Physical Match Demands of Women’s International Cricket

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Thesis Abstract

The need to understand the physical match demands required for female international cricketers is growing. Chapter 3 identified the physical match demands of female international cricketers in Twenty20 (T20) matches compared to One Day International (ODI) matches and between seam and non-seam bowlers. When comparing T20 and ODI matches, cricketers covered greater distance across matches in all speed bands. When expressed relative to per minute played, distances were greater across most speed bands in T20 cricket. There was little difference in absolute and relative values between seam bowlers and non-seam bowers apart from absolute and relative high-speed running, where seamers covered greater distances. Additionally, meters per minute were greater in T20 compared to ODI, whereas greater total distances were covered in ODI cricket. Different preparation strategies are therefore required for ODI and T20, with considerations around high-speed running needed for seamers in comparison to non-seamers. Chapter 4 explored the time motion analysis of an impactful match batting innings in T20 and ODI cricket. An impactful innings in ODI matches required a greater absolute physical demand than T20, specifically walking, low-speed running and low intensity accelerations. Whereas, when expressed relative to balls faced, T20 matches demanded significantly greater distances jogging, high-speed running, medium intensity accelerations than ODI. This data suggests T20 cricket requires a greater relative demand for high intensity movements, meanwhile, ODI matches demand higher total amounts of low-intensity movements throughout a batting innings. For the first time, this thesis has provided an overview of the demands of international female cricket across batting, bowling and fielding, in seam bowlers and non-seam bowlers and in ODI and T20 cricket.

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Abbreviations

(T20) – Twenty20 / 20 over cricket

(ODI) – One Day International / One Day cricket

(GPS) – Global Positioning System

Thesis Overview

Thesis Justification

Quantifying movement patterns in female cricketers is a research area that has not been previously explored. The importance of this is to aid the support staff and coaches in preparation for different formats of female cricket, in particular Twenty20 (T20) and One Day International (ODI) cricket. The lack of research in this area limits our understanding of the physical demands placed on a female cricketer in a T20 and ODI match scenario.

Thesis Aims

Study 1

1. To compare the physical match demands of an innings in international female cricketers in T20 compared to ODI cricket.

2. To compare differences in the physical match demands between seam bowlers and non-seam bowlers in T20 and ODI cricket.

Study 2

1. To quantify the physical match demands of international female batters during an impactful innings in T20 and ODI cricket.

Chapter 1: Literature Review

1.1 Introduction

Cricket is a field-based, highly technical team sport, comprising of different formats which ranges from 3 hours to 5 days in duration (Stuelcken, Pyne and Sinclair, 2007; Talukdar, 2020). Cricket is a bat and ball sport played by 11 individuals on each team, with the aim to score more runs than the opposing team. Each team completes an 'innings', consisting of overs (6 balls) that can vary depending on the format (20 overs, 50 overs, up to 100 overs a day covering 4 or 5 days) (Mukandi et al., 2014). Playing positions are categorised into bowlers, batters and fielders, each containing specialised positions such as a wicket keeper in fielding, an opening batter, and a seam bowler for bowling.

There are three main formats of cricket played around the world; Twenty20 or T20 played with 20 overs, One Day or One Day Internationals with 50 overs, and multi-format played within 5 days. Duration in these formats differ between how many deliveries are bowled. T20 cricket is a fast moving, shorter format of the game in comparison to 50 over cricket. This is evident as a T20 cricket match is played in 120 balls, whereas one day cricket is played in 300 balls. Due to the shorter match format, T20 cricket increases the demand to score runs more quickly, often leading to greater scoring risks through the need to hit 4s and 6s (Sholto-Douglas, Cook, Wilkie, and Christie, 2020). On the other hand, 50 over cricket demands an increased absolute physical and mental load, requiring skills to be implemented for a greater duration (Bailey and Clarke, 2006; Vickery et al., 2018). More recently, Cricket has seen the inclusions of additional competition formats such as the Hundred in the UK, and the T10 League in Abu Dhabi. With these new formats, professional cricket can be considered as a growing sport, as franchised competitions across the world emerge resulting in increased television and social media coverage (Clarkson, Bowes, Lomax and Piasecki, 2021; Irvine and Kennedy, 2017; Sharp et al., 2011).

Across all three formats of cricket, the male and female laws differ in terms of specifications of play. Specifically, cricket balls are lighter with a smaller circumference, and the inner fielding circles and outer boundaries are reduced (Garcia-Byrne et al., 2020; McErlain-Naylor et al., 2021). Stuelcken, Pyne and Sinclair (2007) found male bowlers were taller, heavier, had longer limb length, breadth and girth in comparison to their female counterparts. For years the sport has traditionally been played by men at professional level, yet the inclusion of females into elite sector in 2003 brought greater attention to female cricket, mainly due to inclusion of the faster and more exciting T20 format (Perera, Davis and Swartz, 2016; Warren, Dale, McCaig and Ranson, 2019). Currently there are over 20 affiliated international teams in the world, cricket is played by over 294,000 male and females in the UK (Cricket participation England 2016-2020 | Statista, 2022). This magnitude of participation highlights the growth in popularity and participation that cricket has had in the UK and worldwide. As participation grows over time, further research will be required to aid development of the sport.

1.2. Development and Demands of Female Sport

Female sport has seen growth in participation within sports such as rugby union, netball and football incorporating elite competitions that attracts financial investment as a consequence of a growing audience (Datson et al., 2017; Sella et al., 2019; Sheppy et al., 2020). Traditionally, research in these sports is male dominated, although coverage and sponsorship has supported the professionalisation of female sports (Morgan, 2019). An example of this is the inclusion of the Women's Super League Football within the UK has seen female elite sport grow in statue (Culvin, 2021). Increased coverage and sponsorship have also driven competition in women's football, creating a higher wage opportunity, greater TV scheduling, and professional game competition (Fielding-Lloyd, Woodhouse and Sequerra, 2018). However, much like other female sports such as cricket, research in areas of physical demands, physical and technical characteristics and match statistics are lacking. Encouragingly, the rise in participation has driven an investment in research for some sports. Female rugby union is an example of the recent evolution of research, evidenced through increased publications and greater attention to the sport (Nyman & Spriet, 2021; Posthumus et al., 2020).

The physical requirements of female sport is an area of increasing research in sports such as rugby league, rugby union and football. Research demonstrates development not just in physical demands of female sport but the development of playing level (Datson et al., 2017; Sella et al., 2019; Woodhouse, Tallent, Patterson and Waldron, 2021). Despite the increased physical demands in female elite sport, there has not been a concurrent increase in performance-based research, limiting the ability of practitioners to apply evidence-based practice to real-world performance. Developing research has also been an issue, as highlighted by Emmonds, Heyward and Jones (2019), research cohorts in female sport are limited in size and in elite playing level, particularly when compared to male sport.

Women’s cricket is globally expanding, with increasing fixture demands of domestic and international competitions (Warren, Dale, McCaig and Ranson, 2019). Despite this, literature is limited to male cricket. A lack of focus on elite female cricket literature has exposed a requirement for understanding how women’s cricket has developed over time. With an improved understanding, practitioners will be able to predict the performance direction of the game and understand which elements of performance produce the greatest impact. The female game has seen growth in popularity and participation since the inclusion of the first Women’s World Cup in 1973, followed by a further growth from the first T20 World Cup in 2009. An example of this growth is in English women’s cricket, which has seen an increase in funding over the last 2-3 years, an expected additional £50 million to be invested over a 5-year period (ECB announce funding boost to transform women's cricket, 2022). Currently, this expansion is consistent, with the participation of such professional domestic competitions such as, T20 Blast and the Rachel Heyhoe Flint Trophy, with the newest inclusion of a new format competition, The Hundred.

Even though participation in female sport is increasing (Fielding-Lloyd, Woodhouse and Sequerra, 2018), the availability for evidence-based data in similar cohorts across sport is limited. Rugby Union highlights this issue, with studies by Busbridge et al. (2020), Hene, Bassett and Andrews (2011) and Suarez-Arrones et al. (2014) all investigating young or amateur athletes which may not replicate the demands of elite female athletes. Clarke, Whitaker and Sullivan (2021) investigated elite Australian female footballers, spanning across a 3-year period, although this research could only provide data from 44 players from a single club. Such data collection aids female elite research but highlights the limitations of only one of few available academic papers in comparison to literature based on amateur athletes (Busbridge et al., 2020; Hene, Bassett and Andrews, 2011; Suarez-Arrones et al., 2014). This makes practical application at an elite level a challenge and limits the best available evidence to amateur or professional levels.

Improvement in research on elite players and focussing on specific cohort size could target the international elite section of women's sport. As this expands in football, rugby and cricket, potential data could be available across a longitudinal period, yet this is dependent on individual teams' collection method and whether a practitioner actively records and stores data over time. Woodhouse, Tallent, Patterson and Waldron's (2021) recent 5-year longitudinal study on elite international female rugby is an example of the development and changes in female sport over time at a high level. These authors highlight how increased demands in running (accelerations, decelerations, and high-speed running) over a 3-year period saw consistent growth in physical demands. The collection of such longitudinal data allows practitioners to identify the patterns of physical development over time and to understand the requirements of achieving peak performance. This is also possible due to collection of time-motion analysis data through Global Positioning System (GPS). Although it is evident that female sport is growing and female literature in sport is becoming more available and the practical need for greater evidence at elite level is required.

As female cricket increases in participation and popularity, the need for understanding physical match demands is at its greatest. As previously explored by Garcia-Byrne et al. (2020), with the use of time-motion analysis, physical demands such as sprints, high-speed running, distance covered, accelerations and decelerations can be analysed to expose an overview of what is required from a female cricketer at elite level. This information could be pivotal for coaches when preparing athletes for the physical demands of certain formats such as T20 and ODI, with variables found to be varying between formats in the male game (Duffield and Drinkwater, 2008; Petersen et al., 2010; Scanlan et al., 2016).

1.3 Physical Movement Demands of Cricket

Research in cricket is quantified physiologically, psychologically and biomechanically, with specific inclusion of performance measurement, team selection, physical demands and decision making (Bhattacharjee and Lemmer, 2016; Duffield and Drinkwater, 2008; Sholto-Douglas, Cook, Wilkie, and Christie, 2020). To date, this is largely unknown within female cricket, especially at elite level. The current physical demands male cricketers can face vary in output intensities within performance, high forces of impact when fast bowling, rapid changes of direction in batting and fielding, and can endure long periods of low intensity movements such as walking and jogging with sharp demands for high-speed running and sprinting (Petersen et al., 2010; Scott et al., 2022). Despite such research being present in male cricketers, there is little evidence of physiological and biomechanical research currently in female cricketers.

Within cricket there are 3 main player positions: batting, bowling and fielding. Due to the importance of batting and fast bowling as key components of a cricket match, research has focused on the physiological and biomechanical demands. In particular, there is focus on higher intensity areas of each discipline such as on sprinting and turning for batters, along with the biomechanical and physical demands on fast bowlers (Scanlan, Berkelmans, Vickery and Kean, 2016; Vickery et al., 2018). These movements can be required at unpredictable times throughout a fielding innings, although batting and bowling require greater amounts of sprinting and high-speed running in short intervals (Petersen, Pyne, Portus and Dawson, 2009).

1.3.1. Batters

Batting is a skill that requires the player to score runs at different frequencies, depending on format type, whilst aiming not to be dismissed by the opposing team (Lopes, Goble, Olivier and Kerr, 2021; Peploe, King and Harland, 2014). With the predominant aim in cricket being to score as many runs as possible, researchers have attempted to identify factors that may affect batting performance. These factors include the biomechanics of batting, influence of fatigue on performance, internal responses to periods of batting (metabolic and cardiovascular), and external workloads associated with batting (activity frequencies, movement distances and durations) (Duffield and Drinkwater, 2008; Portus and Farrow, 2011). This information is of great importance in providing a practitioner with an understanding for the factors that influence the batters' ability to score runs.

Duffield and Drinkwater (2008) analysed and quantified the time-motion analysis of batting activity to score 50, 80 and 100 runs in a test match and a one-day match in men's cricket. Coded through video analysis, the authors categorised 5 movement velocities (standing, walking, jogging, striding and sprinting) along with playing a shot movement and a lateral motion of 180° when running between the wickets. In One-Day cricket, results showed that lower intensity movements were at a greater frequency and higher duration of minutes were spent in stationery and walking movements. As the score increased from 50 to 80 to a 100, the higher intensity efforts gradually increased at a similar rate with lower intensity movements (34.2% of time walking and 1.7% of time high-speed running in ODI cricket). Although these changes were gradual, results still showed a significant difference between formats. Despite the variation for movement in one-day cricket was much higher than test match cricket, one-day cricket demands produced greater high intensity movements such as striding and sprinting than test match cricket. Such results can be used as a training scenario for potential impact on match performance. A practitioner could use the mean data for scoring 50, 80 or 100 as normative performance data for an athlete to make a positive match impact. For example, the amount of sprints or turns required in scoring 50 or 100. When factoring in fatigue, it could be hypothesised that high intensity movements such as high-speed running and sprinting would need to be performed effectively throughout a match to a competitive level to allow them to continue to perform their skill effectively.

Sholto-Douglas, Cook, Wilkie, and Christie (2020) investigated the physical movement demands of male T20 players in the Australian Big Bash League. On average, batters covered 1.78 km and spent 40.4 minutes batting per match across the 12 matches analysed. Batters spent the most amount of distance walking at 0 – 3.1 m/s (1294m ± 850m) and low-speed running at 3.9 – 5.8 m/s (300m ± 112m) per hour in an innings, in comparison to jogging, striding and sprinting. Striding (or high-speed running) at 5.8 – 7.2m/s was recorded at 43m ± 34m per hour, indicating T20 requires a high amount of high intensity movement as well as a demand for constant low intensity movements in walking and running. These results align with findings from Petersen et al. (2010), suggesting conditioning in T20 cricket should focus on preparing a batter for higher intensity workloads, in order for a player adapt to performing their skill when physical demands are at their highest.

Najdan et al. (2014) found 3 additional key performance indicators for success in T20 cricket, highlighting individual batters scoring 75+ runs, contributing between 50-74 runs individually, and teams having batting partnerships of 50+ runs. Along with this, Najdan et al. (2014) data identifies winning teams had a similar number of players scoring 25+ runs, yet there was greater quantity of this in losing teams. With these results, there is indication that 25+ runs individually scored in an innings could provide a greater impact on the result of a match in T20 cricket.

Patterns have also been analysed and applied into training scenarios described by Houghton, Dawson and Rubenson (2011) and Vickery et al. (2018), who used simulated training methods to replicate and exceed demands required by batters to succeed. Vickery et al. (2018) compared how the principle of specificity based on the outcome of one-day format physiological demands to specialised strength and conditioning training could increase batting performance when applied in a centre wicket training simulation. The authors highlight the importance of identifying physiological match demands and implementing into training scenario through match play simulation. It was found that batting performance increased when placed into a simulated match scenario in comparison to traditional net practice. As the physical demands placed on an elite female batter individually is so far unknown, identifying and quantifying these demands could inform practitioners of normative demands for a successful elite female cricketer, based on match-winning performance. By quantifying movement demands in female batters, coaches can have a recorded understanding of the demands required at international level, which could be imperative to their preparation and an athlete's physical development.

1.3.2. Bowlers

Bowling can be quantified into 2 main types; slow/spin bowling and fast/seam bowling, with the demand of each bowling discipline differing in regard to format. Each format has a legal cap on how many overs can be bowled by each player (T20 – 4 over each, 50 over cricket – 10/12 overs each, test match – unlimited), thus providing a coach with a challenge of preparing a bowler for varying match demands. Within a season, a bowler must continuously alter between game formats (Ahmun et al., 2020; Petersen, Pyne, Portus and Dawson, 2009). The discipline of seam bowling is an area of research that has received a large amount of focus and attention due to the physical demand placed on a seam bowler (Johnstone et al., 2014). Despite seam bowling dominating research in this area of the game, spin bowling has been investigated, although due to a lower physical demand (Gregory et al., 2002), literature is not highly populated.

Kinematic movements and specific performance ability of the bowler has greater research relevance due to a lesser intensity, although bowling overs may be greater than a seam bowler in test match cricket (Callaghan et al., 2019; Crowther et al., 2021). The ground reaction forces produced by a fast bowler can be over eight times their body weight at the point of contact with the ground (Scott et al., 2022). At front and rear foot contact, these large peak forces are repeatedly required within a match, together with trunk and shoulder flexion and rotation, to release the ball at high-speed (Callaghan et al., 2021). Ahmun et al. (2020) identified the physical demands and physiological profiles of male international cricketers, comparing senior and under 19 seam bowlers with senior and under 19 batters. Although it was found that 10m, 20m and 40m sprint times were similar, there was a significant difference for body mass and height, indicating senior seam bowlers were larger in stature when compared to batters and under 19s. Senior seam bowlers also created greater horizontal force (*d* : 0.78) and sprint times across 10m, 20 and 40m (2.23s ± 0.07s; 3.56s ± 0.10s; 5.73s ± 0.19s) in comparison to senior batters and U19s. Using GPS, this investigation showed that male senior seam bowlers produce greater force in bowling and perform a greater number of sprints than batters in senior and under 19s. These demands are important when considering physical preparation, particularly when choosing and monitoring correct bowling loads in seam bowlers to reduce fatigue and injury risk, such as soft tissue and stress fractures (Orchard et al., 2015). Although it should be noted that these results were taken from performance testing and not in a match scenario. When comparing the speed of delivery in men's cricket, a spin bowler delivers an average of 87kmph, yet a seam bowler averages speeds of 144kmph. This pinpoints the greater need for understanding the demands of a fast bowler over a spin bowler due to the high workload demands (Crowther et al., 2018; Worthington, King and Ranson, 2013).

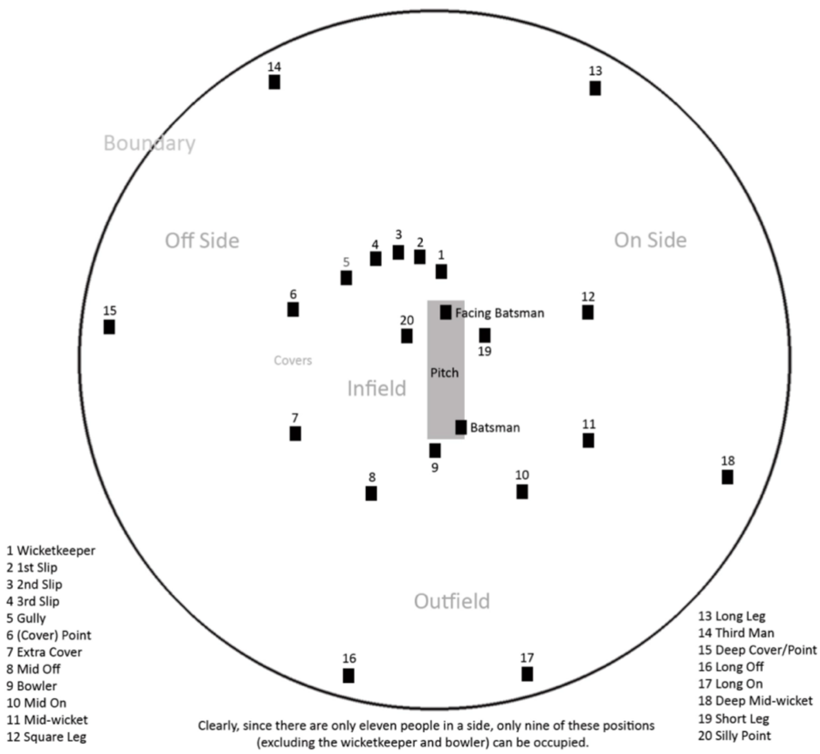
The continuous increase in professional cricket competitions and professional players contracted to world-wide competitions provides major complications in workload monitoring and management. The COVID-19 pandemic forced professional cricket to condense competition fixture adversely in the past 18 months, forcing a predicted change of physical demands on players, in particular the fast bowler (Cricinfo, 2022). As fixture demands increased, it is thought that the increased demand for greater repeatability of high intensity workloads would have a greater fatigue effect than the prevalent injury rate recorded on an average schedule (Orchard, 2010). As no other sport has such changing physical competitive demands across formats, the reliance of coaches and practitioners is key to maintain players performance and fatigue levels (McNamara, Gabbett and Naughton, 2016).

1.3.3. Fielders

Fielding is a key aspect in cricket for the team bowling, with adequate skill execution such as catching, quick retrieval of the ball and accurate throwing preventing the batting team from scoring runs (Saikia et al., 2012). T20 cricket and 50 over cricket require greater demands for fielding due to a greater accumulation of runs scored in these formats, demanding increased frequency for sprints (MacDonald et al., 2013). Perera, Davis and Swartz (2017) used a simulation with data from international and Indian Premier League T20 men's cricket creating an algorithm, finding the best fielders will save an average of 1.2 runs per match in comparison to average performing fielders. Despite this data collection being notational, Perera, Davis and Swartz (2017) results suggest a coach could identify that the greater the conditioning of a player, the higher the fielding performance.

In limited overs cricket, the importance of saving runs has become more vital with higher scoring games and closer match finishes. Shilbury (1990) identified up to 25 key positions in the field, pre T20 cricket, with 'cover' 'mid-off' and 'mid-on' recognised as the most featured within a match. T20 cricket is showing to be a higher intensity format of cricket compared to one-day cricket and test match, consequently increasing the requirements for fielders to possess greater technical skills and demonstrate them at a higher rate (Bray et al., 2016).

Figure 1. Cricket Fielding Schematic (Set up for a right handed batter) (Right Off The Bat, Cricket and baseball fielding positions 2012)



There is a lack of recent research in positional patterns, demands and effects of fielding in comparison to other disciplines. Petersen et al. (2010) and Petersen, Pyne, Portus and Dawson (2009) gave an overview of positional movement demands in professional cricket, with a specific focus on T20 cricket. Petersen et al. (2010) found within seven T20 innings, fielders produced 23m ± 10m sprints per hour, a mean sprint distance of 15m ± 4m per hour and maximum sprint distance of 31m ± 14m. More recently, Sholto-Douglas, Cook, Wilkie and Christie (2020) evaluated fielding movement demands of T20 Big Bash Australian League cricketers. This study identified that fielders covered a mean distance of 5.9km (± 0.9km). Petersen, Pyne, Portus and Dawson (2009) study also found fielders recorded the greatest number of sprints in T20 cricket (4 ± 8 efforts), mean sprint distance of 17m ± 2m and total sprint distance of 0.7km ± 0.2km. Similarly, Sholto-Douglas, Cook, Wilkie and Christie (2020), Petersen, Pyne, Portus and Dawson (2009) identified a fielder's total distance covered (6.4 - 8.5km) over an 80-minute innings. Despite data predominately in male cricket, it could be inferred that these demands would show degree of similarity in the women's game, but further research is required.

Research currently presented on the requirements of fielding are conducted on the male formats of cricket. To understand the key fielding movements of female cricketers and how the movements compare to male cricket, further research is required. For practical purposes, a coach could use this data as a marker to condition an elite athlete in preparation for match play scenario, especially for the high workload of fast bowlers and fielders. Such research over time has shown a positive relationship between high physical output and specific player position. It should be considered that from match to match, it is highly likely that a player will field in different positions, changing the amount of movement workload required each match (Turner et al., 2020). Further research could identify which key changes in match preparation are needed to meet a successful level of performance in female cricket.

1.4. Time Motion Analysis System

Time Motion Analysis is an approach used to investigate movement patterns and demands sequences of play that can be required in team sports (Castellano, Blanco-Villaseñor and Álvarez, 2011). Monitoring movements and providing detailed data of individuals can determine the preparation required and inform of player intensity output to monitor fatigue and injury precursors (Lovell & Abt, 2013). Time-motion analysis requires systems such as video analysis, notational analysis and GPS (Lovell & Abt, 2013; Manchado et al., 2013). At present, literature in time-motion analysis of team sports investigate player movement through GPS to provide an insight into physical movement demands such as distances and speed thresholds (Gabbett, 2010; Jennings et al., 2012; Molinos Domene, 2013).

1.4.1. Global Positioning System (GPS) and Sport

GPS technology is a satellite inertial measurement unit system that has become a key measuring tool for determining the movements associated with match play in professional sport (Coutts & Duffield, 2010; Edwards et al., 2018). Variables such as accelerations, decelerations and total distances can be tracked and quantified to give the athletes, coaches, and practitioners an understanding of the players current output and possible areas for improvement. Such data could be applied within a strength and conditioning environment off the field to support an athlete in reaching their peak performance on the field (Jackson et al., 2018), providing useful information to aid the prescription of training, manage training loads, analyse player readiness, and evaluate injury or return to play risk (Howe et al., 2020). Periods of play or time can be assessed and applied into match scenarios or training drills to improve on game performance. A highly GPS-utilised sport, as football is, incorporates the characterisation of total sprints, acceleration, deceleration and positioning which correlate to patterns that affect play and performance (Brickley and Smeeton, 2018; Hennessy and Jeffreys, 2018). This GPS utilisation can be key in the implications of positioning and match tactics in cricket, providing an insight into patterns and sections of a match. Furthermore, GPS technology can be useful for practitioners and coaches to identify and apply interventions to an athlete's weakness such as acceleration or power output. Interventions to these type of key performance indicators can be vital to successful performances or returning from injuries (Orchard, 2010; Orchard et at., 2015) and obtaining key data metrics from the GPS system that apply to certain key performance indicators could inform the coach whether best practice is being implemented.

Figure 2. Example of a Catapult GPS Unit.

GPS units (figure 1) with a higher frequency have been demonstrated to provide a greater reliability within a team sport setting (Johnston et al., 2014; Tierney, Young, Clarke and Duncan, 2016). Johnston et al. (2014) looked at the reliability of using interunit 10Hz and 15Hz GPS units on an individual's movements in a team sport scenario. The authors compared 1Hz and 5Hz units to 10Hz and 15Hz units across total distances, low-speed, high-speed and very-high-speed running of 8 male athletes. This investigation found interunit validity and reliability of units were greater in 10Hz and 15Hz compared to 1Hz and 5Hz when collecting at low-speed and high-speed running, and number of sprint efforts, with a reduced level of error. Microelectromechanical sensors (MEMS) are small sensor chips that detect and measure changes in movement through an axis, usually placed in wearable technology such as GPS (Russo et al., 2021). The use of MEMS has improved this level of error, with such units as 'Catapult' implementing accelerometers and gyroscopes (Hennessy and Jeffreys, 2018; Jennings et al., 2010). GPS units can become less reliable with faster movements, however they are still a valuable tool for a practitioner (Johnston et al., 2014). These units provide valuable and practical insights into the physical demands of a number of sports. As this technology becomes more advanced, improvements have allowed for greater accuracy with sampling rates of 5, 10 and 15Hz and triaxial accelerometers leading advancements (Scott, Scott and Kelly, 2016). Triaxial accelerometers have allowed for improved accuracy when estimating a player's workload and force output (Cummins et al., 2013). Accelerometers allow for the acquisition of physical loads, movement patterns and work rates (Waldron et al., 2011). Using three axis planes (x, y, z), GPS can present a player's acceleration and deceleration rates, which can be a useful tool in such sports as football and seam bowling cricket which require high amounts of deceleration

(Bliss et al., 2021; Buchheit, Gray and Morin, 2015). It should be considered that GPS tracking does have limitations, with Jackson et al. (2018) showing reduced accuracy for calculating rapid changes of direction at speed and other high-speed movements >20km/h. Despite this GPS continues to be applied in sport as a valuable measure of performance (Coutts & Duffield, 2010; Edwards et al., 2018).

1.5. Time Motion Analysis in Cricket

GPS time-motion technology has been used in cricket for over a decade, quantifying differences in movements patterns between playing positions and formats (Petersen, Pyne, Portus and Dawson 2009). Historically, cricket has been labelled a low intensity sport, with early research in multi-day cricket suggesting walking can make up to 90% of a player's overall game movement (Petersen, Pyne, Portus and Dawson, 2009). The importance of understanding the remaining 10% could be important to match preparation for a cricketer. This remaining game movement has been identified in the men's game as jogging, high-speed running and sprinting (Petersen, Pyne, Portus and Dawson, 2009; Sholto-Douglas, Cook, Wilkie, and Christie, 2020).

Within positional and movement pattern quantification, fast bowling load and injury risk are analysed with the use of GPS in cricket. Petersen (2009) and Petersen (2010) used GPS data in professional T20 and One Day matches to quantify movement patterns in male cricketers. Petersen, Pyne, Portus and Dawson (2009) study on positional characteristics in Australian state players identified the demands for sprinting in fast bowlers and fielders outweighs the other respected disciplines within four T20 matches. Sholto-Douglas, Cook, Wilkie, and Christie (2020) conducted a study on elite Australian male crickets for the Big Bash League season to quantify physical movements in players movements batting, bowling, and fielding. They identified that seam bowlers covered the greatest distance (6547m ± 530m) across all 12 games played. Players covered the greatest differences jogging (1294m ± 850m) and high-speed running (377m ± 124m), indicating T20 cricket requires periods of high intensity as well as constant movement patterns with jogging. It should be noted, although there is literature on T20 and ODI cricket, and investigations on physical movements in player positions, little research has yet compared T20 and ODI cricket in male or female cricket (Bliss et al., 2020). Literature in the requirements of movement demands of cricketers in T20 and ODI formats has so far identified the need for constant low intensity movements through jogging. Yet T20 requires a larger amount of higher intensity movements such as high-speed running and sprinting especially within fielding. The understanding of these movements within female cricket is still largely unknown and requires further research.

1.6. Physical Demands of Female Cricket

Only one study has quantified the time-motion analysis of female cricket. Garcia-Byrne et al. (2020) identified external workloads on female T20 cricket and the effect these demands have on locomotor performance in a match. Between international, national and youth female cricketers, the authors found international cricket required greater distances covered (5250m ± 1664m) and greater high-speed running (73m ± 62m) demands in absolute value than national and youth teams. Garcia-Byrne et al. (2020) also identify meterage per minute to be higher in international T20 cricket (53m ± 16m), significantly different to that of national T20 cricket (23m ± 7m). These results highlight the intensity of physical movements in female international cricket. This can also be highlighted with greater high velocity movements in international cricket such as relative band 4 movement (20.99 to 25.99km/h) (42m ± 32m) and relative high-speed running (>21km/h) (45m ± 18m). Coinciding with this, international demands were shown to be higher in absolute and relative per hour values than national and youth cricketers. It should be noted than international and national matches were a longer duration than youth matches, thus requiring further demands with greater playing time. Much like male T20 cricket research, Garcia-Byrne et al. (2020) show high variation from match to match in international T20, highlighting the difficulty in predicting exact frequency in movement patterns per game. A small sample size in an international match limits reliability of results. Increasing the size of the match sample may not decrease the margin of error in results, as the variability of results per match remains constant. However, it may aid coaches in identifying recurring movement patterns across matches.

Table 1. External workload demands of women's twenty 20 cricket competition (Garcia et al. (2020)

	International	National	Youth
Total Duration	1:39:53	1:31:28	1:11:48
Total Distance (m)	5250 ± 1664	4113 ± 885	3436 ± 1026
Meterage per minute (m)	53 ± 16	23 ± 7	23 ± 10
Velocity band 1 (0–11.02 km/h) (m)	4011 ± 1197	3363 ± 695	2901 ± 785
Velocity band 2 (11.03–14.00 km/h) (m)	677 ± 192	365 ± 140	235 ± 143
Velocity band 3 (14.01–20.99 km/h) (m)	616 ± 311	365 ± 211	257 ± 122
Velocity band 4 (21.00–25.99 km/h) (m)	55 ± 39	34 ± 28	24 ± 17
Velocity band 5 (>25.99 km/h) (m)	4 ± 10	2 ± 2	2 ± 3

Garcia-Byrne et al. (2020) only compare the T20 format of female cricket and did not quantify player positions within the results. Unlike male cricket, the quantification of

ODI female data remains unknown. Identifying physical demands in both female T20 and ODI formats would allow a coach to recognise key differences when preparing athletes. It is also important to highlight there is no data on female batting requirements within Garcia-Byrne et al. (2020) research, limiting our understanding of how demands may differ when compared to data derived from male players. Furthering research in this area will also help coaches identify the demands required from a batter when scoring a match impacting performance.

When comparing female T20 to male T20 cricket, literature suggests the male format may require greater workloads and intensities, although further research in female cricket is required to credit this (Petersen et al., 2010; Petersen, Pyne, Portus and Dawson, 2009; Sholto-Douglas, Cook, Wilkie, and Christie, 2020). Sholto-Douglas, Cook, Wilkie, and Christie (2020) showed T20 fielding distance covered of male cricketers at 5.9km ± 0.9km, in comparison to 5.25km ± 1.6km in female T20. When comparing T20 high intensity movements, Petersen et al. (2010) quantify fielders to cover 31m ± 14m in an innings when sprinting. This is considerably lower than female T20 sprinting distances (4m ± 10m) (Garcia-Byrne et al., 2020). The comparison of distance demand requirements shows a similar result despite a difference in pitch sizes between male and female. Yet, the difference in high intensity movements suggests that male cricket requires greater higher intensity than female cricket, although it is difficult to make a distinctive and reliable comparison as there is only a single article on female T20 cricket demands. It should also be considered that movement thresholds such as high-speed running and sprinting may be different between the men’s game and the women’s game.

1.7. Summary

Currently, research into female international cricket is limited to Garcia-Byrne et al. (2020) study on external workloads of female cricketers which includes international and amateur level. Literature solely based on the demands and exposure of an international female cricketer's movement patterns does not currently exist. Understanding the literature available it is evident for a coach to understand the demands that are required for a female elite cricketer in T20 and ODI cricket. This normative data could support coaches to prepare a player for the next T20 or ODI match by quantifying the optimal physical demands required for each format or role. The role of fielder has been quantified by Petersen, Pyne, Portus and Dawson (2009), Petersen et al. (2010) and Sholto-Douglas, Cook, Wilkie, and Christie (2020) in to disciplines of bowler, wicket keeper, fielder or batter. This thesis will explore the movement difference in fielding between seam bowlers and non-seam bowlers between T20 and ODI formats over an international calendar year, including an ODI World Cup (Chapter 3). At present, there is no literature on the role specific demands for batting and the movement patterns it associated with producing a significant match impacting score. Petersen et al. (2010) and Sholto-Douglas, Cook, Wilkie, and Christie (2020) identify batter's movements per hour, yet this has not been identified in female cricket. To date, this information has yet to be researched in the male or female formats of cricket. Duffield and Drinkwater (2008) are the only literature to currently explore speed and distance variables of male cricketers when scoring 50, 80 and 100 runs in test and one day matches. In this thesis (Chapter 4), we will be exploring the demands of making an impactful score in T20 cricket (30+ runs) and ODI (50+ runs), quantifying the impact per ball as well as a batter's overall innings.

Chapter 2: Methodology

2.1. Introduction

This chapter summarises specific methodology used across both studies in chapter 3 and chapter 4.

2.2. Ethical Approval

Data was collected by the England and Wales Cricket Board on a match-by-match basis on international female players. Prior to obtaining and analysing data, ethical approval was granted by the University of Essex and the England and Wales Cricket Board.

2.3. Data Collection

Player's data was collected from the England Women's cricket team, using GPS units, which were worn during the fielding innings of each international match. Each player wore a sports-vest fitted with a Catapult Vector S7 4GHz (Catapult Innovations, Melbourne, Australia) GPS device, which was located on the upper back of the individual. Units were activated approximately 10 minutes prior to start of player innings and deactivated at completion of the match when the player vacated the playing area. GPS devices had to be worn throughout the whole fielding innings. Devices were then inserted into a unit docking station where data was collected from the devices onto Catapult software. Raw GPS data was 'clipped' and exported on

Catapult Openfield (OpenField 3.7.2 Build #79515). Data was analysed on catapult then exported to an CVS file for further analysis. Data was compared to a GPS database used by the England and Wales Cricket Board to ensure accuracy, and data that did not present as a full innings was excluded. A full innings was defined as a player complete a match from stepping on to the field at the start of play, to end of play and exiting the field. The physical match demands were quantified, with distance covered at five velocity thresholds (0 – 5km/h; 5 – 11km/h; 11 – 16km/h; 16 – 20km/h; >20km/h). Other variables recorded were total distance covered; match duration; meterage per minute; maximum velocity; acceleration counts between band 1 (2 - 3m/s²), 2 (3 - 4m/s²) and 3 (>4m/s²); deceleration counts band 1 (-2 - -3m/s²), 2 (-3 - -4m/s²) and 3 (>-4m/s²); and velocity total efforts band 5 (+20km/h). Velocity thresholds used were based on an international female rugby union study by Woodhouse, Tallent, Patterson and Waldron (2021), which showed the closest threshold values to those used by the focused team. Acceleration and deceleration thresholds were based on literature by Bliss et al. (2021). Absolute data, collective across a full match, and relative data, presented as demands per minute (study 1) or per ball (study 2) were used across all physical match demands.

Chapter 3: Physical Match Demands of T20 vs ODI Cricket Comparing Seam Bowlers vs Non-Seam Bowlers in International Female Cricketers

3.1. Introduction

T20, ODI and multi-day cricket primarily make up international cricket. Current research investigates T20 and ODI cricket formats, exploring physical demands separately, yet there is no literature in the female game comparing both formats. Two studies have compared the physical match demands in men's T20 and ODI cricket. Bliss et al. (2021) and Petersen et al. (2010) both quantified differences between both formats in male cricketers. T20 cricket was significantly greater in distances covered through walking, jogging, striding, high-speed running, sprinting in absolute value, along with meterage covered relatively per minute and hour. Bliss et al. (2021) demonstrated absolute distance thresholds presented a greater demand in ODI cricket. This shows that in men's cricket, T20 cricket has a greater demand of intensity, whilst ODI produced a greater demand for volume.

Much like formats, literature in male cricket has quantified time-motion demands of different roles within cricketers. These roles are usual classified as; seam-bowler, fielder, batter, wicket keeper and spin-bowler. The scientific literature investigating the physical match demands of cricket have primarily been centred around seam bowlers. This is due to seam bowlers having the highest involvement in a match and a high workload of combined bowling kinematics and fielding, covering up to 80% greater distance than other positions across both T20 and ODI formats (Ahmun et al. 2020;

Petersen et al. 2010). Currently, research has explored men's normative data on physical match demands between each role in a single team. Sholto-Douglas, Cook, Wilkie, and Christie (2020) investigated elite male Australian domestic T20 cricket to quantify movement demands across a 12-game season. Comparing seam bowlers, fielding innings and batters, the author found fielding covered the greatest walking distance (4576m ± 406m), whilst seam bowlers covered the most total distance (6547m ± 530m), along with the highest distances covered jogging (1294m ± 850m) and high-speed running (377m ± 124m). These findings in seam bowlers quantify the high outputs required in this discipline across a 20-over match. Within the same investigation, fielding demands were of similar intensity with sprinting distance (39m ± 33m) and sprint efforts per minute (1.7 ± 1.7). Despite non-seam bowling fielders covering less distance at speed than seam bowlers, there is an indication that a non-seam bowling fielder covers distances at higher intensities compared to the other on-field disciplines in T20 cricket through short-burst movements. Therefore, further research is required to investigate the differences between seam and non-seam bowlers.

Currently there is only one published study which investigates the physical match demands of elite level female cricketers, highlighting the requirement for further research into female cricket to inform best practices (Garcia-Byrne et al., 2020). Garcia-Byrne et al. (2020) explores physical workloads of international, national and youth level female cricketers in T20 matches. When evaluating absolute values of matches, greater distances in comparison to national and youth were found in all speed variables apart from walking and sprinting. Total distance (5250m ± 1664m), velocity band 1; 0 – 11.02km/h (4011m ± 1197m) and velocity band 2; 11.03 –

14.00km/h (677m ± 192m) all showed the greater between international players and national and youth. Yet, in relative values per hour, only velocity band 2 showed a positive significant difference towards international players (377m ± 181m). Despite national players covering the most distance at velocity band 3; 14.00 – 20.99km/h (287m ± 231m), it was noted this difference was not significant. It can be considered that overall, in matches between the three playing levels, female international cricketers required the highest physical demands. When measured per minute, this difference was much less, making it difficult to differentiate workloads between the three playing levels. It needs to be considered the duration of youth matches are less than international and national matches (Garcia-Byrne et al., 2020), suggesting less physical demand when duration is lower. Even though this study investigates international female players, the sample size is small containing 3 players over 19 matches, in comparison 16 non-international players.

Very little literature exists to support practitioners understanding for the physical demands associated with the different formats of elite female cricket. The purpose of this study was to investigate the differences in the physical match demands between ODI and T20 cricket in seam bowlers and non-seam bowlers in international female cricketers. The study hypothesised T20 match format would require greater physical match demands per minute of play, when compared to ODI cricket in international female cricketers. Although, ODI cricket would require greater total work. This study also hypothesised that physical match demands in international female cricketers are greater among seam bowler compared to non-seam bowlers across both match formats.

3.2. Methods

Eighteen female international elite cricketers from the England Women's Cricket squad participated in the study. Players (age 26.4 ± 4.6 years old) completed T20 (n=6) and ODI (n=18) international matches between 2021 and 2022, which included the 2021 Women's Cricket World Cup. Matches included required the full number of allotted overs for the format to be delivered, the batting run target to be reached or the opposing team to be bowled out. Player's roles were categorised into 'Seamers' (n=8) and 'Non – Seamers' (n=10). A seamer was defined as a player that has played the game as a pace-bowler and a non-seamer defined as any other outfield player (wicketkeepers excluded). Method of GPS collection can be found in section 2.3 of Chapter 2.

3.2.1. Statistical Analysis

Statistical match analysis was performed in IBM SPSS Statistics v27.0.0 (IBM, Armonk, United States of America). Mixed Model Linear Analysis was used to assess differences in Match format (T20, ODI) and role (seamers, non-seamers). Match format and roles were entered as fixed factors, whilst players were entered as random factors. Significance was set at $p<0.05$, with the use of Bonferroni *post-hoc* testing for pairwise comparisons. Hedges g effect sizes were used between ODI and T20 formats and seamers and non – seamer roles which were observed at *small* – 0.2; *medium* – 0.5; *large* – 0.8; *very large* – 1.4 (Swinton et al., 2022).

3.3. Results

Table 1 depicts both absolute and relative values for time motion in ODI and T20 formats, with seamer and non-seamer players described across both ODI and T20 formats. In general, absolute match demands were significantly greater in ODI than T20, with ODI recording a significantly greater total distance covered when compared to the T20 format. Walking band 1 (p<0.001; d = 1.32; [ES: 1.00 to 1.62]) and jogging band 2 (p<0.001; d = 0.87; [ES: 0.57 to 1.17]) showed a significant *large* difference towards ODI cricket. Low-speed running band 3 (p= .001; d = 0.47; [ES: 0.18 to 0.76]), high-speed running band 4 (p<0.001; d = 0.40; [ES: 0.10 to 0.68]) and sprinting band 5 (p= .002; d = 0.31; [ES: 0.02 to 0.60]) all displayed a greater higher *medium* difference in ODI cricket compared to T20 cricket, meanwhile maximum velocity and total efforts in velocity band 5 (p= .760; [ES: -0.19 to 0.38]) showed no difference between formats. A higher amount of accelerations band 1 counts (p<0.001; d = 0.58; [ES: 0.28 to 0.87]) and decelerations band 1 (p<0.001; d = 0.74; [ES: 0.44 to 1.03]) in ODI cricket than T20, displaying *medium* effect. Other corresponding acceleration bands showed no difference in absolute value between the two formats.

In relative terms (table 2), T20 showed a greater positive difference compared to ODI cricket. Meters per minute illustrated a higher intensity in T20 cricket with a significant *small* difference (p= .031; d = -0.29; [ES: -0.58 to 0.00]). Walking band 1 (p= .010; d = -0.27; [ES: -0.56 to 0.02]) and jogging band 2 (p<0.001; d = -0.27; [ES: -0.56 to 0.02]) also showed a significant *small* difference towards T20. Distance covered within low speed running band 3 (p<0.001; d = -0.78; [ES: -1.08 to -0.48]), high-speed running distance band 4 (p<0.001; d = -0.64; [ES: -0.93 to -0.34]) and sprinting distance band

5 (*p*<0.001; *d* = -0.49; [ES: -0.78 to =0.19]) in T20 cricket compared to ODI, with *medium* effect. Acceleration band 1 counts (*p*<0.001*; d* = -0.48; [ES: -0.76 to -0.18]) and band 2 counts (*p*<0.001; *d*= -0.75; [ES: -0.94 to -0.35]) displayed significant *medium* difference along with deceleration counts band 1 (*p*<0.001; *d* = -0.30; [ES: -0.77 to -0.18]), deceleration counts band 2 (*p*<0.001; *d* = -0.76; [ES: -0.39 to 0.18]) and *large* effect deceleration counts band 3 (*p*<0.001; *d* = -0.93; [ES: -0.53 to 0.05]). However, there was no significant difference found for acceleration counts Band 3 (*p*= *.879; d* = -0.04; [ES: -0.65 to -0.07]). When comparing seamers and non-seamers, very *large* differences between both formats were only identified in absolute (*p*<0.001*; d* = 2.64; [ES: 2.25 to 3.02]) and relative (*p*<0.001*; d* = 2.45; [ES: 2.07 to 2.82]) high-speed running (16-20km/h). All other variables within these comparisons showed no difference.

Table 2. **Differences in absolute match format and role distance variables with associated *p* values.**

	ODI		T20		P Value		
	ODI – Seamer (n = 65)	ODI – Non-Seamer (n = 93)	T20 – Seamer (n = 14)	T20 – Non-Seamer (n = 28)	Game Format	Role	Interaction
Total Distance Covered (m)	8941.45 ± 2734.39	8629.33 ± 2078.54	5004.11 ± 644.34	4720.09 ± 796.49	<0.001	.514	.857
Max Velocity (km/h)	24.96 ± 5.42	25.89 ± 6.45	25.05 ± 1.68	24.05 ± 2.42	.240	.908	.504
Match Duration (minutes)	183.07 ± 34.74	185.64 ± 27.60	85.14 ± 9.88	88.07 ± 8.23	<0.001	.583	.971
Distance Band 1 – Walking (0-5km/h)	4125.65 ± 1176.77	4572.51 ± 850.82	1973.46 ± 220.71	2174.98 ± 312.68	<0.001	.099	.460
Distance Band 2 – Jogging (5-11km/h)	3008.65 ± 1059.07	2801.01 ± 890.90	1675.62 ± 470.19	1627.55 ± 395.86	<0.001	.771	.646
Distance Band 3 – Low Speed Running (11-16km/h)	977.02 ± 441.24	994.03 ± 606.58	770.09 ± 310.94	722.87 ± 252.02	.001	.287	.915
Distance Band 4 – High Speed	648.92 ± 246.23	170.19 ± 106.39	455.60 ± 117.05	131.32 ± 98.17	<0.001	<0.001	.001

Running (16-20km/h) Distance Band 5 – Sprinting (>20km/h)	180.94 ± 165.02	91.23 ± 73.72	129.12 ± 68.34	62.70 ± 62.78	.002	.189	.245

Table 3. **Differences in absolute match format and role acceleration and deceleration variables with associated *p* values.**

	ODI		T20		P Value		
	ODI – Seamer (n = 65)	ODI – Non-Seamer (n = 93)	T20 – Seamer (n = 14)	T20 – Non-Seamer (n = 28)	Game Format	Role	Interaction
Acceleration Count Band 1 (2-3m/s²)	40.93 ± 25.81	27.32 ± 11.91	25.14 ± 13.74	17.28 ± 10.14	<0.001	.782	.016
Acceleration Count Band 2 (3-4m/s²)	9.26 ± 8.77	11.53 ± 8.91	11.28 ± 6.59	6.96 ± 5.37	.005	.566	.174
Acceleration Count Band 3 (>4m/s²)	0.10 ± 0.35	0.46 ± 0.85	0.28 ± 0.46	0.21 ± 0.41	.392	.643	.159
Deceleration Count Band 1 (-2- -3m/s²)	39.53 ± 15.63	32.09 ± 19.20	24.07 ± 5.60	16.60 ± 9.17	<0.001	.947	.504
Deceleration Count Band 2 (3- -4m/s²)	10.00 ± 11.01	7.15 ± 8.76	8.14 ± 3.41	7.46 ± 6.68	.669	.429	.506
Deceleration Count Band 3 (>-4m/s²)	2.15 ± 2.77	2.30 ± 2.67	3.28 ± 4.19	3.35 ± 4.46	.055	.847	.948
Velocity Band 5 Total Efforts (+20km/h)	15.49 ± 18.51	9.95 ± 11.57	13.14 ± 12.34	10.67 ± 10.18	.760	.256	.526

***Table 4.* Differences in relative match format and role distance variables with associated *p* values.**

	ODI		T20		P Value		
(Per minute)	ODI – Seamer (n = 65)	ODI – Non-Seamer (n = 93)	T20 – Seamer (n = 14)	T20 – Non-Seamer (n = 28)	Game Format	Role	Interaction
Meterage Per Minute (m)	51.19 ± 19.19	48.97 ± 14.41	58.99 ± 6.39	53.66 ± 8.32	.031	.820	.853
Distance Band 1 (0-5km)	22.44 ± 4.72	24.70 ± 3.23	23.58 ± 4.72	24.82 ± 3.72	.010	.147	.818
Distance Band 2 (5-11km/h)	16.29 ± 5.00	15.01 ± 3.86	19.41 ± 4.90	18.51 ± 4.37	<0.001	.753	.356
Distance Band 3 (11-16km/h)	5.30 ± 2.25	5.26 ± 2.93	8.95 ± 3.39	8.14 ± 3.80	<0.001	.464	.906
Distance Band 4 (16-20km/h)	3.51 ± 1.18	0.90 ± 0.53	5.52 ± 2.23	1.47 ± 1.02	<0.001	<0.001	<0.001
Distance Band 5 (>20km/h)	0.97 ± 0.88	0.48 ± 0.38	1.51 ± 0.81	0.70 ± 0.70	<0.001	.113	.202

***Table 5.* Differences in relative match format and role acceleration and deceleration variables with associated *p* values.**

	ODI		T20		P Value		
(Per minute)	ODI – Seamer (n = 65)	ODI – Non-Seamer (n = 93)	T20 – Seamer (n = 14)	T20 – Non-Seamer (n = 28)	Game Format	Role	Interaction
Acceleration Count Band 1 (2-3m/s²)	0.22 ± 0.13	0.14 ± 0.58	0.30 ± 0.16	0.19 ± 11	<0.001	.460	.918
Acceleration Count Band 2 (3-4m/s²)	0.50 ± 0.04	0.06 ± 0.04	0.12 ± 0.07	0.07 ± 0.59	<0.001	.867	.002
Acceleration Count Band 3 (>4m/s²)	0.0006 ± 0.001	0.002 ± 0.004	0.003 ± 0.005	0.002 ± 0.004	.144	.985	.164
Deceleration Count Band 1 (-2- -3m/s²)	0.21 ± 0.08	0.17 ± 0.11	0.29 ± 0.99	0.18 ± 0.10	.012	.459	.114
Deceleration Count Band 2 (3- -4m/s²)	0.05 ± 0.06	0.03 ± 0.04	0.09 ± 0.03	0.08 ± 0.08	<0.001	.188	.653
Deceleration Count Band 3 (>-4m/s²)	0.01 ± 0.02	0.01 ± 0.01	0.03 ± 0.04	0.03 ± 0.05	<0.001	.879	.772
Velocity Band 5 Total Efforts (+20km/h)	0.08 ± 0.09	0.05 ± 0.06	0.15 ± 0.14	0.12 ± 0.12	<0.001	.090	.909

3.4. Discussion

This study was the first to investigate the differences in the physical match demands between ODI and T20 cricket in seam bowlers and non-seam bowlers in international female cricketers. Findings from this investigation show absolute match demands are greater in ODI when compared to T20 cricket. However, when time motion data was calculated relative to time, the physical demands were greater in T20 cricket. These findings correspond with data from men's international cricket (Bliss et al., 2021; Petersen et al., 2009), highlighting the different demands match formats may impose on players. Specifically, this investigation shows the demands are greater in ODI cricket in absolute terms due to the duration of matches. Alternatively, T20 cricket requires a greater number of higher intensity efforts relative to time when compared to ODI in female cricket. This study also showed there was little difference between seamers and non-seamers within physical demands. There was only a *very large* difference in absolute and relative high-speed running values, favouring seamers in comparison to non-seamers. This result was expected in the hypothesis but a greater difference in a higher number of variables was expected.

The T20 format showed a greater intensity than ODI cricket, with a greater *small* difference in meterage per minute (47.16m ± 15.83m). Sprinting distance per minute (0.98m ± 0.83m) and total sprint efforts per minute (0.13 ± 0.13) were higher in T20 cricket when compared to ODI. This could be due the demand for greater amounts of runs in a shorter time than ODI, resulting in greater higher intensity fielding movements. Garcia-Byrne et al. (2020) quantified T20 workloads in Australian international female cricketers over a similar time frame, identifying intensity by meters per minute at 53m ± 16m, in comparison to the current study at 47.16m ± 15.83m. Similarity of findings may suggest from 2016-2017 to 2021 there has been no notable increase in intensity, showing the women's game may not have increased in intensity. However, this comparison should be interpreted with care as a sample size of only three international players were present within Garcia-Byrne et al. (2020), with also a lack of specificity of player role creating further difficulties in predicting physical demands for specific roles. Even though T20 players covered a greater meterage per minute than ODI players, data analysed displayed only a *small* difference between the two formats, unlike Bliss et al. (2021) literature in the male formats that showed a *large* difference. Despite T20 showing a greater intensity than ODI cricket, no difference was observed between roles, suggesting no greater demand for either seamer or non-seamer is apparent within fielding. As T20 cricket commonly demands greater intensity in terms of meters covered, sprints, accelerations and decelerations in male cricket (Bliss et al., 2021; Petersen et al., 2009), a greater difference in intensity in female cricket was hypothesised due to greater anthropometrical characteristics in males and greater quantities of cricket played in the male T20 format (Stuelcken et al., 2007). Such outcome suggests despite there being some differences, these differences can vary between both T20 and ODI games in female cricket and the rate of development within the female game is difficult to interpret.

High-speed running (16 - 20km/h) in absolute and relative value was shown to be greater (*very large)* in seam bowlers compared to non-seam-bowlers. The greater amount of high-speed running is likely a result of the seam bowler's delivery run-up. Duffield, Carney and Karppinen (2009) investigated five meters of velocity within a bowling run up, before the delivery stride in male seam bowlers. High-speed running (quantified as running velocities between 14km - 20km/h) is main demand of the run-up phase for male seam bowlers and may likely influence a female cricketer's performance when fast bowling. This finding highlight that a seam bowler is exposed to a notable amount of high intensity running. Duffield, Carney and Karppinen (2009) data highlight the high inclusion of high-speed running in seam bowlers in delivery run up. It should also be considered that this study involved male cricketers and with run up speeds likely lower for female cricketers (Cheuvront et al., 2005). Anecdotally, it can be suggested that positions such as fine leg and long-on are frequently used with seam bowlers within T20 and ODI cricket. Although it is key to consider transitional periods in the field between overs, previous data would suggest that this movement may not be significant enough to have an impact on high-speed running (Turner et al., 2020). However, the current study suggests seam bowlers' physical match demands require greater physical preparation, with the possibility of bowling delivery repetition having a greater effect on specific distance covered.

Relative to time, it was also shown that T20 cricket produces a *small* difference of high-speed running compared to ODI cricket, whereas in absolute terms, ODI cricket had a *small* difference in high-speed running than T20 cricket. These results show how T20 cricket is more intense over a shorter period of time compared to the longer format of 50 over cricket. This could inform a strength conditioning coach of the higher match intensity difference required between the two formats when preparing athletes for competition. Further investigation is required to identify how this intensity between the two formats in the female game develops over time.

When reviewing acceleration and deceleration movements within formats and roles, results found higher total counts of accelerations in band 1, and decelerations band 1 and band 2 in ODI cricket compared to T20. Bliss et al. (2021) and Bliss et al. (2022) provide quantification of acceleration and deceleration in fielding with time motion analysis in international men's cricket. Bliss et al. (2021) evaluation of T20 and ODI show similarities to this chapter with greater absolute lower accelerations and deceleration counts in ODI when compared to T20 cricket. As ODI duration is greater than T20, the demand for higher accelerations and decelerations will be greater. Additionally, the number of accelerations and decelerations within Bliss et al. (2020) were similar to those presented in Table 1, suggesting correspondences between the men's and women's game in both formats. Much like this current chapter, significant differences were observed, yet it should be noted that both studies identify a large degree of variability shown through standard deviation. In relative terms per minute, there is a *medium* difference in acceleration counts in band 1 and band 2 favouring T20 cricket, along with a greater amount of deceleration counts band 1 with a *medium* effect (Table 1). This is supported with both Bliss et al. (2021) and Bliss et al. (2022) literature despite this study selecting three thresholds. At present, there are currently no standardised acceleration and deceleration thresholds used across cricket research (Varley et al., 2012). With accelerations and decelerations being prominent in both formats, this suggests that these initial movements are used in fielding to move into walking and jogging more so than sprinting which could require higher acceleration demands. Even though differences were observed between formats, when comparing the roles of seamers and non-seamers across formats, there was no difference in acceleration counts or deceleration counts. This result is unexpected considering the deceleration movement required within seam bowling, requiring further investigation to understand the lack of difference between fielding bowling decelerations.

Unlike the hypothesis of this study, there was very little difference between roles in absolute and relative value. As previously discussed, high-speed running was the only different between seamers and non-seamer, which does not align with the patterns of men’s data in both match types (Bliss et al., 2021; Petersen et al., 2009; Petersen et al., 2010). The hypothesis predicted a greater difference between variables within roles and match formats. As seam-bowlers perform greater amounts of higher velocity movements, it was expected for a non-seamer to have a higher duration of low-intensity movements such as a walking (Bliss et al., 2021). Non-seamers generally perform shorter and lower velocity movement within spin-bowling and fielding, thus creating expectation that walking duration would have had greater difference. It is possible that both roles fielding positions could differ from match to match, resulting in seamers and non-seamers completing as much workload as each other. In comparison of formats, the female game shows similarities in physical demands to the male game but further longitudinal research across a greater time period could provide a clearer indication of progression and help to further predict where future demands of the female formats.

3.5. Conclusion

This study aimed to quantify and evaluate the physical match demands of international female cricketers in ODI and T20 formats, between seam bowlers and non-seam bowlers. Results found ODI cricket to demand greater physical outputs than T20 cricket over a longer period. Whereas T20 cricket to be at a greater intensity and demands per minute than ODI cricket. The intensity per minute did not show a large difference as hypothesised, thus not following a pattern of which the men's game possess. There was not a clear significant difference between the roles of a seamer and non-seamer when fielding, apart from seam bowlers covering a considerably greater amount of high-speed distance compared to non-seam bowlers. Despite this significant difference in high-speed running in absolute and relative values, this study suggests further investigation could focus on longitudinal data to understand patterns of development from year to year. This could provide a greater prediction and understanding for a coach of how elite female cricket will develop. This current study intended to provide a coach with normative data on the physical match demands of female international cricketer that had until now not been investigated. This data would also allow for a greater understanding of how to differentiate the demands between match types and roles for efficient and effective match preparation. It is suggested that elite female cricketers are required to produce greater distance per minute in T20, similar to male cricket, recommending more focus on high intensity movements such as high-speed running ad sprinting frequencies.

Chapter 4: Time Motion Requirements of International Female Cricketers in an Impactful Batting Innings in ODI and T20 cricket

4.1. Introduction

Batters can score runs by running approximately a minimum of 19m between the wickets, hitting the ball over the boundary rope with at least 1 bounce resulting in 4 runs or over the boundary rope with no bounce for 6 runs. Compared to multiday cricket, limited overs cricket, such as T20 and One-Day makes up a large portion of the cricket played around the world (Petersen et al., 2009).

Batting is an intermittent discipline within cricket, which requires periods of high intensity movement, along with short periods of low activity movement such as walking and jogging (Christie et al., 2008). However, the role of a batter in both T20 and ODI formats of cricket change with duration and the strategy of the game. As overs are limited with T20, the demand for scoring rate increases (Scanlan et al., 2016). Consequently, the order of batters in a team line up generally is classified on ability, with the stronger batters at the top of the order and the bowlers towards the end (Swartz et al., 2006). As skill levels of batters will likely be higher towards the top of the order, it could be suggested batters would spend longer time batting and in turn, produce a more impactful score. Research in batting has predominately focused on biomechanical determinants of technique (Pote & Christie, 2013). While research exists for physical running demands between the wickets (McErlain-Naylor et al., 2021), this research is derived from training scenarios and not competition. There is a lack of literature investigating the difference in physical batting performances between formats. Research would identify the match demands of batters during an innings to allow a practitioner to optimise physical preparation.

Determining a match impact differs between T20 and One Day cricket. This is because of changes in duration, match situation or conditions. Performance indicators in cricket are used to identify successful performance impacts that may result in a winning result Petersen et al. (2008). Key indicators for success in T20 identified players individually scoring 25+ runs could impact a match winning result Najdan et al. (2014). It should be considered that there is a high variability of batting duration in this format of cricket (Sholto-Douglas, Cook, Wilkie, and Christie, 2020), thus making higher scores more difficult to produce and potentially making lower scores more impactful. Further research into the quantity of impacts a score of 25 – 50 runs could provide practitioners with greater information on the frequency of runs scored and help focus on what is required to successfully repeat such performance.

Petersen et al. (2010) identified batters covered an average total distance of 2.6 km/h, yet this depends on how successful the batter is within the innings. If successful, a batter could cover around 8.7km and 3.5km in One Day and T20 cricket, respectively (Petersen et al., 2010). Sholto-Douglas, Cook, Wilkie, and Christie (2020) also investigated male T20 cricketers, identifying that T20 requires batters to perform at a higher intensity relative to time when compared to ODI cricket, interspersed with low intensity actions such as walking.

When scoring 50 and 100 runs in a One Day cricket match, it was identified that low-intensity distance were greater than high-intensity distances (Duffield and Drinkwater, 2008). The more successful a batter may be the longer the duration of the innings, thus requiring greater physical demand in movement patterns (Pote & Christie, 2014). When understanding and applying these workloads, coaches should be considerate of the innings to innings variability. Changing intensities regularly in match preparation could condition a player to variable demands. As each match outcome varies depending on performance, predicting the specific of each match is difficult. Greater repeatability of these types of studies in T20 cricket and the inclusion of longitudinal studies would help to further predict a pattern of physical workload. Despite there being literature available for coaches to use as normative data in men's cricket, there is little representation in the women's game. By implementing such batting research in female cricket, coaches can identify and practically apply the physical requirements in a batting innings into match preparation, similar to that currently used in men's cricket.

The aim of this study was to quantify the time motion analysis of an impactful batting innings international female cricketers in T20 and One-Day International cricket. It was hypothesised that physical match demands of batters in ODI cricket would be greater than T20 cricket due to greater duration and higher batting scores. Absolute value would be greater than relative value in ODI cricket compared to T20 cricket with greater amounts of high-speed running and sprinting. This study is the first to investigate physical match demands of batters in female international cricket.

4.2. Methods

Nine female, international elite cricketers from the England Women's Cricket squad took part in the study, with data collected by the England and Wales Cricket Board. Players (age 25.1 ± 5.1 years old) completed a batting innings in T20 (n=22) and ODI (n=13) international matches between 2021 and 2022, which included the 2021 Women's Cricket World Cup.

In this study, physical requirements of batters were recorded in absolute values across matches and in relative value, evaluating requirements per ball across all matches. By evaluating batters' physical requirements per ball, this could provide a more accurate assessment of the movements needed when batting. As there are always two batters at the crease, if relative measurements were quantified in time, then the accuracy of the demands needed when facing deliveries may not be fully true. A minimum inclusion of scores 30+ in T20 innings and 50+ in ODI innings were discussed and aligned with skill coaches and analyst interpretation of an impactful batting innings. These scores are statisticalyl considered notable milestones for batters in each format respectively by cricket analysts. Method of GPS collection can be found in section 2.3 of Chapter 2.

4.2.1. Statistical Analysis

Statistical match data was analysis was performed in IBM SPSS Statistics v27.0.0 (IBM, Armonk, United States of America), using a single fixed Mixed Model Linear Analysis. ODI and T20 were identified as the fixed factors and players entered as random factors. Significance was set at *p*<0.05, with the use of Bonferroni *post-hoc* testing for pairwise comparisons. Hedges g effect sizes were used between ODI and T20 formats which were observed at *small* – 0.2; *medium* – 0.5; *large* – 0.8; *very large* – 1.4 (Swinton et al., 2022).

4.3. Results

Means and standard deviations for time motion demands of elite female batters in ODI and T20 are presented in Table 3. Batters that contributed a match impact in ODI cricket covered on average 4.36km per innings, which was significantly greater ($p<0.001$; d = 2.39) in comparison to 2.07km per innings in T20 cricket. Values in distance variables were significantly greater in T20 cricket per ball than ODI values with jogging (p =.011; d = -0.89), high-speed ($p<0.001$; d = -1.41) and sprinting (p = 0.29; d = -0.65). When analysing relative distance overall, there was no significant difference between T20 (62.7m ± 12.95m) and ODI (55.66m ± 8.76m) cricket in distance covered per ball.

Table 6. **Differences in absolute match format in a batting innings for distance variables with associated *p* values.**

	Format		P Value	ODI CV %	T20 CV%
	ODI (50+ runs) n = 13	**T20 (30+ Runs) n=** 22			
Total Distance Covered (m)	4361.42 ± 1283.15	2072 ± 708.74	<0.001	29.42	34.20
Max Velocity (km/h)	23.57 ± 0.89	23.17 ± 1.51	.683	3.75	6.52
Match Duration (minutes)	114.07 ± 32.02	49.53 ± 15.59	<0.001	28.06	31.46
Distance Band 1 (0-5km/h)	2676.91 ± 856.07	1179.51 ± 428.01	<0.001	31.97	36.28
Distance Band 2 (5-11km/h)	598.74 ± 182.83	317.03 ± 104.36	<0.001	30.53	32.91
Distance Band 3 (11-16km/h)	589.68 ± 215.30	254.74 ± 105.53	<0.001	36.51	41.42
Distance Band 4 (16-20km/h)	4147.85 ± 151.27	263.90 ± 96.41	.001	36.20	36.53
Distance Band 5 (>20km/h)	77.73 ± 36.04	56.77 ± 43.21	.189	46.37	76.11
Acceleration Count Band 1 (2-3m/s²)	55.62 ± 25.23	25.09 ± 9.86	<0.001	47.05	39.27
Acceleration Count Band 2 (3-4m/s²)	31.38 ± 14.51	20.55 ± 10.56	.006	46.21	51.39
Acceleration Count Band 3 (>4m/s²)	0.54 ± 0.66	0.27 ± 0.63	.324	122.61	231.39

Deceleration Count Band 1 (-2--3m/s²)	17.46 ± 6.46	11.05 ± 5.40	.003	37.01	49.91
Deceleration Count Band 2 (3- -4m/s²)	12.77 ± 6.39	8.91 ± 5.82	.040	50.05	65.34
Deceleration Count Band 3 (>-4m/s²)	7.38 ± 4.23	4.36 ± 3.76	.037	57.32	86.19
Velocity Band 5 Total Efforts (+20km/h)	13.31 ± 7.62	8.55 ± 6.49	.079	57.25	75.98

Table 7. **Differences in relative match format in a batting innings for distance variables with associated *p* values.**

	Format		P Value	ODI CV %	T20 CV%
(Per ball)	**ODI (50+ runs) n =** 13	**T20 (30+ Runs) n=** 22			
Total Distance Covered (m/ball)	55.66 ± 8.76	62.71 ± 12.95	.094	15.74	20.64
Distance Band 1 (0-5km)	33.91 ± 6.53	35.76 ± 9.47	.535	19.22	26.49
Distance Band 2 (5-11km/h)	7.78 ± 1.71	9.81 ± 2.55	.011	21.98	25.99
Distance Band 3 (11-16km/h)	7.54 ± 1.58	7.55 ± 1.89	.842	20.88	25.02
Distance Band 4 (16-20km/h)	5.36 ± 1.41	7.99 ± 2.08	<0.001	26.27	26.05
Distance Band 5 (>20km/h)	1.06 ± 0.59	1.59 ± 0.94	.029	55.44	59.23
Acceleration Count Band 1 (2-3m/s²)	0.68 ± 0.21	0.76 ± 0.20	.242	31.30	26.20
Acceleration Count Band 2 (3-4m/s²)	0.41 ± 0.19	0.60 ± 0.23	.017	45.55	37.76
Acceleration Count Band 3 (>4m/s²)	0.01 ± 0.01	0.01 ± 0.02	.731	120.05	253.02
Deceleration Count Band 1 (-2--3m/s²)	0.22 ± 0.06	0.34 ± 0.15	.012	25.02	44.58
Deceleration Count Band 2 (3- -4m/s²)	0.17 ± 0.07	0.29 ± 0.19	.077	43.30	64.35

Deceleration Count Band 3 (>-4m/s²)	0.10 ± 0.07	0.14 ± 0.12	.390	66.78	89.54
Velocity Band 5 Total Efforts (+20km/h)	0.18 ± 0.12	0.27 ± 0.21	.158	63.10	78.13

Figure 3. **Absolute comparisons of ODI and T20 cricket.**

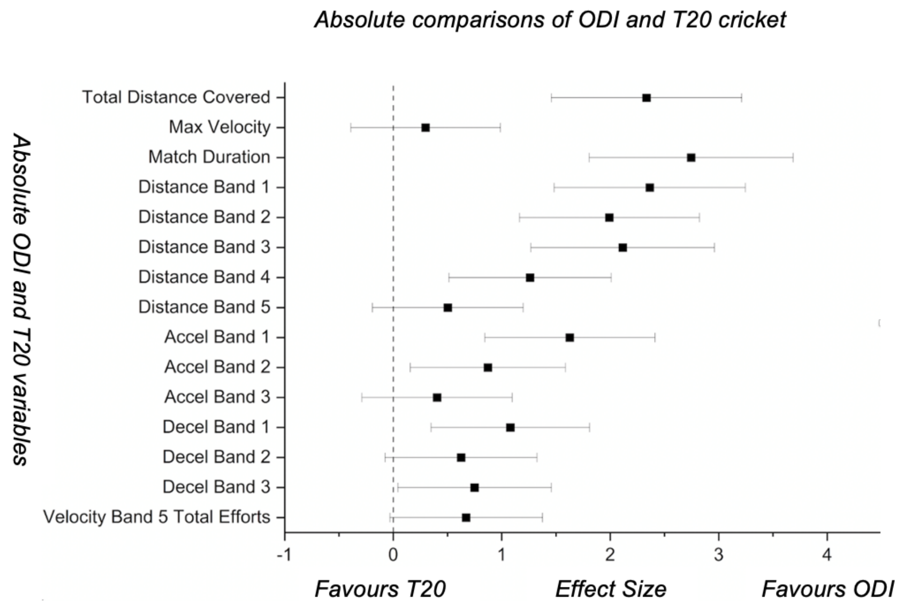
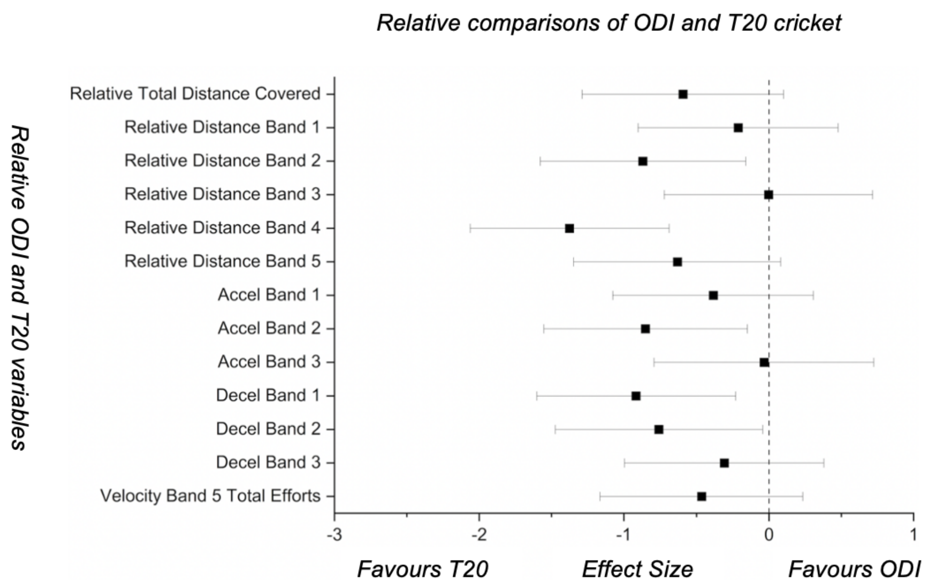


Figure 4. **Relative (per ball) comparisons of ODI and T20 cricket.**



4.4. Discussion

The aim of this study was to quantify and evaluate the physical match demands of batting in international female cricketers when having a positive match impact in T20 and ODI cricket. We hypothesised physical match demands of batters in ODI cricket would be greater than T20 cricket due to greater duration and higher batting scores. Absolute values would be greater in ODI compared to T20 cricket, but relative values higher in T20 in comparison to ODI cricket. This study found for a meaningful innings in ODI cricket required greater absolute physical demands than T20 cricket. These demands were higher in ODI compared to T20 in walking, jogging, low-speed running and acceleration band 1. When comparing relative results, T20 cricket showed higher distances covered compared to ODI, in jogging, high-speed running, acceleration band 2 and deceleration band 1.

It was found that absolute match demands between both formats when having a positive match impact were far greater in ODI cricket, with predominately *very large* differences. Whereas T20 cricket showed a much greater difference when comparing relative values per ball delivered. As expected, absolute batting match duration and total distance covered were significantly greater in the ODI format due to the higher number of overs available and the need to score more runs in the longer format (Pote & Christie, 2014). This investigation included all batting actions for scores 30+ and 50+ respectively for both ODI and T20, whereas previous data published by Petersen et al. (2009) excluded innings below 15 minutes or above 30 minutes in length. The importance of evaluating the length of a successful innings between formats could indicate the physical demand differences to help prepare players. Although greater time at the crease has indicated a high distance covered in ODI batters, it does not necessarily mean greater scores will be produced in comparison to T20 cricket when quantified by per delivery. The practical aim of this study was to provide a coach with normative physical demand data to help effectively prepare a batter for T20 and ODI cricket.

Acceleration counts in band 1 and band 2, and declarations counts in band 1, band 2 and band 3 were recorded at much a greater difference in ODI cricket in absolute terms than in T20 cricket. As the velocity achieved during the initial 5m of a run determines success (Callaghan et al., 2015), the demands of HSR in ODI and T20 cricket are significant. In the faster group, batters ran 5m in a mean of 0.913 seconds (± 0.44s), with greater predicted success than the slower group (1.020s ± 0.028s). This shows the importance of the initial acceleration phase to perform a quick single. Comparing Callaghan et al. (2015) results with the current research, the high demand for acceleration counts in batters successfully scoring 50+ in ODI cricket can suggest the frequency of runs scored could have possibly come from running 1s, 2s or 3 between the wickets. This is hypothesised from the present study's high absolute match demand for initial acceleration and deceleration. It should be acknowledged that a breakdown of the scoring for each included innings (i.e., number of 1,2,3,4 and 6s scored) was not included within the analysis for this investigation. Despite this, a practitioner could be informed that in preparation for a One Day match, a batter requires greater focus on accelerations over a 5m distance to have the possibility of a more successful innings. Along with batting duration, these absolute acceleration and deceleration counts in ODI suggest that a range of running speeds between the wickets for 1s, 2s and 3s could be used. Acceleration counts at band 2 show a *large* difference in T20 cricket per ball than in ODI cricket. This result a batter is required to perform higher initial accelerations when batting in T20 cricket in comparison to ODI cricket. This suggests that there is a greater requirement for a batter to run a quick single in T20 cricket rather than ODI cricket. This data could highlight to a coach the importance of including high intensity accelerations in match preparation, with the more efficient a batter can accelerate between the wickets the greater the chance of scoring more runs.

Low intensity deceleration counts at band 1 were greater in T20 than ODI cricket per ball. The low deceleration counts suggest despite the demand for high intensity from a high acceleration count in band 2, batters could have performed less running between the wickets in run 2s and 3s, as they require higher decelerations. As previously discussed, due to a fewer number of deliveries faced, a batter in T20 cricket may be more likely to attempt to score boundaries (4s and 6s) than run 2s and 3s between the wickets. This data shows a *large* difference in low-intensity decelerations and agrees with this suggestion, indicating batters tended to attempt single runs between the wickets. This is further supported by the high number of accelerations at band 2. Although this present data has proposed decelerations are at a low intensity, it is important that a coach to does not disregard the possibility of high accelerations in batting.

Absolute values in low-speed running (distance band 3) and high-speed running (distance band 4) displayed a *very large* difference in ODI cricket in comparison to T20 cricket. Along with the absolute data, relative values for (distance band 2) and high-speed running (distance band 4) showed greatest distance covered per ball, which was greater in T20. Sholto-Douglas, Cook, Wilkie, and Christie (2020) identified a batter completed 134m ± 112m of jogging and 43m ± 34m of high-speed running games across a T20 season. As T20 cricket is known for a higher intensity of movement velocity and effort in fielding than ODI (Petersen et al., 2010; Scanlan et al., 2016), the demand for physical movements of medium to high velocity suggest a batter is required to consistently perform locomotive activity. This alludes to T20 having a greater intensity of movement per ball in a shorter period, thus demanding a high workload. To acknowledge how intensity in T20 cricket is greater, a study by Duffield and Drinkwater (2008) quantified the physical match demands of batters in 12 ODI matches that reached 50+ runs, identifying walking (29.3m ± 6.6m) and jogging (3.0m ± 1.3m) as the prominent actions/activities when a male batter scores 50+ runs in a ODI match. This suggests that despite a longer format of the game, in female cricket, greater demand for higher intensity movements such as high-speed running occur in the shorter format of the game. With this, there could be a concern for increased demand for high-speed running is the effect it may have on hamstring load. Orchard et al. (2017) indicates that hamstring incidence rates for batters could be higher in ODI cricket as the total workload is higher, thus imposing a greater repetitive strain onto the hamstring muscle, increasing injury risk. This assumption along with the current study’s findings suggests there may be a higher probability of hamstring strain incidence. A practitioner should ensure an athlete’s readiness to perform prolonged periods of high-speed running to reduce hamstring injury rates, with the more successful the batter the greater the demand for these movements (McHugh, 2003). One application of this could be through the phenomena of repeated bout effect. By exposing an athlete to repeated hamstring contractions could have a positive effect when repeating high-speed running.

Sprinting (band 5 >20km/h) showed a *medium* difference in T20 cricket per ball. This present data is in agreement with studies on T20 cricket from Petersen et al. (2010) and Petersen et al. (2009) who have suggested a similar amount of time sprinting has been undertaken when batting. These findings suggest women's cricket demands a high number of sprints when batting. Christie et al. (2019) explored sprinting times in university male batters over a 0 – 7 over period, across moderate-volume (striding) and high-volume running (sprinting). Sprinting in the first 3 overs (18 balls) found an increase from 7.7s to 8.4s, and as the overs progressed, sprint time decreased. Despite the decrease being non-significant, the Christie et al. (2019) found a high variability within high volume running. It should be noted that figures for medium-volume and high-volume metrics and data were not published. The findings from this study with elite international female cricket players shows the number of sprints to be similar between match formats when absolute values are analysed. However, T20 demands a greater number of sprinting actions per ball. This can also be identified in this present study from T20 having a greater sprint efforts per ball than ODI, which is supported by Christie et al. (2019), although the current results did not track movement across overs. Meanwhile, this data does not correlate with recent T20 match data by Sholto-Douglas, Cook, Wilkie, and Christie (2020), who's study on professional men's cricket suggests the demand for sprinting was low in comparison to high-speed running and jogging. It should be considered that this study had a limiting factor of matches played and participants in comparison to this current study which affect the reliability of the data. It is important to recognise the high variability in this current data and that duration of distance covered by sprinting can vary dependant on a batter's scoring performance.

4.5. Conclusion

This study quantified and provided the first insight into female international elite cricket batting physical match demands. Absolute low-speed and high-speed running data suggested a greater amount of running in volume between the wickets, although it should be considered that innings duration was higher which provided more opportunity to cover greater distances. As T20 cricket highlighted a greater amount of low and high-speed running per ball, it could be suggested that in preparation for T20 matches, practitioners should focus on increasing a batter's intensity in acceleration, deceleration and higher intensity running over 17.2m. Although due to high variability of results pre match and limited sample size of the study, it is recommended that further research investigates volume and repeatability of a female batter in a match impacting innings.

Chapter 5: Discussion of Findings and Recommendations for Future Research

5.1. Overview of Findings

This thesis explored the physical match demands of international female cricketers during both fielding and batting. The aims of this thesis were to quantify and determine the differences in positions and match format through time-motion analysis using GPS. Variables such as total distance, speed thresholds (walking, jogging, low-speed running, high-speed running and sprinting), accelerations and decelerations were all explored. Research in male cricket has explored such time motion analysis (Bliss et al., 2022; Petersen et al 2009; Petersen et al 2010; Sholto-Douglas, Cook, Wilkie, and Christie, 2020), yet literature in international female cricket was unknown prior to this thesis.

When evaluating elite female formats, differences were apparent between absolute and relative values for time motion analysis. When relative to playing time, T20 showed the greatest requirement for high-velocity movements such as high-speed running, sprinting yet also high amount of jogging which suggests a need for consistent movement patterns. In absolute terms, ODI cricket showed greater demands over time for all thresholds and variables. This could be due to a higher number of overs played and is in line with men's cricket (Duffield and Drinkwater, 2008). Total distance covered, high-speed running and sprinting between both formats respectively can play an important part in the preparation for duration of both match lengths. ODI cricket requires a greater mean distance covered over a longer period, whereas T20 requires approximately half of this but at higher intensity. A coach could use the highest number of these variables recorded as the 'Worst case Scenario' to demonstrate the highest workload that may be required. If a player can exceed that workload with quality, then it could be assumed the skills could still be performed at high standard to match the level of fitness.

When assessing player roles when fielding, it was apparent there was very little difference between seam bowlers and non-seam bowlers when comparing absolute and relative values. It should be highlighted that seam-bowlers performed a much greater amount of absolute and relative high-speed running during both match formats. With the threshold for high-speed running set at 16-20km/h in this thesis, it is likely that an international female seam bowlers run up involves high amounts of high-speed running, as has been shown in male seam bowlers (Ferdinand et al. 2010). When physically preparing fast bowlers, it is important that the coach considers these demands for high-speed running. Yet, these numbers give a good indication of worst-case scenarios for non-seam bowlers to ensure fitness levels are to what is required throughout a full team.

When investigating the effect of batting match impact, the aim was to quantify movement patterns when a batter scores 30+ in a T20 and 50+ in an ODI. The results from this thesis found jogging and high-speed running prevailed as most distance covered in absolute movement and when a player performed per ball. Per ball was an important factor to include as it represented how many deliveries the batter faced in comparison to the time spent in the innings, while not accounting for the total runs scored. These relative findings were similar to key fielding movements suggesting these movements are important for match preparation for both fielding, bowling and batting.

Absolute batting values were greater in ODI cricket in comparison to T20 cricket. This finding could potentially be linked to the greater number of runs scored and greater time spent at the crease. Batters on average covered twice the distance during ODI when compared to a batter playing T20 cricket. When analysing relative values, a batter completed a great total distance when controlling for balls faced during T20 cricket. In particular, relative values for jogging, high-speed running, medium accelerations and low decelerations were all greater during T20 cricket. This indicates that batters possibly attempted a greater amount of running 2s between the wickets in T20 cricket compared to ODI cricket because of the of the high-speed running between the wickets not meeting max velocity and the low decelerations. Both these variables indicate that as movement was not maximal, a single run (which can require maximal effort) was not performed.

5.2. Limitations

A limitation that should be highlighted within this study is the observational type of researched used. Because of this, research only focussed on a certain time period. A longitudinal study could have identified if a players match demands had increased or decreased over a longer period. By undertaking this type of research, a coach could have the data to help predict a player’s future preparation. This study also only focused on one international team. Physical match demands may differ from team to team at international female level. This could be due to the quality of teams changing, changing of locations and pitch quality, and change of competition from friendlies to world cups.

5.3. Further Research

This current research is the first to solely focus on the physical match demands of international female cricketers using time-motion analysis. Both the studies presented in this thesis have addressed the lack of focus of performance related literature in elite female cricket. Longitudinal data over extended period of time (i.e., >1 year) would provide a practitioner with an insight into the development of the women's game and allow for comparisons against the evolution of the men's game. Current analysis only provides an insight to selected movements in certain time periods. Understanding these developments are important as they can help a practitioner to predict the direction female cricket may be heading physically. As previously highlighted as a limitation, observing differences against different oppositions could help a coach gain an understanding to how requirements differ in regard to opposition quality. Such research has been explored in female rugby union but to date has not been investigated in female cricket (Woodhouse, Tallent, Patterson and Waldron, 2021). It should also be considered that additional research should address the playing standard between international and regional cricket in female formats of cricket. To date, only Garcia-Byrne et al. (2020) have explored the differences between female playing quality. Investigating differences in international and regional cricket would give coaches an understanding of the requirement differences between both standards. In finding these differences, coaches could focus on the areas that need to be improved on to be international level to help an athlete perform to the best of their ability with consistency. As research has focussed on seam bowlers in male cricket (Bliss et al., 2022), there is limited researched based on female seam bowlers and the physical profile of female seam bowlers over a prolonged period. Lumbar stress fractures are a common occurrence in male cricketers (Schouten et al., 2021), research on the occurrence of such injury in female cricketers has yet to be investigated. The use of time-motion analysis through GPS could monitor the progress and development of female cricketer's load before and at the crease when bowling a delivery, tracking changes of rotation through fatigue in match or season.

Unlike female cricket, research in professional cricket tends to investigate the male cohort in performance, the impact or prevalence of injury and psychology of cricketers. Warren, Dale, McCaig and Ranson (2019) study on professional women's cricket in England is currently one of only a limited amount of research articles available. The combined use of GPS data in seam bowlers and Inertial Measurement Units could provide coaches and practitioners manage stress injuries such as tibial bone stresses. Inertial Measurement Units have recently been used within men's cricket but not yet within female cricket (McGrath et al., 2021; Perrett et al., 2021).

The inclusion of longitudinal research in female cricket could have a great effect on how future approaches of the demands of domestic competitions, such as T20 and The Hundred, are prepared for and executed. Comparing characteristics and demands across age groups and playing levels, coaches and practitioners could identify progressions, physical changes and differences in player positions and workloads. These comparisons could help optimise players at younger ages.

5.4. Practical Applications

The quantification of fielding and batting demands in female cricketers will allow coaches to focus on areas of highest requirements when preparing for matches. When evaluating the needs of seam bowlers, a coach can identify the high demand for high-speed running in comparison to non-seam bowlers. Using the normative data from the current study, this high intensity movement can be prepared for in match preparation to help with performance and occurrence of hamstring injuries. Alongside this, in batting, a coach can identify the need for quick accelerations, high-speed running and sprinting. To make a positive match impact when batting, a player would be required to perform these skills to the best of their ability and to be able to identify these in preparation will aid this.

A coach can apply running distances found in international female cricket, such as jogging, high-speed running and sprinting, to aid match preparation in either T20 or ODI formats. This match preparation data can then be compared to a players live match demands to inform a coach whether the player is achieving distances set in training to match demands. Such data can also be used to monitor a player's condition and fatigue. If a player is completing higher amounts of running distances than recorded in previous match or training scenarios, the risk of greater fatigue or risk to injury may increase. By monitoring this, a coach can intervene before this risk gets too great. Finally, collecting and comparing a player's normative data with this studies data, a coach can identify a players peak physical demands in their peak performance. When a player is returning to play from injury, a coach can compare this normative data to a players injury data to track progression through rehabilitation.

5.6. Concluding Remarks

The understanding and development of female cricket has so far been limited in research and has lack the attention the male formats of cricket have received. This thesis focused on the match demands of female international cricketers when fielding in T20 and ODI formats to provide coaches with an understanding into the typical requirements needed between roles. This current thesis also investigated the demands of a female international batting innings. When comparing the demands of fielding and the demands of batting, it is apparent that international cricket requires greater demands of jogging and high-speed running than other movement variables. These demands match those in men’s cricket but further research is required to understand whether these demands could change over time.

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