with coding line and length in cricket is acknowledged as one of many examples of sports performance that cannot be described precisely or practically in words (O'Donoghue, 2010). Moreover, the classification of the length of a delivery has been recognised as specific to a bowler and prone to change with different types and speeds of bowler (Justham et al., 2008; Najdan 2011). Consequently, although the reliability of the data collection process was deemed acceptable, limitations surrounding the method of coding were raised.

Accordingly, the randomly selected match coded for the original reliability agreements was re-coded using a new modified method of coding (Appendix 8). Instead of attempting to replicate the exact spot where the ball had pitched onto the pitch map (Figure 1); the new method involved the researcher deciding what line and length, out of the eighteen categories, the delivery pitched on and coding in the middle of the corresponding section on the pitch map (Figures 1 & 2 - Appendix 8). This method removed any doubt of which line and length the system would assign to a delivery.

Intra-reliability of the new coding method was assessed using the same methodology as the original reliability analysis. Despite minimal practice using the new coding method, reliability agreement improvements were observed for all but one KPI (Appendix 8). Moreover, improvements in the levels of agreement for sequential coded data were also observed. Consequently, it is recommended that any PA consultancy or research using the Feedback Cricket™ system adopt the newly modified coding method. However, it is still recommended that future studies make use, where possible, of Hawkeye (Hawkeye Innovations, Winchester, UK) or similar automated technology to achieve improved objectivity and reliability, and not rely on the subjective opinion of an individual observer (Najdan 2011; O'Donoghue, 2010).

5.5.2 Future Directions

Prospective research should also aim to include pitch-level analysis in relation to the type of bowler. There are many classifications of bowling style, so research into the number of overs bowled, wickets taken and runs conceded by each type would provide crucial insight for coaches during the team selection process. This analysis could be cross-referenced with the phases of an innings, enabling the specific timings of when particular types of bowlers are successful to be determined. Additionally, any relationships between specific line and length combinations and types of bowlers can also be identified. A cross-referencing of pitch-level data with the phases of an innings would also provide a useful extension to the findings of this study and allow the conclusion of successful short-pitched bowling within the early overs and successful 'death' bowling during the latter overs to be investigated more thoroughly. A further extension to this study could again focus upon the finding of successful wicket taking short-pitched bowling in List A matches. The contributing factors to short-pitched bowling including the pace of delivery, type of bowler and the timing of short-pitched bowling during an innings could all provide further crucial information to bowlers and bowling coaches.

Finally, a key limitation of the current study was the small sample size used. However, it represented a limited but opportunistic sample due to the researcher having access to the matches as part of their employment as a performance analyst. Supplementary matches could have been accessed from the ECB; however, with the reliability limitations identified within this study, and the predicted decrease in reliability agreements due to matches being coded by unknown analysts, the limited sample size was considered acceptable. However, an increased sample size would have increased the likelihood of identifying significant differences between the KPIs of winning and losing team performances, and allowed superior statistical tests, such as the Chi Square test (x^2), to be conducted. The increased quantity of pitch-level data would have resulted in no more than 20% of the expected counts of line and length data being less than five, and all individual expected counts of one or more (Yates, Moore & McCabe, 1999). Consequently, this would have enabled any significant differences between winning and losing team performances and the line and lengths of deliveries bowled when boundaries were scored and wickets were taken to be identified. Subsequently, cross-tabulation residual values would have been used to determine which individual line and length combinations had contributed the most to any significant relationships identified (Yates et al., 1999).

5.6 Conclusion

In conclusion, the current investigation has identified the key determinants of success in English List A matches, providing coaches with the objective information to plan team selection, strategy and tactics. Batting strategy should focus upon retaining wickets and building partnerships during the early overs, with the secondary aim of outscoring the opposition through scoring a higher number of boundary fours. A new key phase was identified of overs 25-32, in which batsmen should again aim to outscore the opposition through scoring a high proportion of boundary fours. Moreover, teams should seek to retain wickets during this phase to enable the associated increase in run-rate to be continued into the latter overs. Additionally, at least one or two of the top-order batsmen should contribute a score of 50 to 100+ runs. Bowling strategy should focus on taking wickets throughout an innings and during the mandatory powerplay and overs 25-32 in particular. Bowlers should utilise a high percentage of short-pitched bowling during the early overs before switching to a high percentage of full and yorker length deliveries during the latter overs. However, bowlers should still aim to develop a repertoire of bowling variations to remain unpredictable to the batsmen, and at least one or two bowlers should contribute 3 to 4+ wickets.

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