

Performance analysis of fielding and wicket-keeping in
cricket to inform strength and conditioning practice

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In Memorandum

Dr. Richard Stretch

Trusted advisor and at last, esteemed colleague.

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Attestation of Authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

Danielle Catherine MacDonald

Candidate Contribution to Co-authored Works

Chapters two, three and four in the thesis have been published in peer-reviewed journals. All journals have copyright permissions that allow the journal publications to be included in the thesis for educational purposes. The contribution of co-authors for publications (e.g. MacDonald, 80%) arising from these studies and from whom approval has been granted in this doctoral thesis, is as follows:

Published in peer-reviewed journals (See Appendix 9)

MacDonald, D. C. (80%), Cronin, J. B. (10%), Stretch, R. A. (5%), & Mills, J. (2013) (5%). Wicket-keeping in Cricket: A literature review. *International Journal of Sports Science & Coaching*, 8 (3), 531-541.

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MacDonald, D.C. (90%), Cronin, J.B. (10%). (2014) Fielding and Wicket-Keeping in Cricket: A performance analysis and strength and conditioning perspective. Bay of Plenty Polytechnic Sports Research Symposium, Tauranga, New Zealand.

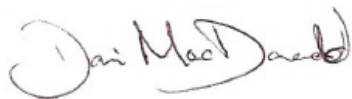
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Other outputs

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Co-authors Signatures

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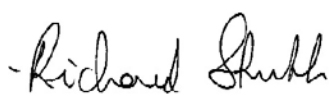
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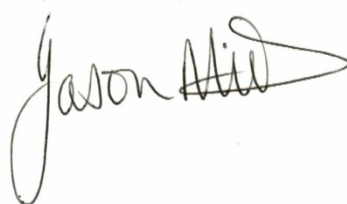
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Mr. Jason Mills

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Ethical Approval

Ethical approval for this thesis research was granted by the Auckland University of Technology Ethics Committee (AUTEC). The AUTEC application number was:

12/293 - Chapter 4: A survey of the performance demands of fielding and wicket-keeping. Approved 16 November 2012 (see Appendices). There was no conflict of interest for this study.

Abstract

The purpose of this thesis was to contribute to the scientific understanding of the performance demands of One Day International (ODI) fielding and wicket-keeping, and to provide recommendations for improving athlete performance, assessment and coach education. Two comprehensive literature reviews of the physical, technical, physiological and tactical components of fielding and wicket-keeping were conducted.

Given the gaps identified in the literature reviews, an online mixed method survey of cricket players, coaches and trainers was designed to investigate the performance requirements of the wicket-keeper, close, inner and outer circle fielders. Players and coaches rated agility the most important physical attribute for the wicket-keeper (4.7/5), close fielders (4.6/5), and inner circle fielders (4.8/5). Speed (4.8/5) and agility (4.6/5) were rated most important for outer circle fielders. Coaches raised the issue of the lack of a cricket specific agility test. An emerging theme for all categories was the importance of the mental aspects of the game such as positive attitude and concentration, particularly for the wicket-keeper.

To validate the use of video footage for performance analysis a comparison was made between televised and purposefully collected video for event coding. The variables of interest were derived from the literature reviews and corroborated by the survey. The ICC for intra-coder reliability for all but two variables was between 0.88 and 1.00 the exceptions were lateral footwork (step 0.83 and shuffle 0.55) likely due to the subjectivity of defining footwork patterns. The televised footage under-reported the frequency of wicket-keeping activity ($\approx 4.5\%$), except for lateral footwork, which was under-reported by the purposefully collected video ($\approx 13.5\%$) due to the movement being perpendicular to the camera view. Even though fielding activity was under-reported (≈ 4.25) by televised footage, this footage was deemed to be most appropriate, as the collected footage resulted in a field of view that made the finer details of fielding difficult to distinguish.

Performance analysis studies on fielding and wicket-keeping were carried out using televised footage from the 2011 ODI World Cup. The majority of the wicket-keepers movements were lateral (75%); primarily repetitive low intensity movements interspersed with explosive movements such as diving and jumping. Wicket-keeping glove-work skills (69%) were the most performed skill activity, the quality of which was quantified using a catching efficiency measure (93%).

Close, inner and outer circle fielders had variable involvement in fielding activities. Close fielders were involved in 20% of the fielding activity, the bowler the most (58%) involved. The inner circle fielders were involved in 50% of fielding contacts; of whom cover was the position most involved (21%) Inner circle fielders had to display the greatest range of skills within the field, such as catching from different heights, varied throwing and ground fielding techniques. Outer circle fielders were involved with 30% of the fielding contacts; the outer circle position most involved was long on (14%). Long sprints were the hallmark of outer circle fielding, following the sprint, they often had to perform explosive movements such as a dive or a jump to field the ball; they rarely had the opportunity to stop and position themselves to perform their skill. Additionally, catching (75%,89%, 85%) throwing (0%,12%, 33%) and overall fielding performance (89%,98%,99%) were quantified using efficiency calculations for close, inner and outer circle fielders respectively.

The findings of the literature reviews and studies expanded upon the only previous study to quantify fielding performance, and informed the development of performance profiles of fielding and wicket-keeping. Subsequently recommendations for assessment, training and coaching have been made, which will be integrated into New Zealand Cricket resources. Most notable are suggestions for improving the existing skill and physical testing batteries

Chapter 1 - Introduction

"But even the most enthusiastic supporters of One Day cricket could never have foreseen the revolution One Day cricket would trigger: the limited-overs game may have undermined batting techniques and made certain attacking bowling tactics extinct, but it has single-handedly transformed fielding from a sedate accessory to an athletic, exciting and absolutely crucial pillar of the modern game."

Bob Woolmer (1948-2007)

Rationale

Cricket is a bat and ball team sport which enjoys great popularity throughout the world (Bartlett, 2003), particularly in the Commonwealth. The traditional format of cricket is 'test' cricket which lasts five days. However, in more recent times, shorter formats of the game have been developed. There are now three formats of the game played at elite level; Test, One Day International (ODI) and Twenty20. The duration and intensity of the formats vary (Petersen, Pyne, Dawson, Portus, & Kellett, 2010). In test cricket, each team has two innings, the duration of these innings for each team is not fixed (the innings is over when all batsmen are dismissed), instead the match lasts for 5 days, with 90 overs of cricket to be played each day. ODI cricket and Twenty20 cricket are 'limited overs' formats of the game; each team have one innings of an allocated number of overs, either fifty (ODI) or twenty (Twenty20). The advent of shorter formats of cricket has made cricket increasingly popular for viewers and lucrative for players and stakeholders as leagues are played all over the world year round.

Due to the traditionalist nature of cricket coaches generally rely on experience and anecdotal evidence when coaching. It is widely believed that batting and bowling are an inherent talent which players naturally possess (or not), whereas fielding is a series of skills which can be taught and improved (Woolmer et al., 2008). While an excellent all-round performance is required in all forms of cricket, it is particularly important in the shorter forms of the game. However, despite the adage that 'catches win matches' there has been little research into fielding and wicket-keeping in cricket compared to other areas of the game (Bartlett, 2003). For example, on the subject of cricket batting there has been research into the physical and physiological demands (Christie, 2012; Christie, Todd, & King, 2008; Taliep, Prim, & Gray, 2010) and visual information cues and decision making (Croft, Button, & Dicks, 2010; Müller et al., 2009). In contrast, while there have been numerous time-motion analysis studies of cricket fielding (Petersen et al., 2010; Petersen, Pyne, Portus, & Dawson, 2009a, 2011), fielding research lacks the

breadth and depth of other areas of the game. In practice players will undergo specialised batting and bowling training but fielding and wicket-keeping are not always afforded the same degree of attention, this is also the case in cricket research.

Cricket is considered to be the most popular summer sport in New Zealand (Gemba Sports and Entertainment Report, 2012), governed by New Zealand Cricket (NZC). One of the performance targets set by High Performance Sport New Zealand (HPSNZ), the organisation responsible for supporting elite sport in New Zealand, was for the New Zealand Black Caps to win the 2011 ODI World Cup. This target was not achieved; they were knocked out in the semi-final stage of the competition. Although the New Zealand Black Caps already have a reputation for being an excellent fielding side, there is still a lack of empirical evidence to inform their training practices. As part of their High Performance Plan, NZC provide recommendations for Core Playing Skills (Pamment, Mills, & Stronach, 2013) at different levels of competitions. However, the Core Playing Skills document provides test standards for the physical requirements of performance (i.e. sprint speed over 40 m) and recommendations for skill levels; as yet there are no means to assess this skill. Given this lack of empirical research into fielding and wicket-keeping in cricket, this doctoral thesis was designed to further improve understanding of the performance demands of fielding and wicket-keeping and provide evidence to enhance strength and conditioning training and assessment practices. As such, NZC and HPSNZ provided a PhD Scholarship to support this field of research.

Research Aims

New Zealand Cricket has stated that their main performance goal is to improve world standings in ODI hence this format of cricket provides the focus of this thesis (J. G. Wright, personal communication, September 2, 2011). Given the lack of peer-reviewed research into fielding and wicket-keeping, there is a need to better understand the performance demands of these areas of cricket so that all-round performance of players can be improved.

In this regard, the overarching question that guided this thesis was “what are the performance demands of fielding in ODI cricket?” By answering this question, a fielding and wicket-keeping performance profile was developed to be used to inform strength and conditioning practice and coach education content.

Therefore the aims of this thesis were:

- 1) To increase the knowledge base in fielding and wicket-keeping through the use of systematic literature reviews and coach, player and trainer surveys.
- 2) To quantify the movements and skills specific to fielding and wicket-keeping through the use of video analysis.
- 3) Provide recommendations regarding methods of assessing fielding and wicket-keeping performance and implications for training and programming.
- 4) To present the findings in peer reviewed journals as well as a series of technical reports and coaching suggestions to NZC.

Significance of Research

It is widely accepted that to excel in sport a player must possess a multitude of physical attributes and skills to cope with the performance demands of the sport. Therefore to improve performance it is necessary to understand the requisite physical and skill requirements of the sport. However, fielding and wicket-keeping have not been afforded the same attention as bowling and batting both in scientific research and in practical applications such as training and conditioning.

Performance analysis is a relatively new branch of sports science which aims to advance understanding of game behaviour to improve future outcomes (McGarry, 2009).

Performance analysis is a broad term which includes biomechanical analysis, notational analysis, video analysis or even collecting longitudinal fitness data. Many professional sports teams, such as Rugby League (Sirotic, Coutts, Knowles, & Catterick, 2009) and Australian Rules Football (Appleby & Dawson, 2002; Dawson, Hopkinson, Appleby, Stewart, & Roberts, 2004) now employ performance analysts to gain understanding of their own and opposition team's tactics and performance strength and weaknesses. This practice is slowly being adopted by cricket teams; for example, West Indies Cricket use the performance analysis software SportsCode (Sportstec, 2008) and NZC have developed their own bespoke software Feedback Cricket (FeedbackSport, 2006). However, New Zealand Cricket estimate that they currently only use their performance analysis resources to 30.0% of its potential capacity (B.Stronach, personal communication, September 2011).

Therefore this research utilised performance analysis techniques to conduct research to provide practical recommendations to New Zealand Cricket for training, assessment and

improving performance in fielding in wicket-keeping. In particular, methods of measuring fielding performance were proposed so that individual strengths and weaknesses can be identified. Knowledge of players' strengths and weaknesses will allow coaches to prescribe appropriate training to improve performance and will also assist in talent identification. Video analysis of the performance demands of elite performance will provide information which will be beneficial from grassroots to elite level. The information resulting from this research should be of interest to specialist fielding and wicket-keeping coaches and strength and conditioning practitioners. It is hoped that this research will be used in coach education programmes so that practices and standards can be improved through all levels of cricket.

Thesis Structure

The terms 'fielding' and 'fielders' refer to all players; however for the purpose of this doctoral research the wicket-keeper has been considered a specialised position for the following reasons:

- 1) They wear pads and gloves.
- 2) Their activity is far greater than other fielders (Shilbury, 1990).
- 3) On medium pace and spin deliveries they stand closest of all fielders to the wickets.

Therefore throughout this doctoral research, the wicket-keeper is considered separately from the rest of fielders; this is reflected in the thesis structure illustrated in Figure 1.1.

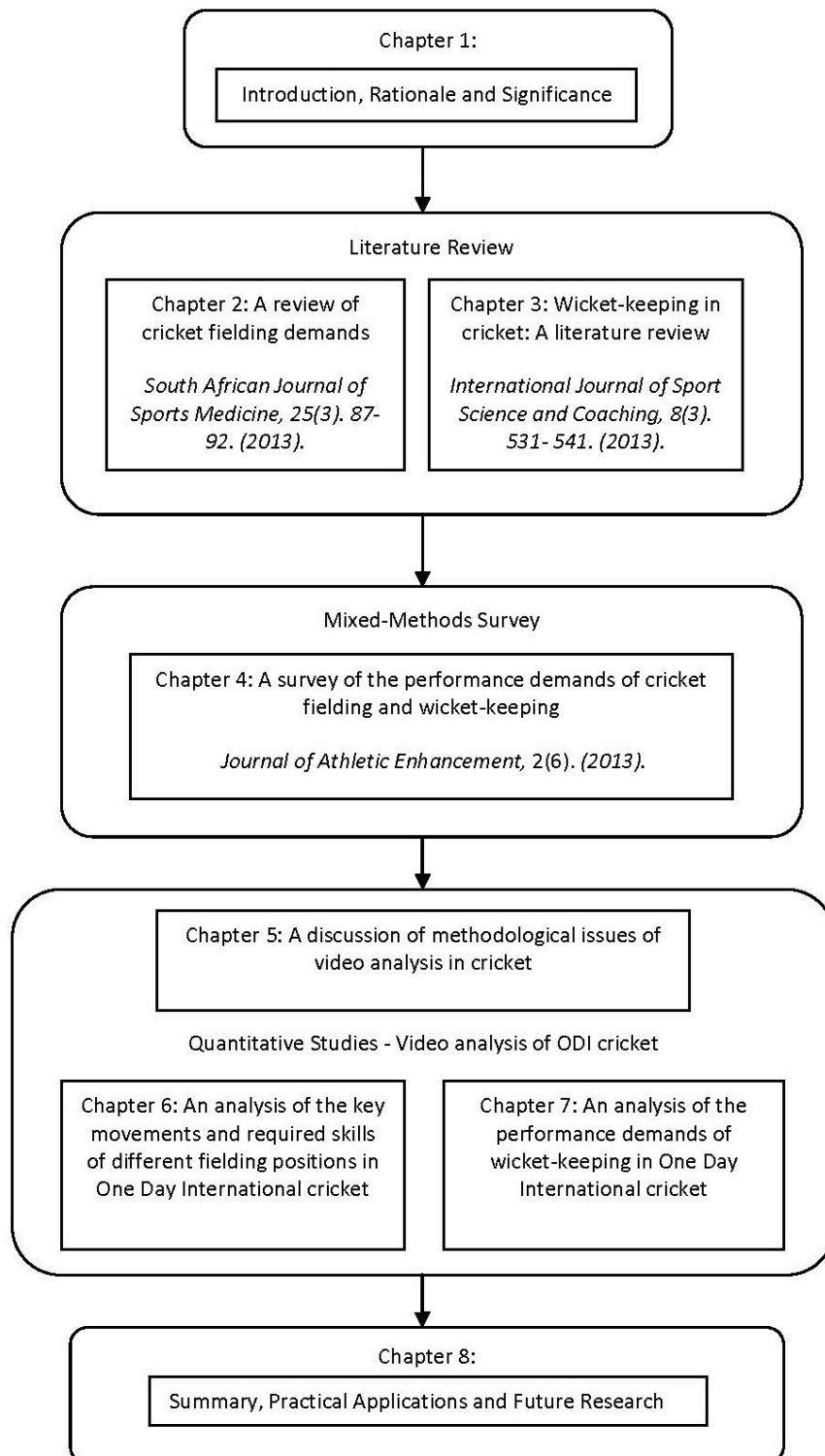


Figure 1.1: Thesis structure

The thesis follows the institution's "Pathway 2" model, which is a thesis by publication. Three chapters (2-4) have been submitted and accepted for publication. Therefore, these chapters are presented in the format of the journals for which they were written; with the exception that each chapter is preceded by a brief explanatory prelude rather than an

abstract. Due to the fact that Chapters 2 to 4 were written as standalone articles, there is some degree of repetition in the introductory paragraphs of each chapter; familiarizing the article readers with the basics of cricket.

The first section of the thesis consists of two descriptive literature reviews, for fielding (Chapter 2) and wicket-keeping (Chapter 3). From the literature reviewed, it was observed that there were significant gaps in scientific knowledge and understanding around fielding and wicket-keeping. This necessitated the acquisition of information from other sources, therefore an online survey was designed to determine what players, coaches, and strength and conditioning coaches base their practices on. The survey collected both quantitative and qualitative data; the collation and analysis of this data forms the contents of Chapter 4.

The main section of the thesis focussed on video analysis of fielding performance in cricket. Chapter 5 is a discussion of the methodological issues associated with video analysis in cricket using either specifically collected footage or televised footage. In particular, the pros and cons of each footage type and issues of validity and reliability were discussed. Chapters 6 and 7 present the results of event coding and video analysis of elite ODI fielding and wicket-keeping respectively. The main findings of the research were summarised and recommendations for training, assessment and practical implications for improving performance were presented and discussed in Chapter 8.

For consistency, all referencing is in APA 6th edition format, with a single reference summary contained at the end of the thesis. An appendices section including relevant documents such as ethics approvals and other documentation, and additional academic outputs resulting from this research is included at the end of the thesis.

Chapter 2 - A review of cricket fielding demands

Prelude

The first step in understanding any subject area is to review the associated literature to determine what is known and what requires further investigation. With this in mind, this chapter reviews the literature with respect to the technical, tactical, mental, physiological and physical factors that are thought important to fielding. This was performed so as to better understand what is currently known of the performance requirements of fielding in cricket. The mental and tactical components of performance are included, but are not the main focus of this research and are therefore not subject to the same depth of discussion as the physical and technical aspects of performance. The wicket-keeper has been identified as a specialist position, and therefore for the purpose of this thesis the wicket-keeper has been investigated separately from the rest of the fielders, and will be discussed in Chapter 3.

Introduction

Internationally, three formats of cricket are played at elite level; Test, ODI and Twenty20 (Petersen et al., 2010). All players bat and field, while only some players bowl, and one person keeps wicket. Dismissing a batsman can be achieved in different ways, some specific to fielders, hence catching and throwing are vital skills. Common requirements for these skills are speed and accuracy, particularly in the shorter forms of the game. Therefore, optimizing the movements and skills required to successfully field can have an important influence on the game. However, despite the adage that ‘catches win matches’, research into fielding is sparse compared to that for batting and bowling (Bartlett, 2003). This review critiques existing knowledge of fielding in cricket with the intent of better understanding the performance demands of fielding.

For this review, fielding performance has been divided into a number of components (Figure 2.1), which will be systematically reviewed. The reviewed literature consists of peer reviewed articles, and one chapter from an edited book.

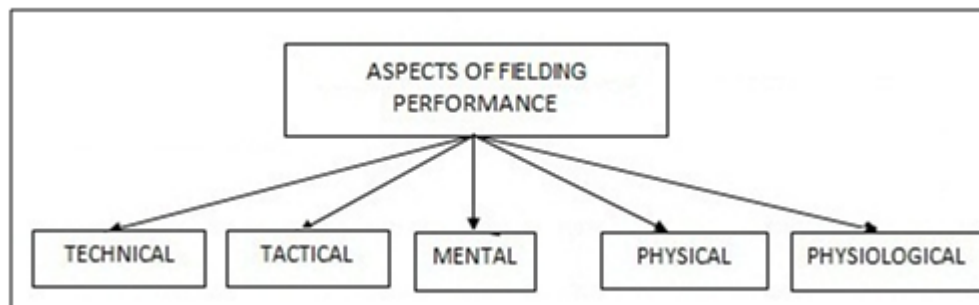


Figure 2.1: Aspects of fielding performance

All aspects contribute to fielding performance, however given the purpose of this thesis is to employ performance analysis techniques in order to inform physical conditioning and practice, this thesis focuses on the technical, physical and physiological aspects of performance. The tactical and mental components of performance are acknowledged and discussed superficially throughout as they do not form the main focus of the thesis.

In order to find literature suitable for this review, the University library online literature search engine was used. Variations of keywords such as "cricket", "fielding", and "performance" were used in order to search for literature.

Technical

In cricket the playing field is not of fixed dimensions. According to the Law of Cricket, "The playing area shall be a minimum of 150 yards (137.16 m) from boundary to boundary square of the pitch, with the shorter of the two square boundaries being a minimum of 65 yards (59.43 m)" (Marylebone Cricket Club, 2010). Due to the large and varying size of the pitch, the skills of fielding in cricket will vary considerably depending on where fielders are placed. For this review the fielding positions have been categorised as close (e.g. slips and short leg), inner circle fielders and outer circle fielders (Figure 2.2).

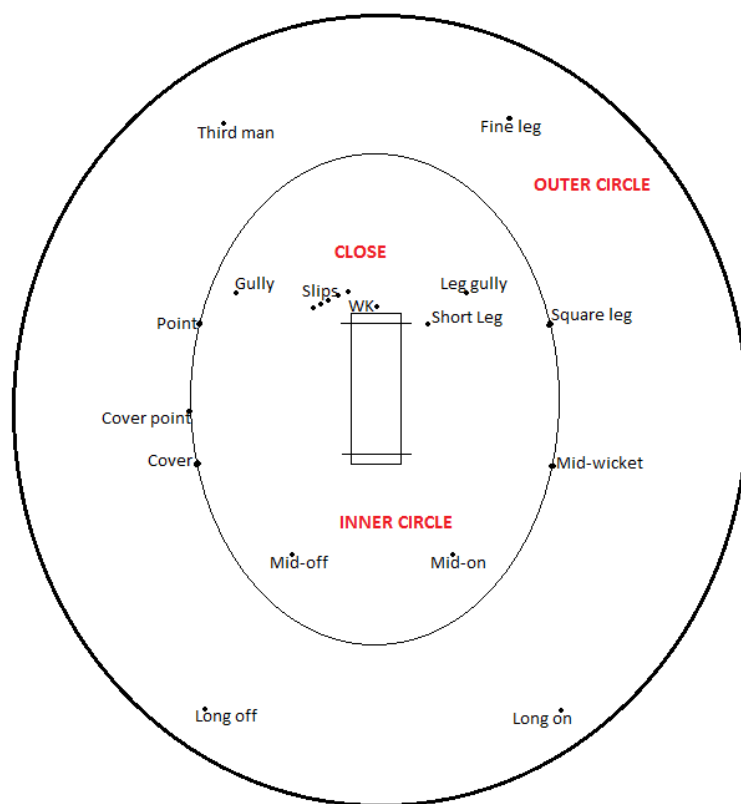


Figure 2.2: Pitch map showing the difference fielding categories and positions

Shilbury (1990) researched the frequency of fielding skills for 25 defined positions, and the fielding patterns of individual players of an 'A' grade cricket team playing first class multi-day cricket. The data was divided into four skill categories; fielded ball, fielded ball and throw, fielded ball and underarm return, and catches and attempted catches. The author reported that the wicket-keeper played a central role in a fielding side, taking 21.0% of all fielding contacts. This finding indicates that the wicket-keeper is a vital, specialist position, and is therefore investigated further in the following chapter. The next positions with the most contacts were cover (12.0%), mid-off (10.0%) and mid-on

(9.0%) respectively. These four infield positions took 52.0% of all fielding contacts studied.

Cover has traditionally been considered a position which requires good attacking skills, such as being able to move towards the ball, field and throw quickly, often from unbalanced positions (Elliott & Anderson, 1990). However, only 13.0% of cover's fielding contacts required attacking skills; the majority of actions were defensive that required practically no diving or lateral movements. This finding is not consistent with conventional wisdom.

Although Shilbury (1990) is the only published study, it is dated and used data from only six domestic games. Given the developments in the game since the 1990s, research based on a larger number of more recent international matches would be more appropriate and useful. These findings will assist the development of assessment and training protocols for the different formats of the game at the highest level.

A fielder's ability to throw a ball over considerable distance with speed and accuracy if aiming for a run out, requires excellent throwing technique. It can be postulated that the requirements are specific for the different field positions. The slips mostly intercept a fast moving ball coming off the edge of the bat and reaching them below chest height (Cook & Strike, 2000). They have little need for throwing long distances. Infielders require good reactive ability to catch a ball falling from above their heads and strong over-arm throwing ability (Bartlett, 2003) to attempt run outs. Outfielders often have to cover a considerable distance, so sprinting ability is vital, and they need to throw accurately over long distances (Elliott & Anderson, 1990). Good techniques are not only essential to win matches, they also minimise the risk of injury (Freeston & Ferdinands, 2007).

Distinguishing different throwing techniques has led to the identification of important performance variables (Cook & Strike, 2000). The relationship between over arm throwing velocity and accuracy in elite and sub-elite cricketers was investigated using a specifically designed throwing test (Freeston & Ferdinands, 2007). A speed-accuracy trade-off was detected. Subjects improved accuracy scores at velocities between 75.0% and 85.0% of maximal throwing velocity. Senior elite players performed better than other groups.

Synchronised high-speed video cameras (Freeston & Ferdinands, 2007) have been used to study the biomechanics of throwing. Throwing in cricket is found to be similar to baseball hence baseball literature could complement the limited cricket literature. No research into sidearm or underarm throwing in cricket has been found. Using the correct technique is crucial for success; the lack of scientific data in this area is detrimental to the development of optimal training programmes.

For skill development, player selection and talent identification, it is important to correctly test for skill and movement efficacy. This can assist a coach in detecting strengths and weaknesses in performance and in identifying the specific training needs of the individual. Stretch and Goslin (1987) devised a set of cricket skills tests, encompassing all components of the game.

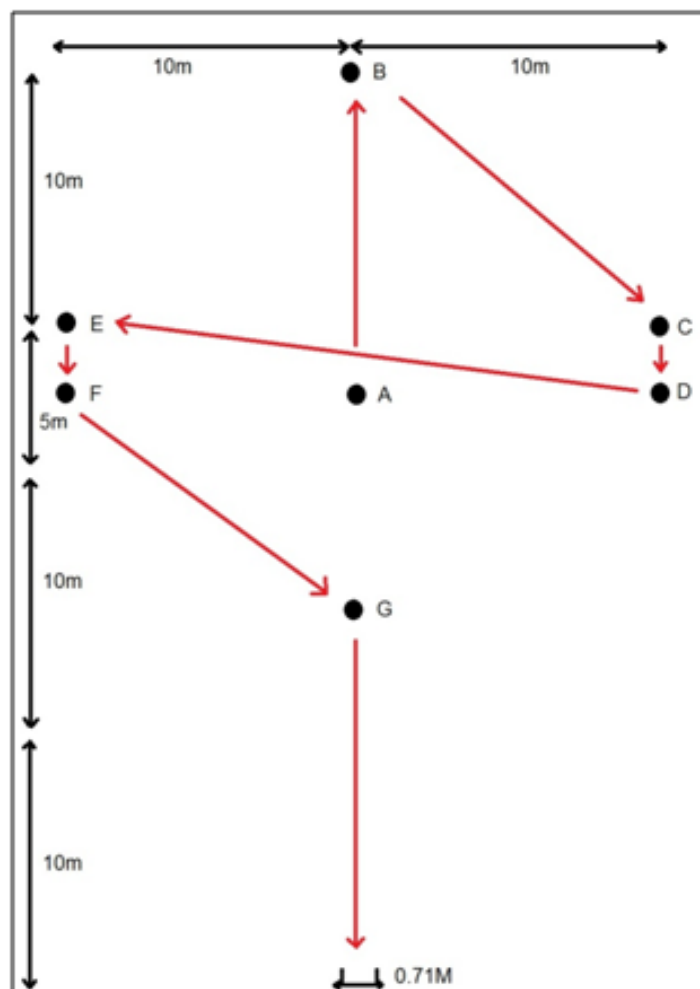


Figure 2.3: Schematic of the fielding agility test used by Stretch and Goslin (1987).

Adapted from "Validity and reliability for an objective test of cricket skills", by R. Stretch and B. Goslin, 1987. *Australian Journal of Science and Medicine in Sport*, 18-23.

In regards to fielding, the majority of run outs occur between 10 m and 35 m (Bland, 1969), and these were the distances tested in the fielding test (Figure 2.3). The authors and coaches also used their knowledge of the game to subjectively determine the players' potential success in a match (Stretch & Goslin, 1987). The validity of the fielding tests was tested by comparing the objective tests to the subjective opinion of coaches. The relationship between the objective fielding test scores and the subjective fielding evaluation was low ($r = 0.47$, $p < 0.05$). However, the sample size was relatively large ($n = 155$), hence the authors decided that the lower correlation was acceptable. The diagnostic utility of this test could be questioned given the composite nature of the test with many skills assessed within one test.

Tactical

There has been no peer-reviewed literature on the tactical component of fielding. This is most likely because tactics in cricket are dependent on a variety of factors including the weather, the pitch and the format of the game. A captain will set attacking or defensive fields depending on the team position in the game. Objective information of each player's capabilities would greatly assist the coach to field a balanced and effective team. However, lack of such knowledge greatly restricts the options of a coach and he often has to make tactical decisions based on subjective judgments.

Mental

Cricket requires inordinate physical skill and mental aptitude, including the ability to concentrate intensely for very long periods, for which a high level of physical fitness cannot fully compensate (Noakes & Durandt, 2000). Fielders have to concentrate on every ball of the innings, regardless of their positions. They have to be able to maintain their concentration for the entire duration of an innings (ranging from approximately an hour and a half in a T20 innings to a total of six hours a day in a test match), through changing conditions as play progresses through the day. Some mental aspects of fielding have been investigated (Hopwood, Mann, Farrow, & Nielsen, 2011; Scott, Kingsbury, Bennett, Davids, & Langley, 2000) although most studies have focussed on batting (Croft et al., 2010; Land & McCleod, 2000; Müller et al., 2009).

With ODI cricket, matches began to be played into the night, and the ball colour was changed from red to white to be better seen under floodlights. Scott, Kingsbury, Bennett, Davids and Langley (2000) investigated the effect of light levels and ball

colour on catching, particularly for slip fielders in simulated field conditions.

Photoelectric timing gates were placed in front of a ball projection machine and lever micro-switches were placed on the thighs of the players to establish reaction times to balls projected at a speed of 20 ms^{-1} over a distance of 8.4 m. The speed was considered representative of the demands of slip catching performance in addition to being the upper limit of speeds safe for use under laboratory conditions. Catching performance was scored using a scale adapted from Wickstrom (1983), which rated catches from 0 (no ball contact at all) to 5 (clean catch). After performing a 2 (ball) x 3 (light level) ANOVA, no significant effects were noted for catching performance and movement initiation times for ball or light levels. The authors concluded that the change in ball colour or diminishing light levels were not detrimental to performance. However, the sample of this study was very small ($n = 5$), which may account for the lack of statistical significance. Also, the testing protocol required players to assume a standing position which may not be normal under game conditions.

The effect of a visual-perceptual training programme on fielding in cricket has been investigated using a test-retest design incorporating a six-week training intervention (Hopwood et al., 2011). The tests involved an in-situ fielding test, and also athletes were required to react (predict and move in the direction the ball was hit) to a life-sized video projection of a batsman hitting strokes, with the video occluded at the point of ball contact. The video was filmed from the perspective of three different fielding positions; extra cover, mid-on and mid-off. Whether or not the fielder moved in the correct direction for each video was used to determine decision accuracy.

The training group underwent an additional three perceptual training sessions per week in addition to the on-field training programme undertaken by the control group. The training group performed significantly better than the control group in the two tests. It was concluded that while six weeks of regular on-field training may lead to improvements in fielding performance, greater advantages could be gained when it is combined with visual perceptual training sessions.

Physiological

The most prevalent approach to quantifying the physiological demands of cricket is time-motion analyses using Global Positioning System (GPS) units. Rudkin and O'Donoghue (2007) performed 27 observations of a fielder positioned at cover point, during first class multi-day games. They used the CAPTAIN time-motion analysis

system to define seven movement classes; stationary, walking, shuffling (rapid non-running movement of the feet), jogging, running, low intensity fielding and high intensity fielding. It was found that the cover point fielder spend the majority ($94.2 \pm 2.4\%$) of match time in stationary activity and walking, while high intensity activities represented just $1.6 \pm 0.8\%$ of movement activity. It was concluded that first-class fielding entails less high intensity exercise than other team sports such as hockey and soccer. However, the conclusions are of limited validity, as only one fielding position was analysed.

Time-motion studies could help develop knowledge of positional differences in workload between the different formats of cricket and this allows conditioning coaches to prescribe game-specific training programmes (Petersen et al., 2010). Petersen, Pyne, Portus and Dawson have conducted several studies (Petersen et al., 2010; Petersen, Pyne, Portus, & Dawson, 2009b; Petersen et al., 2011) using GPS technology investigating physiological demands of performance in the three different formats of the game. Unlike the Rudkin and O'Donoghue (2007) research, five movement categories were established (standing/walking, jogging, running, striding and sprinting) and investigated the three different cricket formats.

Table 2.1 summarises the main findings for each format; it shows that fielding intensity is greatest in a T20 match and fielders covered approximately six km during the 90-minute game, while fielders covered 16 km per day of a multi-day game. These findings are consistent with those of Rudkin and O'Donoghue (2007).

Table 2.1: Summary of findings from time-motion analysis studies

Study	Quantifying positional movement patterns in Twenty20 cricket. Petersen, Pyne, Portus, Dawson (Petersen, Pyne, et al., 2009b)	Comparison of Player Movement Patterns between 1-day and Test Cricket. Petersen, Pyne, Portus and Dawson (Petersen et al., 2011)	
Game Format	Twenty20	ODI	Test
Position	Fielders (n = 14)	Fielders (n = 17)	Fielders (n = 25)
	Distance per hour		
Walking (0-2.0 m.s ⁻¹) (m)	3286 ± 726	2419 ± 708	2263 ± 629
Jogging (2.0-3.5 m.s ⁻¹) (m)	1532 ± 361	616 ± 272	621 ± 135
Running (3.5-4.0 m.s ⁻¹) (m)	377 ± 156	147 ± 62	137 ± 44
Striding (4.0-5.0 m.s ⁻¹) (m)	497 ± 316	159 ± 89	166 ± 62
Sprinting (5+m.s ⁻¹) (m)	416 ± 265	90 ± 73	155 ± 71
Total Distance (m)	6106 ± 981	3430 ± 883	3342 ± 759
	Time		
Walking and jogging (s)	3263 ± 187	3504 ± 46	3496 ± 30
Running, Striding and Sprinting (s)	275 ± 146	91 ± 45	104 ± 30
	Sprint		
Number (#)	23 ± 14	6 ± 4	8 ± 4
Mean sprint distance (m)	17 ± 4	15 ± 4	18 ± 5
Maximum sprint distance (m)	54 ± 23	34 ± 12	43 ± 15
Maximum sprinting speed (m.s ⁻¹)	8.6 ± 1.1	7.9 ± 1.2	8.5 ± 0.9
	High Intensity Efforts		
Number (#)	98 ± 43	34 ± 17	34 ± 11
Mean effort duration (s)	2.8 ± 0.4	2.6 ± 0.3	3.1 ± 0.3
Recovery between (s)	45 ± 21	134 ± 73	116 ± 37

Note: High intensity efforts were defined as running, striding and sprinting.

Petersen, Pyne, et al. (2009b) tested the validity and reliability of three commercially available sports GPS units to monitor cricket-specific movement patterns. They found disparate and inconsistent measures for the validity and reliability of low and high intensity activities. They advised that conditioning coaches should be aware of the likely under-reporting of high intensity activity and over-reporting of low intensity efforts when using GPS in training. All studies detailed thus far fail to document the physiological demands of the different fielding positions, as generally fielders, without distinction, are compared to bowlers and batsmen.

Physical

The physical aspects of performance have been investigated with respect to injury incidence and prevention, particularly for fast bowling and throwing, but little investigation into the physical aspects of fielding has taken place. In this section, physical aspects such as anthropometry, strength, speed and aerobic and anaerobic fitness will be considered.

Anthropometry

Several studies have investigated the anthropometric profile of first class cricketers (Bourdon, Savage, & Done, 2000; Johnstone & Ford, 2010; Portus, Kellett, Karppinen, & Timms, 2013; Stretch, 1987, 1991) mostly by comparing groups of players, such as batsmen, bowlers, or all-rounders. The measures used were mass and stature measurement and the sum of seven skin folds (biceps, triceps, subscapular, supra-iliac, abdominal, thigh and medial calf). Portus et al. (2013) have extensively researched the characteristics of Australian players. These findings probably are not valid globally given ethnic differences in stature. The anthropometry for specific fielding positions has not been explored. It is likely that anthropometry will contribute to the ideal fielding position of a player.

Aerobic and Anaerobic Fitness

With modern cricket, players can be expected to tour for up to eleven months of the year, therefore physical fitness is increasingly important. The only study (Fletcher, 1955), which specifically studied the calorific energy demand of cricketers analysed multi-day cricket in 1955 and its validity in representing the demands of modern players would seem problematic.

More recent research has indicated that cricketers generally rely on aerobic energy supply and that the rates of energy expenditure of cricket are relatively low, with the

exception of fast bowlers during a bowling spell (Fletcher, 1955; Johnstone & Ford, 2010). This generalisation is supported by the findings of time-motion analyses (Petersen et al., 2010; Petersen, Pyne, et al., 2009a, 2009b).

The multi-stage fitness test is recommended to test aerobic power as it is inexpensive, easy to administer and applicable to many team sports with respect to the stop, start and change-of-direction movement patterns (Bourdon et al., 2000). Johnstone and Ford (2010) established physical fitness profiles of cricketers grouped into bowlers and batsmen ($n = 15$) using this test. The authors recorded the number of completed shuttles (12.4 ± 0.9), end heart rate (190.4 ± 11.2) and predicted the VO_2max (54.9 ± 3.7). The researchers concluded that the VO_2max results of cricketers were superior to the general population (Johnstone & Ford, 2010). These results are comparable to the normative data presented for cricket players in *Physiological Tests for Elite Athletes* (Portus et al., 2013).

Anaerobic fitness has generally been tested using sprint tests. Johnstone and Ford (2010) found that running speed for each of the groups was similar, although the bowlers achieved moderately better results (1.5%) in maximal repeated sprint tests than the batsmen. Sprint tests in cricket have typically varied in distance (10 – 40 m) therefore it is difficult to compare results between studies. Johnstone and Ford (2010) recommended that future assessment of cricket-specific speed should use short distances of 5 – 15 m because these may be associated with higher levels of match-winning fielding performances. However, sprint testing over a large range of distances may be justified, because of the size of the pitch players will have to cover varying distances depending on fielding position.

In summary, cricket players require a high level of aerobic fitness in order to play for up to six hours a day, with a very small anaerobic energy demand. Whether these demands differ as a function of fielding position has not been researched. It may be that a position such as slips with potentially less aerobic demands may benefit from greater doses of high intensity reactive training. Nevertheless, given the length of the international cricket season and the tour demands of cricketers, superior aerobic fitness will assist players in recovery and sustaining performance at the highest level.

Strength, Power and Speed

Upper body

The results of studies on strength and power profiles of cricketers have so far been ambiguous and seem to lack logical or face validity. Johnstone and Ford (2010) for example measured upper body strength and power using a medicine ball throw and timed press up tests. There were marked differences between batsmen and bowlers, the batsmen were superior in the timed press up tests, but the bowlers produced greater backward throws. However, the significance of these results and their relation to performance is unclear. There is no research on specific fielding positional demands and nor have normative data for each fielding position been established. Nevertheless, it appears that different strength requirements may be needed for different fielding positions (for example, the throwing demands of an outfielder versus a slip fielder).

Lower body

Leg strength and power are important for cricket fielders as they contribute to the speed and agility required for fielding. However, there has been little research on the lower body strength profile of cricketers. Johnstone and Ford (2010) tested lower body strength and explosive power using a counter-movement jump and repeated vertical jump test. The authors suggested that tests such as the counter-movement jump give an indication of slow stretch-shortening cycle performance, and found that there were negligible differences between the bowlers and batsmen. Bourdon et al. (2000) also recommended a series of tests for profiling the physical fitness of elite cricketers, the lower body tests included a vertical double leg jump, abdominal strength stage test, straight sprint speed (10, 20 and 40 m), and a run three agility test. While the abdominal stage test is lauded as particularly important for fast bowlers, the authors noted that batsmen and fielders would benefit from good abdominal strength during long periods in the field or at the batting crease.

It is clear that the leg power demands of fielding are little understood. For example, there is little logic in using only a vertical jump test when research and observation show that fielders need to move in all directions and therefore need multi-directional lower leg strength and power. Correctly assessing the multi-planar movement ability of fielders would lead to better training programs. While there is a lack of knowledge and research concerning the physical attributes of fielding performance there may be merit in consulting research in sports with comparable movements, for example tennis

(Salonikidis & Zafeiridis, 2008) and football (Burgess, Naughton, & Norton, 2006; Spratford, Mellifont, & Burkett, 2009).

Conclusions

There is a paucity of scientific information on the performance demands of fielding across all the areas of interest briefly discussed in this article e.g. technical, mental etc. There seems to be little appreciation of the technical requirements related to different fielding positions. Conventional wisdom on several aspects of the game is not supported by scientific evidence. Given that fielding is an essential component to win matches, the lack of research in this area is disconcerting. A systematic research programme covering all components for all game formats would be beneficial.

Existing knowledge could be complemented by obtaining the considered opinions and insights of coaches and players and by carrying out detailed video and notational analysis. The results would provide greater insight into the skill and movement requirements associated with the different field positions. This information would also provide a framework for the design of fielding specific assessments, which should enable the development of more focussed training, conditioning and coaching protocols. This should enhance fielding performance and contribute to the ultimate goal of winning matches.

Chapter 3 - A review of wicket-keeping performance demands

Prelude

Despite the fact that it is widely acknowledged that the wicket-keeper is a specialist position within a cricket fielding unit, there is a paucity of literature on wicket-keeping, with most cricket research having focused on fast bowling and batting. This review is principally concerned with identifying the performance demands associated with wicket-keeping and the conditioning of these cricketers. To appreciate the performance demands of wicket-keeping, an integrated approach has been taken where the mental, technical, physiological, physical and tactical requirements of wicket-keeping are discussed. The mental and tactical aspects of performance are important contributors to overall performance, however are not the focus of this research and are therefore only briefly discussed.

Introduction

Cricket is a sport widely played throughout the Commonwealth. It has developed throughout the years and is unique in that three formats of the game are played at the elite level; Test, ODI and T20 cricket (Petersen et al., 2010). As with many sports, within cricket there are different performance and skill requirements depending on playing position, which can be categorised as batting, bowling and fielding.

In terms of fielding, these skills vary considerably, from the wicket-keeper and slips, who mostly intercept a fast moving ball coming off the edge of the bat and reaching them below chest height, to outfielders who primarily try to catch a ball falling from above their heads (Bartlett, 2003). Common requirements for fielding skills are speed and accuracy, particularly in the shorter forms of the game, as dropped catches or missed throws at the stumps can mean the difference between winning and losing a match. Therefore optimising the movements and skills required to successfully field and keep wicket can potentially have an influence on the outcome of a game. However, despite the adage that ‘catches win matches’, research into fielding in cricket is sparse compared to that for batting and bowling (Bartlett, 2003).

A strong performance from the wicket-keeper is essential to the success of the team. His actions can positively and actively contribute to the early dismissal of the opposing team (Plunkett, Salter, & Moore, 2005). The wicket-keeper’s role in cricket is unique in that he is the only player who has the potential to be involved in every delivery of the innings. This observation was supported by Shilbury (1990) who reported that the wicket-keeper played a central role in cricket, taking approximately 21% of all fielding contacts in the six games analysed. In some matches the wicket-keeper was involved in as many as eight of the ten dismissals in a single innings (Rosen & Bower, 2006). However, there is a paucity of literature specific to wicket-keeping. Existing knowledge pertaining to wicket-keeping has generally been limited to coaching literature and for the most part this has been based on anecdotal evidence and the advice of former wicket-keepers and coaches (Rosen & Bower, 2006).

Given this, the purpose of this literature review is to better understand the performance demands associated with wicket-keeping. To achieve this, wicket-keeping performance has been broken down into a number of components (Figure 3.1), which will be addressed systematically throughout the paper. The literature reviewed for this article is principally peer reviewed research with the inclusion of one book chapter from an

edited book. It is hoped that such an approach will help the reader to understand the performance requirements of a wicket-keeper and guide the conditioning and development of these players to better effect.

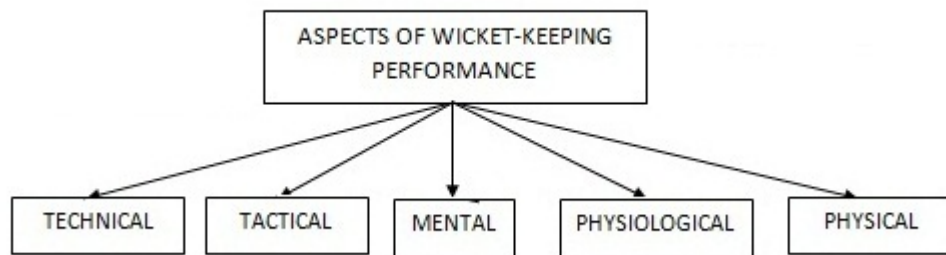


Figure 3.1: Aspects of wicket-keeping performance

The mental and tactical components of performance are discussed briefly in this chapter, however are not the main focus of this research.

Technical

Pre-movement: Crouch

High repetition of explosive, powerful, lateral movement is required for wicket-keepers to effectively take deliveries from bowlers. In addition to this, wicket-keepers also have to field balls returned from other fielders. Therefore the movements required to take stock deliveries should be proficient and require as little physical exertion as possible. The Australian Institute of Sport (2005) published a document investigating the efficiency of movements by wicket-keepers starting from three different crouch positions: the full crouch, semi-crouch and the touch and move stances (Figure 3.2).



Figure 3.2: Side views of full crouch (resting position), semi-crouch and touch and move (power positions) respectively. Photographs credited to the author.

The full crouch was reported as the position most used by wicket-keepers, possibly because of its successful use by past players (Plunkett et al., 2005). However, the full crouch requires the knees to be held in a static position at full flexion, which results in higher compressive forces on the knees than more upright stances. It can be postulated that the semi-crouch and touch and move stances could be associated with reduced

incidence of injury (Escamilla et al., 1998). The full crouch is deemed to be a resting position used prior to moving into what is called a power position (loading phase), which are the semi-crouch, touch and move stances. The power position should only be held for a maximum of two seconds to ensure the power within the muscles is not lost before movement (J. Mills, personal communication, March 13 2013). The ideology behind the touch and move stance is that the keeper is moving from a counter movement, rather than a stationary position. This means that the leg musculature is already activated when the movement up and across to take the ball is initiated (Plunkett et al., 2005). Therefore, the three parts from the stance to the movement phase starts with the resting position (full crouch or a standing position), then into the power position (semi-crouch or touch and move), then into the movement stage towards the ball.

The purpose of the Plunkett et al. (2005) study was to investigate the efficiency of side-to-side movement of wicket-keepers and the loading on the lower limb joints resulting from the three different crouch positions. Plunkett et al. (2005) used 14 male cricketers who played in either under-14 or under-13 competitions. None of these players were specialist wicket-keepers and therefore had received little technical coaching in this position; however they were old enough to have the coordination and physical maturity to be able to keep wicket. After pre-testing for power capabilities, the participants were assigned to three groups corresponding to each of the set up positions, so that the results seen would be due to the different stances rather than variation in physical capabilities and coordination ability. The participants underwent a two-week training protocol during which they completed a mean 678.0 ± 60.8 repetitions of specific wicket-keeping skills. Following the training wicket-keeping skill was tested using a bowling machine to project balls at a mean speed of $82.2 \pm 1.5 \text{ km.h}^{-1}$. The balls were projected to the wicket-keepers left or right in order to simulate stock deliveries for a left or right-handed batsman. In addition to the 14 boys tested, two elite wicket-keepers (a first class wicket-keeper using the touch and move stance and a Cricket Australia Cup representative who used the semi-crouch stance) were also tested, allowing the technique used by the young participants to be compared to the elite wicket-keepers'.

From the results it was concluded that the full crouch technique was associated with the greatest loading at the knee, and therefore a greater range of lower limb extension was required to perform the primary lateral steps in order to take the ball (Plunkett et al.,

2005). This was achieved through the use of significantly greater peak moments in the outside knee. There were no other significant differences in lower limb moments between stances. It would seem that the full crouch was the least efficient position; however despite this there were no significant differences between the times taken to move from the starting position for each stance. Although suggested that players use the touch and move in order to facilitate getting to the ball (by using a countermovement), movements from the touch and move stance did not differ significantly to movements from the other two stances in any peak joint moment. The authors concluded that the semi-crouch would allow the a wicket-keeper to move to the ball proficiently, and with potential lower loading on the knees than the full crouch, but that set-up position should depend largely on individual preference. The authors highlighted the fact that there needs to be more research in this area given the limited data and the experience of the subjects from which these conclusions were made.

Movement

The footwork patterns of elite wicket-keepers (n=12) were investigated by Rosen and Bower (2006). 'Elite' was defined as having played in at least one Sydney Cricket Association first grade cricket team or representing any State team from under-19 level and up. The testing protocol was designed to simulate a wide, low bouncing delivery to a right handed batsman, which would require the wicket-keeper to move to the right to catch the ball. The participants were fitted with reflective makers on nine anatomical landmarks for use with a three-dimensional motion capture system.

Following practice trials, each participant completed twenty wicket-keeping movement trials. Body kinematics were captured and digitised in real time to obtain three-dimensional coordinates. From the results a number of footwork patterns were identified, which were then split into primary and secondary footwork patterns. The primary footwork patterns were identified as ipsilateral take-off, contralateral take-off and jump take-off (Figure 3.3, 3.4 and 3.5); secondary footwork patterns were identified as the lateral shuffle and crossover step. In each of the figures the bold feet marked L and R represent the crouch position, bold feet marked with numbers represent primary footwork patterns and outline feet represent secondary footwork patterns. The numbers indicate the order the feet were placed in.

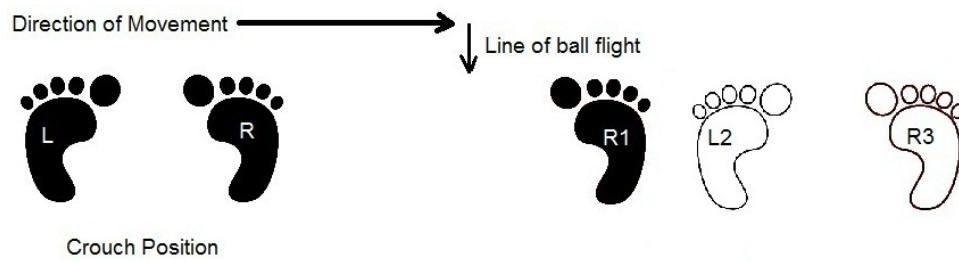


Figure 3.3: Ipsilateral take-off

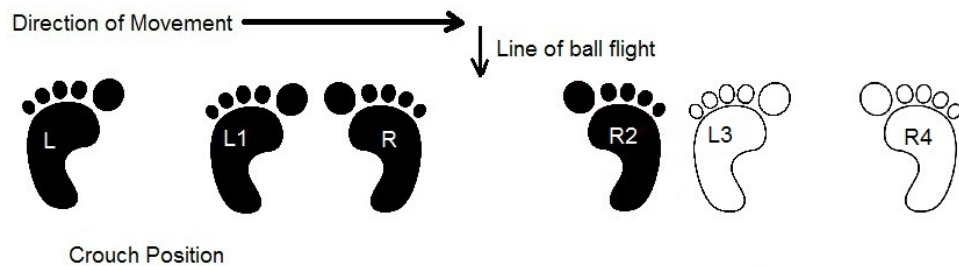


Figure 3.4: Contralateral take-off

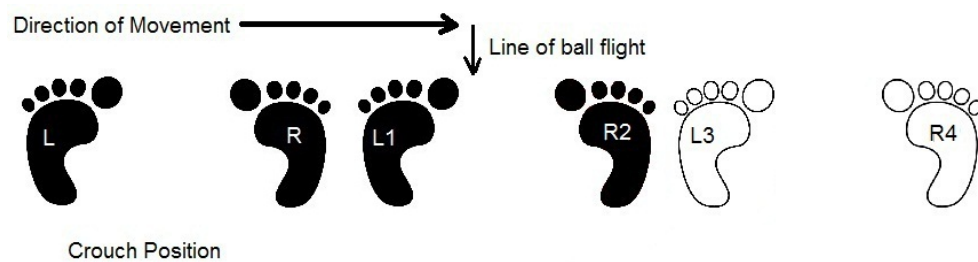


Figure 3.5: Jump take-off

Note: Figures 3.3, 3.4 and 3.5 are adapted from findings from "Analysis of the footwork patters of elite wicket-keepers in cricket, by B. Rosen and R. Bower, *Journal of Human Movement Studies*, 51, 181-196.

The ipsilateral take-off was the primary footwork pattern which was most frequently used by wicket-keepers; the average first step length was 54.5 ± 27.5 cm. The large variation between the placements of the feet indicated great variation between participants, which could be attributed to differences in stature, individual muscular strength, timing and speed of footwork.

The second most common movement sequence was the contralateral take-off, which consisted of a lateral step with the foot on the opposite side of the body from the intended direction of movement. This group of wicket-keepers appeared to have the widest crouch position, although no significant differences ($p < 0.05$) were observed (Rosen & Bower, 2006). The third primary footwork pattern incorporated a jump from the subjects' crouch position, similar to a split step in tennis.

Of the twelve participants, only half exhibited the same footwork pattern throughout the five selected trials while the others used a combination of multiple footwork patterns. It was concluded that the secondary footwork patterns allowed the wicket-keeper to continue the lateral movements initiated in the primary footwork phase and that the crouch position did not differ between subjects, irrespective of which movement pattern they used. Additionally, the wicket-keepers continued their movements after successfully catching the ball, indicating that rhythm and timing are vital to successful catching performance behind the stumps.

This study focused specifically on the wicket-keeper and the movements specific to this position, however there were some limitations which should be noted. The sample size was very small ($n=12$) due to the limited numbers of elite wicket-keepers and this may be why no significant differences were found in some results. The use of markers on the body meant that the participants could not wear the personal protective equipment usually worn when keeping wicket. However, the subjects were asked to comment on whether their movements felt similar to when they wore their pads and the general consensus was that their movements felt the same whether or not protective equipment was used. Additionally, due to limitations in laboratory space the ball projection machine was placed relatively close to the wicket-keeper, therefore for safety reasons ball projection speeds were lower than usually seen in elite competition. As a result of this, the wicket-keepers did not have the usual visual cues from the bowler which they normally use to determine the direction of ball trajectory and when to initiate their movement. The authors attempted to rectify this by giving the subjects a countdown before the ball was released. They were however able to maintain a reaction time between the ball release and contact with the wicket-keepers of 0.7 seconds, which is realistic in respect to match-like conditions.

Given the paucity of research in cricket, and the fact that moving and diving laterally are important movements for successful wicket-keeping, findings from other sports may be of value in understanding how to optimise these movement patterns. There is the potential for much to be learnt from sports such as tennis (Kovacs, 2009; Uzu, Shinya, & Oda, 2009), volleyball (Lobiatti, 2009) and football (Spratford et al., 2009).

Mental

A five day Test match is quite literally a test for all players, requiring them to perform and concentrate for considerable periods of time. This is true especially for the fielding

side, which may spend all day in the field, often under adverse weather conditions i.e. extreme heat. Players have to be able to switch their minds off in between deliveries in order to preserve their concentration. Such is the nature of cricket that the smallest lapses in concentration and resulting errors can mean the difference between a caught or dropped catch and a win or loss.

Perceptual-cognitive skills are an important characteristic of expert sport performance, researchers identifying that experts outperform novices in anticipation and decision-making tasks in a variety of sports (Hopwood et al., 2011). Wicket-keepers have to utilise the same visual cues as a batsman to process information from the bowler's movements and from the trajectory of the ball. The wicket-keeper also has to keep a close watch on the batsman and his position in order to take advantage of any stumping opportunities. The ability to process these various pieces of information in order to make decisions has been addressed by several studies.

In fast-action dynamic sport environments, an athlete's ability to identify advanced sources of information facilitates early decision making and allows time for an appropriate response to be organised (Houlston & Lowes, 1993). The nature of anticipatory cue utilisation in wicket-keeping was investigated using 12 male wicket-keepers sorted into 2 groups; expert and non-expert. A four-stage temporal occlusion paradigm including pre-ball release and ball flight information was used and the subjects were required to predict the position the ball would bounce. From the analysis of radial, lateral and depth accuracy information, Houlston and Lowes (1993) found that there were no significant differences between the expert and non-expert groups, and emphasised the importance of time in terms of successfully predicting ball landing position. However, it was also established that experienced wicket-keepers strategically select visual cues in order, with lateral information taking precedence over depth information.

Given the paucity of wicket-keeper specific literature, insights derived from the analysis of the decision making process in other sports may be beneficial. Similar research has been conducted in tennis which is also a fast-action dynamic sport. Farrow and Abernathy (2002) and A. M. Williams, Ward, Knowles, and Smeeton (2002) showed that with an increase in skill level, there was enhanced ability to search for and utilise cues from earlier occurring events in the display (A. M. Williams et al., 2002). Tennis researchers have also made use of temporally occluded video to investigate training

anticipatory skills through the use of video-based perceptual training (Farrow & Abernathy, 2002; A. M. Williams et al., 2002). In a study investigating difference between implicit and explicit learning use in tennis, the implicit learning group improved their prediction accuracy after appropriate training. These findings on the decision making process in tennis provide additional support for similar type research for wicket-keeping.

The effect of visual-perceptual training on the fielding performance of skilled cricketers was investigated by using twelve highly skilled cricketers from the Australian Institute of Sport Centre of Excellence (Hopwood et al., 2011). All participants were selected to play at senior international level within six months of the conclusion of the study. The study used a test-retest design, which included a six-week training intervention. Both groups participated in the same on field training programme for the six weeks.

Additionally, the test group undertook three video-based perception training sessions per week. Despite no significant differences between the test and control group at pre-testing, the test group scored significantly higher than the control group at post-testing for decision accuracy. The results indicate that six weeks of on-field training combined with visual-perceptual training can lead to improvements in the fielding performance of skilled cricketers above those of on-field training alone (Hopwood et al., 2011). While the study focused on inner circle fielders who have longer to react than wicket-keepers, the value of visual perceptual training should be noted for wicket-keepers, and is a potential area for future study.

Visual evoked potentials (VEP), reaction times and eye dominance in batsmen and bowlers have been investigated (Thomas, Harden, & Rogers, 2005). The findings of this study can potentially be applied to wicket-keepers given that wicket-keepers stand behind the batsman and have to utilise the same visual cues. A skilled batsman picks up sufficient trajectory information during the first 100 – 150 milliseconds of ball flight to estimate the position of the bounce and that lateral information takes precedence over depth information when making decisions (Land & McCleod, 2000). This information illustrates the importance of anticipation for successful wicket-keeping performance.

In summary, perception and decision-making are vital components of cricketing success. Wicket-keepers must be able to understand and prioritise subtle visual cues in order to make decisions. Research has shown that perceptual-decision making skills can be improved using a combination of on-field and video based training. Nevertheless

very little research has focused specifically on wicket-keepers and the processing of visual information required for them to execute their skills successfully. The use of visual-perceptual training in order to improve anticipatory and reactive decision making in wicket-keeping performance is an area for future study.

Physiological

There are very few studies of the physiological demands of cricket or of the specific physiological, biochemical or anthropometric attributes of top class cricketers (Noakes & Durandt, 2000). However, some time-motion analyses investigating the different physiological requirements between the three formats of the game have been undertaken in recent years.

Petersen, Pyne, Portus and Dawson (2009b) used GPS units and time-motion analysis to quantify positional movement patterns in T20 cricket. Players were classified as a batsman, fast bowler, spin bowler, fielder or wicket-keeper. The effect size statistic was used to assess the extent of differences between the generic fielder position and the three specialist positions (wicket-keeper, fast and spin bowlers). During the fielding innings of a T20 match distance covered by players ranged from 6.4 km (wicket-keepers) to 8.5 km (fast bowlers) with 0.1 km to 0.7 km covered at sprinting intensity. For wicket-keepers sprinting accounted for 1% of total distance covered (Petersen, Pyne, et al., 2009a). It was reported that wicket-keepers covered substantially less distance in higher intensity efforts (sprinting, striding, running and jogging) than fielders and had twice the recovery time from high intensity efforts as fielders (101 s compared to the fielders 44 s: ES = 3.0).

In an analysis of movement patterns in the three formats of cricket Petersen et al. (2010) found that wicket-keepers covered more distance per hour in multi-day cricket (2.8 km) than in T20 (2.5 km) and ODI (2.7 km) matches. Furthermore, wicket-keepers covered a greater distance per hour in high-intensity efforts (running, striding, sprinting) in T20 (433 m) matches than in ODI (240 m) or multi-day cricket (109 m) and the recovery times were longer the longer the format of the game. During a full ODI innings the wicket-keepers travelled the least total distance of all the fielding players (9.5 km), averaging only 0.1 km at sprinting intensities. Wicket-keepers covered approximately 16.6 km and 3.3 km in multi-day and T20 innings respectively.

While knowing the proportion of distance and time spent standing, walking, jogging, running, striding and sprinting is useful for training prescription purposes, this type of analysis gives no indication of the direction of movements nor the precise movements and joint kinematics specific to the skill of wicket-keeping. Time-motion analysis should be expanded to include the movements unique to the wicket-keeper, although some of this information will not be possible to obtain with GPS.

Physical

Anthropometry

Data presented in the cricket chapter of *Physiological Tests for Elite Athletes* (Gore, 2000) reported that academy wicket-keepers ($n = 13$) were shorter ($177.1 \text{ cm} \pm 3.7$) than fast ($189.2 \text{ cm} \pm 6.3$) and spin bowlers ($182.5 \text{ cm} \pm 5.6$) but taller than batsmen (168.9 ± 5.3). Wicket-keepers and pace bowlers had similar sum of 7 skinfolds (triceps, subscapular, biceps, supra-spinal, abdominal, thigh, medial calf), but their sum of 7 skinfolds were reported to be less than batsmen and spin bowlers. There has been a more recent study investigating the physiological profile of cricketers (Johnstone & Ford, 2010), but this study grouped participants ($n = 15$) into groups of bowlers and batsmen and the one wicket-keeper included was classed as a batsman.

It must be noted that the little anthropometry data available for cricket has been compiled from cricketers from South Africa (Stretch, 1987; Stretch & Buys, 1991) and Australia (Bourdon et al., 2000), therefore the findings cannot be generalised in regards to cricketers worldwide. For example, general observations have shown that players from the Asian subcontinent have a tendency to be smaller than players of European descent. Due to the fact that cricket is a global sport practiced by people from different ethnic backgrounds, finding universally valid relationships between the different aspects of the game and the anatomy and physique of the players may be a complicated process, and researchers should be aware of this issue. Saying that, in terms of the skills required by the wicket-keeper (diving and catching low balls) and their potential involvement in every ball of an innings, being smaller in stature and carrying very little fat mass would seem advantageous.

Aerobic and Anaerobic Fitness

Given the results summarised in the physical section of this literature review, it is clear that despite the relatively low intensity level of the game, cricketers require a high level of aerobic fitness in order to play for up to six hours a day. Additionally, good aerobic

fitness will help with recovery between days of play, heat stress and the ability to concentrate for long periods of time (Johnstone & Ford, 2010). However, there is a lack of peer-reviewed literature regarding the physiological profiles of professional cricketers and possible differences that may exist among on-field playing positions (Johnstone & Ford, 2010) as the majority of cricket research in this area has focused on fast bowlers .

The physiological profile of professional cricketers has been investigated by putting them through a series of field-based fitness assessments including body composition, flexibility, predicted maximal oxygen uptake, upper and lower body strength, speed and explosive power (Johnstone & Ford, 2010). Compared with normative data, cricketers have some superior fitness parameters compared to the general population. There were also physiological differences between batsmen and bowlers (no wicket-keepers were included in this study, however in previous studies wicket-keepers have been classed as batsmen). The players' predicted maximal oxygen uptake (calculated from a multi-stage shuttle run) was found to be $54.9 \pm 3.7 \text{ ml.kg}^{-1}.\text{min}^{-1}$. It was concluded that cricket has a 'moderate aerobic endurance' component, which may relate to the movement patterns of the game as match analysis indicates that players can cover up to 15 km per day in the field, although the majority of this distance is covered at walking pace (Johnstone & Ford, 2010).

In terms of wicket-keeping, it can be postulated that their aerobic fitness may need to be superior to that of most cricket positions due to: 1) their possible involvement in every ball during the fielding innings; 2) the mental and physical requirements setting for each delivery i.e. the pre-movement; 3) the need to be reactively explosive in order to catch balls from the bowler or off the batsmen; and, 4) in most teams the wicket-keeper is a high-order batsmen expected to perform well with the bat (in the past the wicket-keeper was a specialist position), so the expectation is for them is to score runs and build innings in addition to keeping wicket.

Strength, Power and Speed

Leg strength and power would seem pre-requisite to successful wicket-keeping performance. However, while the movements required by the wicket-keeper have been analysed (Plunkett et al., 2005; Rosen & Bower, 2006), there has been no analysis of the strength profiles required of wicket-keepers. Leg strength and endurance would seem important given the requirements of repeating and holding the crouch position over extended durations. In terms of saving runs and enabling dismissals via catches coming

off the bat, there is no doubt reactive or explosive strength and power would be beneficial. Furthermore multidirectional reactive strength and power would be advantageous as the wicket-keeper needs to be able to dive to both sides (lateral), forward (horizontal) and up (vertical) to catch the ball and enable a dismissal (Plunkett et al., 2005).

In terms of speed, having very good first step quickness or accelerative ability would be another advantageous quality for a wicket-keeper (Rosen & Bower, 2006). From match analysis it is evident that at times the wicket-keeper may be the closest fielder to the ball, therefore the ability to get to that ball quickly and prevent further runs and/or enable a run-out is extremely desirable.

In summary, there has been some research into the physical requirements of cricket however there is little research that has focused on the specific requirements of the wicket-keeper. Further research is needed to identify those qualities and assessments that profile wicket-keeping ability. It is thought that tests of aerobic fitness, multi-directional reactive and explosive leg power and straight line acceleration ability would form the foundation of such a testing battery.

Tactical

As previously mentioned, a wicket-keeper is the only fielder who can potentially be involved in every delivery of the innings, making it important that the tactics employed for the wicket-keeper maximise their performance and are aligned with the rest of the team. The wicket-keeper is frequently positioned close behind the batsman and are therefore in a position to influence the match in a number of ways. Outside their basic catching role, the wicket-keeper plays a pivotal role in terms of analysis of players whether it is their own bowlers or opposition batsman in order to set field positions. However, despite this there has been no peer-reviewed literature found which investigates the tactical requirements of wicket-keeping. This is probably due to the fact that cricket tactics are often influenced by external, uncontrollable factors such as the weather, the pitch or even which batsmen are in.

Conclusions

In summary, there is a paucity of published literature on the performance requirements of wicket-keeping in cricket. In order to optimise performance of the wicket-keeper, a deeper appreciation of the movement requirements is needed. For example, wicket-

keeper specific movements should be documented for the duration of a game to establish the performance requirements in a competition scenario. This information needs to be integrated with existing knowledge around the mental aspects of keeping (e.g. reactive decision-making component) so that specific assessment batteries may be developed that could better guide the conditioning and skill development of wicket-keepers. Information like this will enable a more complete understanding of the conditioning requirements for wicket-keepers.

Chapter 4 - A survey of the performance demands of cricket fielding and wicket-keeping

Prelude

From reviewing the literature in the previous chapters, it was found that there was little published scientific research into fielding and wicket-keeping in cricket. In practice it seems that coaches rely on anecdotal evidence and traditional practices. Therefore expert opinion regarding the performance demands of fielding and wicket-keeping was sought in order to gain a better appreciation as to the skills considered important to fielding and wicket-keeping an online survey of players, coaches, and strength and conditioning coaches (n=41) was conducted, the results of which are presented in this chapter. The mental, physical and technical aspects of performance were explored with respect to wicket-keepers, close, inner and outer circle fielders for all three formats of the game. Closed, quantitative questions were used to determine the importance of difference physical characteristics for each fielding category. Qualitative style questions were used to explore opinions in further detail; thematic analysis allowed emerging themes to be identified.

Introduction

Cricket is one of the most watched team sports in the world (Bartlett, 2003), largely due to its popularity in Commonwealth countries. It is a game that has three formats (Test, ODI, and Twenty20) and all players are required to bat and field, whereas only some players bowl. Despite the importance of cricket fielding in the context of the game, there is a paucity of peer-reviewed research investigating fielding compared to the other components of the game (MacDonald, Cronin, Mills, McGuigan, & Stretch, 2013; MacDonald, Cronin, Stretch, & Mills, 2013). The only study which has investigated fielding skills with respect to position (Shilbury, 1990) acknowledged the wicket-keeper as a specialist position within the fielding unit. Despite this there have been only two studies investigating the wicket-keeper specifically. One study investigated the footwork patterns of wicket-keepers (Rosen & Bower, 2006) and the other investigated movement times and lower limb forces with different wicket-keeping crouch techniques (Plunkett et al., 2005).

The physiology of cricket fielding has been investigated using GPS units to establish the amount of time and distances covered at defined exercise intensities (Petersen et al., 2010; Petersen, Pyne, et al., 2009b; Petersen et al., 2011). Cricket fielding has been shown to be a low intensity exercise with short bursts of high intensity efforts followed by long recovery periods (Johnstone & Ford, 2010; Petersen et al., 2010). However, this type of data collection has failed to provide any indication of the direction of movement, which is specifically relevant for the wicket-keeper who has to crouch repetitively and be able to dive and move in all directions. The studies differentiated between player roles, identifying participants as bowlers, batsmen, and fielders. Apart from the wicket-keeper there has been until now, no investigation which differentiates between the different fielding positions.

Cricket is generally considered to be a very traditional game, and anecdotal evidence is often relied upon in coaching and training. The paucity of research suggests a lack of knowledge as to what is required for successful fielding performance in the modern formats of the game. It is important to understand and measure the performance requirements in order to be able to improve performance. Given this lack of information and the scope of what little research there is, the aim of this study was to gather expert opinion of players, coaches, and strength and conditioning coaches regarding the performance requirements of elite fielding and wicket-keeping. In particular, the

technical and physical requirements of fielding in cricket were investigated via the information collated from a web-based survey. It can be postulated that there would be variation in fielding performance requirements in the three different formats, and therefore questions were related specific to the different formats. The information collated from this study should assist in furthering the understanding of some of the performance requirements of elite cricket fielding and wicket-keeping.

Methods

Participants

As expert opinion regarding elite cricket performance was being sought, participants were included if they were involved with at least first class professional cricket, Major Association (New Zealand), State (Australia) or County cricket (United Kingdom). In order to gather the most complete view of cricket fielding performance, participants included players (former and current), coaches and strength and conditioners.

In total, 41 people participated in the study, filling out the survey to varying degrees of completeness. Twenty two participants identified themselves as players (past and present), 19 as coaches (a mixture of head, assistant, batting, fielding and wicket-keeping) and 12 as strength and conditioning coaches. Some participants identified themselves as more than one role, and therefore will have answered questions from the perspectives of each. The online survey was designed to only show the questions relevant to each participant, based on the roles and fielding categories they provided in the demographics section of the survey. This resulted in small and unequal sample sizes for each group, as not all roles and categories applied to each respondent. The participants were all between the ages of 18 and 54 and had a mean of 10 ± 9 years involvement in professional cricket. By completing the survey, participants indicated that they had given their informed consent to participate in the study. The research methods employed in this study were reviewed and approved by the Auckland University of Technology Ethics Committee (12/293).

Data Collection

A mixed methods research design using a survey was used to collect information of interest to the researchers (Wyatt, 2000). The survey was designed using the online survey platform Survey Gizmo (Widgix, 2011). The survey included information for participants and informed consent, a demographics and basic information section and,

sections to be answered by wicket-keepers, close, inner and outer circle fielders, and coaches and strength and conditioners as applicable.

Using the over-arching research question "what are the performance requirements of ODI cricket fielding", the content of the survey was determined by consulting researchers and cricket coaches. The survey was pilot tested before distribution; the functionality of the online survey and the content was reviewed. The consultation with cricket researchers and coaches allowed the survey's face and content validity to be established. The questions were focused on the technical, physical and mental aspects of performance in each fielding position i.e. wicket-keepers, close, inner and outer circle fielders. The overall data collection was qualitative, using a combination of closed and open questions. The questions included ranking the importance of physical fitness and attributes, where participants were asked to assign a number from one to five (1 being not important at all, 5 being very important) and short answer type questions regarding skills and physical attributes. The mental aspect of performance was briefly explored using open, short answer questions. The questions were asked with respect to each format of cricket, however, ODI cricket is the main focus of this research and therefore the bulk of the survey analysis will focus on this format.

Survey Distribution

As the participants in the study were to remain anonymous, the primary researcher did not directly contact potential participants. The invitation to participate and the link to the survey was distributed to contacts in the cricket and scientific community (including researchers and coaches), who were then asked to distribute the survey to potential participants, a technique known as 'snowballing' (Faugier & Sargeant, 1997; Heckathorn, 1997). The survey was sent to contacts in New Zealand, Australia, South Africa, and the United Kingdom.

Data Analysis

Answers to the survey were downloaded and collated on a Microsoft Excel spreadsheet. As there were only 41 respondents to the survey, for the quantitative questions all data was pooled and no sub-group analysis was undertaken i.e. coaches vs. players vs. strength and conditioning coaches. As the survey included questions which required participants to give each physical fitness component an importance ranking of one to five, it was possible to perform some basic analysis. With regards to the closed Likert scale questions, the mean response was calculated for each of the answers and depicted on spider plots for ease of observation and trend analysis. When interpreting these

spider plots, a higher number reflects greater importance attributed to that quality. In terms of the open questions, higher order themes were identified and key points which emerged are also discussed.

Results and Discussion

Given that the purpose of this study was to identify the performance demands of fielding position with respect to different positions, the results are presented and discussed with respect to wicket-keeper, close, inner and outer circle fielding respectively.

Wicket-Keeper

In total, 32 participants responded to the questions regarding wicket-keeping performance. The importance of each fitness characteristic with respect to each format of the game with reference to the wicket keepers can be observed in Figure 4.1. Respondents considered agility, core and lower body strength/power to be the most important physical characteristics for a wicket-keeper; however, no values were assigned an importance rating less than 3.

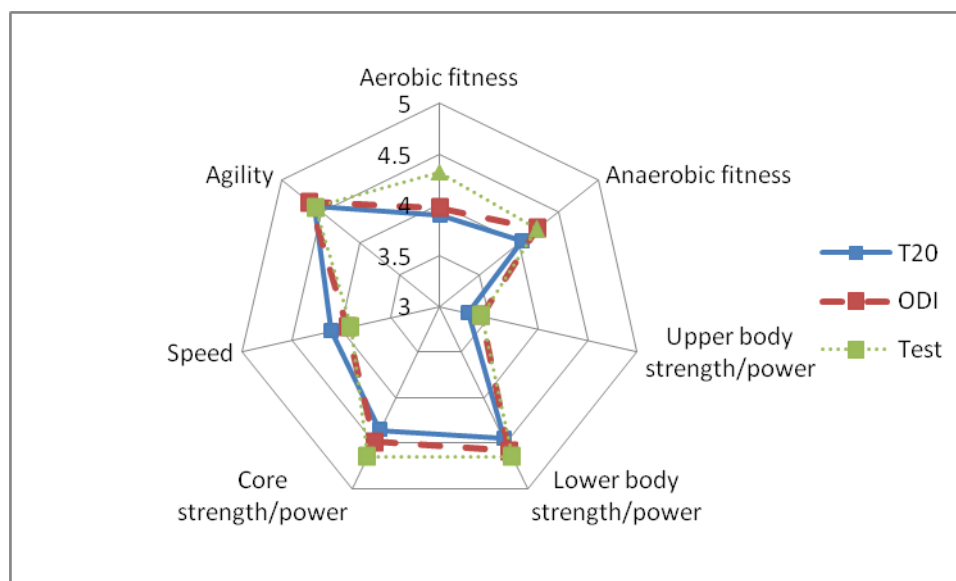


Figure 4.1: Importance of physical characteristics for wicket-keepers with respect to each format of cricket

Agility (4.7) emerged as the most important physical characteristic for wicket-keepers in ODI cricket. In fact the three most important (> 4.2) characteristics remained the same across the three formats; agility, lower body and core strength/power. Upper body strength/power (3.4) was considered to be the least important attribute in all three

formats, which was logical due to the wicket-keeper not being required to throw long distances.

Thematic Analysis of ODI Cricket

Several themes emerged from the open-ended questions posed to players and coaches that can be broadly classified as skill and technique, body type and physical attributes, movement and stillness, mental factors.

Skill and technique

Of the players and coaches who responded, several highlighted the importance wicket-keeping technical ability and skills (referred to as glove-work). Avoidance of injury was frequently cited when players were asked the reason for their particular crouch technique. In addition to the glove-work required of wicket-keepers, in the modern game a wicket-keeper is expected to be proficient in batting to make significant contributions to the score. Therefore, players are likely to be selected based on their batting ability, in addition to the ability to keep wicket. Of the 10 wicket-keepers surveyed, the majority ($n = 6$) batted in the middle order, two batted in the top order and two batted in both the top and the middle order.

Body type and physical attributes

The respondents suggested that certain physical attributes would be advantageous for a wicket-keeper; the ideal being "short of stature and lean". The phrase 'low skin folds' was repeatedly used when asking about the physical characteristics for wicket-keeping. This suggests that there is a certain degree of value placed on anthropometric measurements. One coach responded that the ideal physical attributes for a wicket-keeper would be "proprioception, speed, and agility, perfect balance of strength, power and size".

Movement and stillness

The phrase 'power Z position' was used by several respondents in response to the question regarding the pre-movement for a wicket-keeper. "The Power Z position is when the knees are bent forward and the athlete is on his toes, the head is forward and the torso is obviously leaning forward as well, in essence the body forms the shape of a Z somewhat, I refer to it as the 'spring' that is coiled ready to be released!" was how the Power 'Z' position was explained by one coach, another described it as "the pre loading position a wicket-keeper gets into before they need to react". An online search of the term described the 'power z position' as "the posture that provides stability, control,

power and appropriate head and hand height to a wicket keeper preparing to move into a position to take a ball" (Garaway, 2012).

It is logical to think that movement is important for performing sport specific tasks however the importance of 'stillness' or stability prior to movement was mentioned repeatedly by players and coaches alike when asked about the technical factors of wicket-keeping. Coaching literature recommends that a wicket-keepers stance should give them the best possible sight of the ball, to watch it unblinkingly (Woolmer et al., 2008). This is to enable them to have a clear view of the ball and to have a stable balance point from which they can react in any direction.

Mental Factors

The importance of the mental aspect of performance emerged repeatedly from participant's responses. When players were asked why they became a wicket-keeper, several players made the point that they wanted to be involved with every ball of the innings, as they had "bags of energy" and were "easily distracted in the outfield". Several players also highlighted the fact that a coach had steered them in the right direction when choosing to become a wicket-keeper. It seems that certain personality traits such as enthusiasm and the ability to concentrate for every ball of the innings might be useful for a wicket-keeper, and that it is important for coaches to be able to recognise these traits in young players so that they may be developed into a wicket-keeper.

Close Fielder

In total, 21 participants responded to the questions regarding close fielding performance. The importance of each fitness characteristic for close fielders can be observed in Figure 4.2. Respondents considered agility, core and lower body strength/power to be the most important physical characteristics for a close fielder; however, no values were assigned an importance rating less than 3.5.

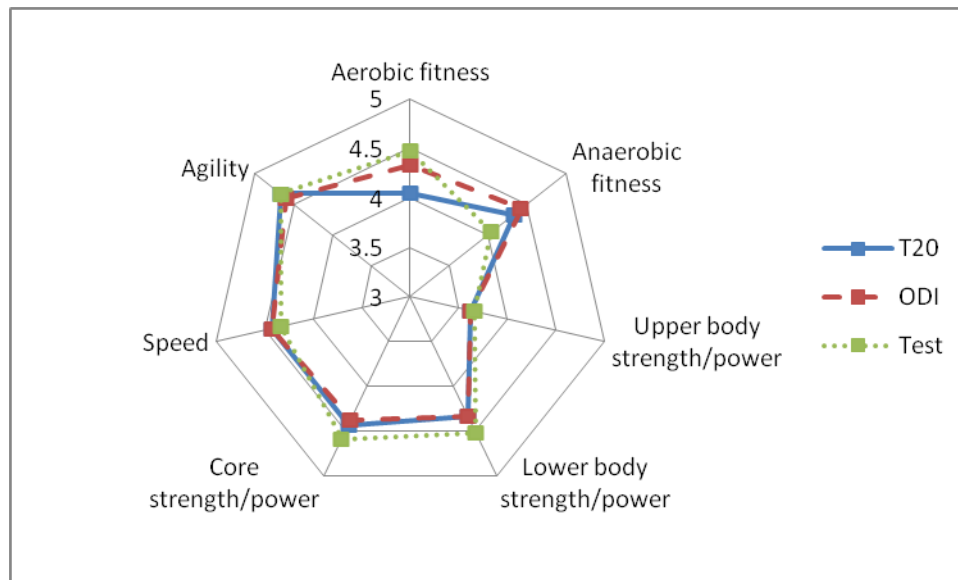


Figure 4.2: Importance of physical characteristics for close fielders with respect to each format of cricket

Anaerobic fitness, and upper, and lower body strength/and power were considered to be less important the shorter the format. In fact, upper body strength/and power was comparatively the least important physical attribute from all formats of cricket (<3.7), which is slightly surprising given that it has been demonstrated as important for cricket batting (Taliep et al., 2010). The importance of aerobic fitness increased as duration of the format increased (T20 4.1, ODI 4.3, and Test 4.5). In all three formats there was ≈ 1 point difference between the most important (agility) and least important (upper body strength/power) characteristics. No participant indicated that there were any differences in close fielding in terms of technical or mental factors between the three formats of cricket.

With reference to the ODI format, none of the physical characteristics received a score less than 3.6, which suggests that respondents considered all physical characteristics to be reasonably important for close fielders. Agility (> 4.6) emerged as being particularly important for close fielding performance (for all formats of cricket); speed (4.4) was the second most important characteristic for close fielders. Upper body strength/power again emerged as the (comparatively) least important physical attribute for close circle fielders (3.6). By definition close circle fielders are placed in positions close to the batsmen, and therefore do not have any great distances to throw. However, they are usually required to return fielded balls quite quickly in order to attempt to dismiss the batsmen. This would suggest that reactive speed rather than strength is important for fielders in these close positions.

Thematic analysis of ODI cricket

Several themes emerged from the open-ended questions posed to players and coaches including preparation for movement, mental factors and body type and physical attributes.

Preparation for movement

When asked about the pre-movement phase for close fielders, several coaches highlighted the importance of the preparatory movement. Phrases such as 'wide stance' and 'split step' were used when they responded to these questions. The coaching literature refers to this as a 'trigger' movement. Jonty Rhodes, arguably one of the best fielders of the modern game, used a trigger movement which left him balanced, with weight equally spread over both feet, but also primed and energised to move in either direction as required (Woolmer et al., 2008).

Getting or staying low prior to movement was also highlighted. A balanced, low stance is important for close fielding. This is because it is easier to move upwards for a catch than go down for it (Woolmer et al., 2008). Due to the proximity to the batsmen, players fielding in this area have very little time to react or adjust position; therefore appropriate preparation for movement is important.

Mental Factors

In response to questions regarding the mental requirements of close fielding performance coaches used the words 'concentration' and 'focus', emphasising their importance. One coach said that close circle fielders need to "set position, read batsman's movement, narrow focus to contact area". The greatest fielders in the game especially those who occupy positions close to the bat, often have highly advanced skills of anticipation. To be a good catcher requires excellent reflexes and alertness and anticipation (Woolmer et al., 2008).

One player commented "again it's about attitude... If you want to be a great fielder and love it then getting ready for each ball should be natural". Another said, "Just tell myself to get involved and this keeps me alert. My routine if this is one is an attitude to want the ball which creates my sense to ready to move and exercise".

Body type and physical attributes

When asked to comment on any other physical qualities which would be ideal for a close fielder, numerous responses suggested there are ideal physical characteristics for a

close fielder. On this point players and coaches seem to agree that close fielders should be "shorter in stature. Ability for explosive movement. Lean, but muscular".

A player made the comment that close fielders should have "long limbs but not excessive height"; another response said "big hands". These responses suggest that there should be anthropometric measures which would help identify players who have the potential criteria for close fielding. However, the traits mentioned are quite specific, and while having them may be seen as advantageous, it would be unwise to exclude players from this position due to anthropometric measures.

Inner Circle Fielder

Twenty participants responded to the questions regarding close fielding performance. Figure 4.3 illustrates the fact that the only characteristics in which there was a marked difference (1 point) in importance between formats were anaerobic (less important for ODI and Test cricket than T20) and aerobics fitness (less important in ODI cricket than the other two formats). Predictably, aerobic fitness increased in importance as the duration of the game increased (4.2, 4.3, and 4.5 for T20, ODI, and Test cricket respectively). Upper body strength/power was once again the least important attribute for all formats of cricket, being given an importance value of ≈ 3.7 between the three formats. While it is the least important attribute, this is the highest importance value provided thus far; suggesting that upper body strength/power is increasing in importance as the fielding positions move further from the batsmen.

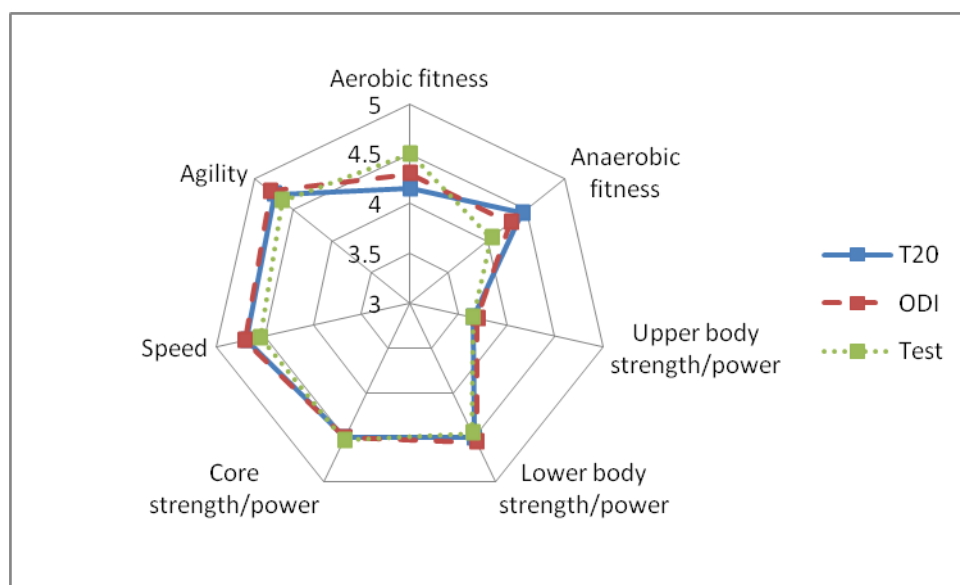


Figure 4.3: Importance of physical characteristics for inner circle fielders with respect to each format of cricket

In terms of the ODI format, agility (4.8) has emerged once more as the most important physical characteristic for inner circle fielding performance. However, as speed becomes increasingly important as fielders move further away from the batting crease, this is reflected in speed being given an importance value of 4.7, just 0.1 behind agility, suggesting that they are almost equally important. In fact, the only physical characteristic which was given an importance value less than 4 was upper body strength/power. Inner circle fielders are required to stay within the 30 yard (27 m) inner circle of the cricket field and therefore are not required to throw great distances.

Thematic Analysis of ODI cricket

Several themes emerged from the open-ended questions posed to players and coaches that can be broadly classified as mental factors, technique and body type and physical attributes.

Mental Factors

When questioned about mental routines in fielding one player responded "always attitude for me. Routine means little until you have the right attitude of wanting the ball to come to you. This to me is 90% of fielding because technique means nothing unless you want to play your role in the field." Another said "switch off after ball is bowled. Relax. Switch on as the bowler begins to approach the crease. Tell myself that this ball is coming to me". The mental component of performance appears to be a theme which is occurring for each of the fielding categories discussed thus far.

Technique

From the responses regarding technical aspects of inner circle fielding performance, it is clear that using the correct technique for catching and throwing is important. 'Hand position' in particular was repeatedly mentioned in responses; another said "fingers up/fingers down". From these responses we can infer that there are different techniques required in different scenarios, and it is important to be able to select the correct technique as appropriate. For example, coaches generally advise that fingers should be pointing upwards when taking high catches, and pointing downwards (so that the hands form a cup shape) when catching low. There are even such subtleties in taking high catches; fingers up with the palms of the hands turned towards the face is referred to as the 'English' method. The 'Australian' method of high catching uses fingers up, palms facing outwards toward the ball; this method is often used in bright conditions, so that

the fielder can get a better view of the ball against the light in order to take the catch (Woolmer et al., 2008).

Technical considerations regarding throwing were also highlighted; coaches repeatedly suggested that players had to be quick to "realign to target" and "establish some sort of base" to be able to throw accurately. The ideal throw is thought to be an overarm baseball throw, however the nature of the game doesn't always allow for ideal technique (in fact, fielders may need to throw the ball underarm, or even backhand), therefore it is important that fielders set themselves up to throw by regaining balance and control of the body as quickly as possible. Respondents emphasised that throwing technique included the whole body, mentioning feet and hips specifically when generating throwing speed. One respondent said that inner circle fielders should be "light on their feet with good hands, good span, and quick throw". The throw, like a bowler's action, must be smooth, fluent and repeatable .

Footwork

It became clear from the inner circle fielding responses that footwork was a key part of inner circle fielding success as it was mentioned in every phase of throwing performance (pre-movement, movement, catch and throw). The timing of footwork in particular was highlighted as an important technical part of performance. In the pre-movement phase coaches recommended that players stay on the balls of their feet, with a 'stable base' or 'set position'. Another respondent said that the inner circle fielder pre-movement should be a "split position, [with] weight on balls of feet". Several different types of preparatory footwork were identified from the responses, for example split, drop jump and jump, which are trigger movements used to get in an ideal, stable position to move in any direction (Woolmer et al., 2008). Descriptive words such as 'smooth' and 'efficient' were used to describe footwork and movement. Balance was another factor which was mentioned in all phases of the performance (pre-movement, movement, catch and throw).

Outer Circle Fielder

Nineteen participants responded to the outer circle fielding questions. Interestingly, outer circle fielding is the only fielding category in which the most important physical characteristic was not agility and the most important characteristic was different for each format (Figure 4.4). The most important characteristics for outer circle fielding were lower body strength/power (4.6), speed (4.8) and aerobic fitness (4.7) for T20, ODI and Test cricket respectively. As the duration of the game increases, there is

increasing emphasis put on the importance of aerobic fitness and speed when compared to other formats.

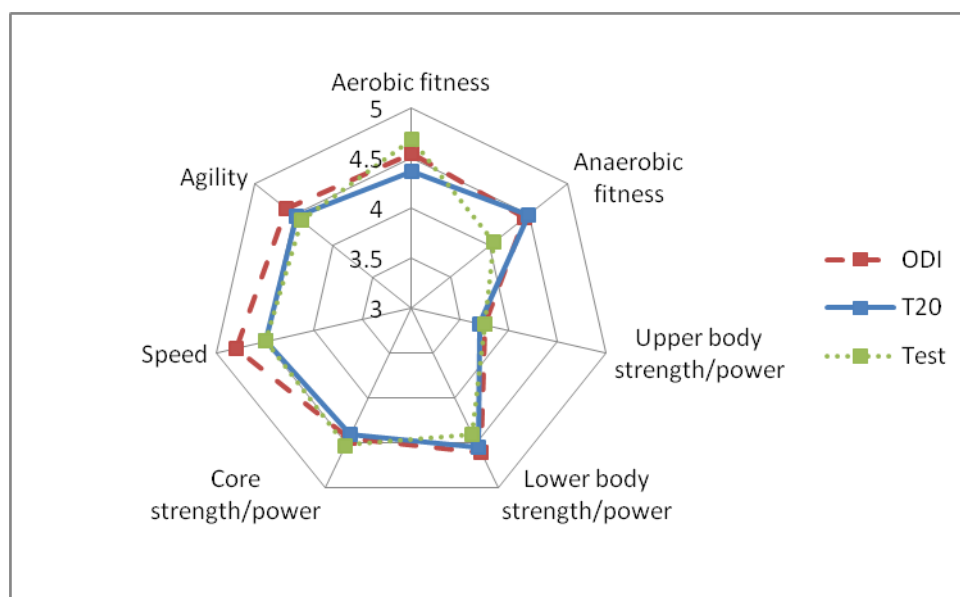


Figure 4.4: Importance of physical characteristics for outer circle fielders with respect to each format of cricket

Outer circle fielding is the first and only category in which agility was not considered to be the most important physical characteristic for ODI cricket. Instead, speed (4.8) was reported to be the most important characteristic in ODI cricket, followed by lower body strength/power and agility (both 4.6) respectively.

The fact that aerobic fitness was the most important attribute (4.7) for an outer circle fielder in Test cricket is testament to the large distances they can cover, up to 14 km per day in a Test match (Johnstone & Ford, 2010). The greater intensity and explosiveness of T20 cricket would contribute to lower body strength/power, anaerobic fitness (sprint ability) and speed being considered almost equally important for T20 outer circle fielders.

Thematic Analysis of ODI cricket

Mental Factors

Players reported that they employed not only physical but mental routines as well when preparing to field in the outfield. This included watching the ball, bowler and batsman for visual cues, and 'switching off' or relaxing between deliveries. One player explained "switch off after ball is bowled. Relax. Switch on as the bowler begins to approach the crease. Tell myself that this ball is coming to me." Another mentioned the fact that he

had a preparatory checklist he used to get ready. Anticipation was repeatedly mentioned by coaches as important for in the pre-movement phase of performance.

Technique

Given the distances to cover in the outfield, it is importance to have a strong throw; both players and coaches agreed on this fact. One coach mentioned that "fast shoulder rotation produces a strong throwing arm". In fact, strong throwing was repeatedly mentioned as being important for outer fielding performance. Given this, the authors were surprised that upper body strength/power was consistently rated as the least important physical characteristic for fielding. However, while considered unimportant when compared to the other characteristics, it received an importance value greater than 3.4 for all fielding positions, further supporting the fact that no physical characteristic was unimportant. Additionally, a coach mentioned that an outer circle fielder should be fast across the ground. One respondent also mentioned flexibility as an important attribute for an outer circle fielder to have.

Further Discussion

Comparing the importance of physical attributes for all positions on the same plot allows the relative differences in importance to be observed (Figure 4.5).

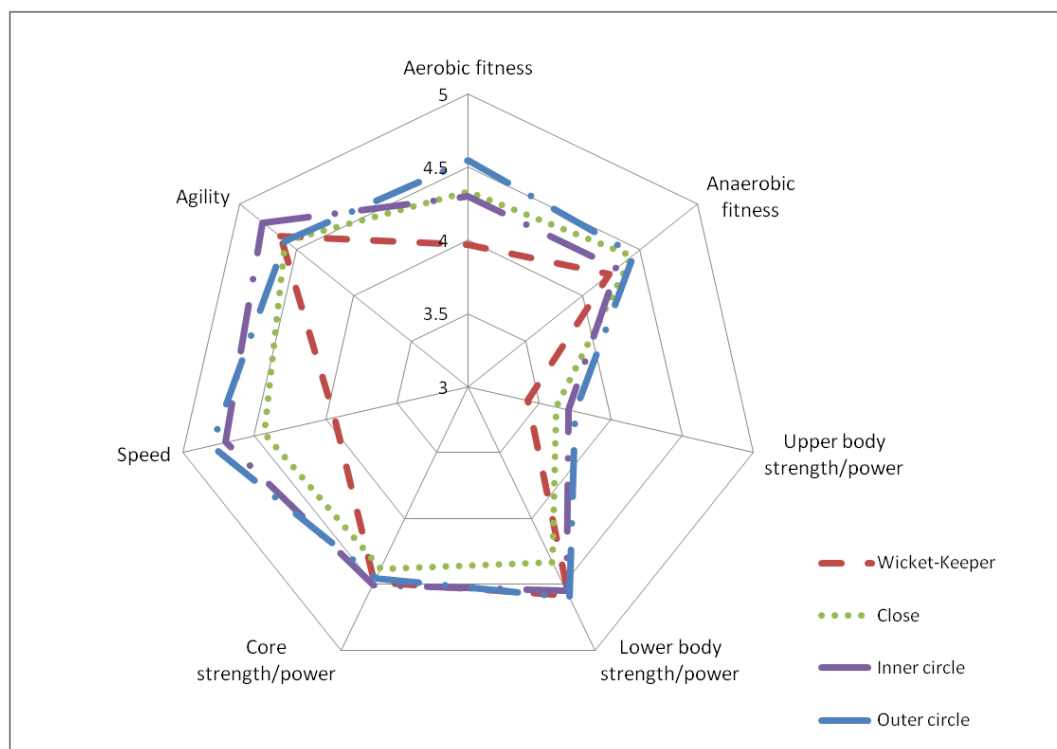


Figure 4.5: Importance of physical characteristics for each fielding category in ODI cricket

Agility, aerobic fitness and core strength and power were considered almost equally important for all fielding positions. This suggests that all fielders require a certain level of agility and athleticism for cricket fielding. Speed and aerobic fitness increased in importance as fielders move further out into the field and have greater distances to cover. While upper body strength/power was considered to be the least important physical attribute for all positions, it cannot be considered to be unimportant (due to the throwing requirement of fielding) and does increase in importance as fielders move to the outfield. Throughout the survey, respondents suggested that low skin folds/leanness was beneficial for all fielding categories. This suggests that cricketers should be as lean as possible without compromising their speed or strength. For all positions, the importance of the mental component of performance was commented on. However, there was no mention made of how the mental aspects of performance could be quantified or assessed. This highlights the mental aspects of performance in cricket as an area in which there is a need for further research.

Of the total respondents, 20 identified themselves as some type of coach. In general, coaches agreed that there was distinct variability of the skills required to field at different positions, but highlighted the importance of players possessing as many of the skills and qualities as possible. In the coaches only section of the survey, coaches were asked about the methods they use to test different aspects of physical fitness. Coaches generally all used a yoyo/beep intermittent recovery test to measure aerobic fitness. There was less agreement between the tests used for measuring anaerobic fitness; several coaches reported that they used repeated sprint tests but there was also mention of the Wingate test, 'strength and flexibility tests' (with no further elaboration). A variety of One Repetition Maximum (1RM) tests were reportedly used to assess the lower body (squats, counter-movement jumps, dead lifts) and upper body strength/power (push ups, bench press, prone pull ups) respectively. Core strength/power was generally assessed with planks, lumbar pelvic control testing, one coach also mentioned that he made sure to include some sort of rotational test also. Speed was generally assessed over a variety of distances ranging from 5 to 30 metres. The 5-0-5 and T-agility tests were reportedly used to assess agility; however in particular, responses highlighted the lack of a valid cricket specific fielding agility test. Generally the same physical tests were used to assess all players, with little to no differentiation between fielding positions.

The disconnect between coaches' opinion (and the anecdotal evidence on which they rely) and facts supported by scientific research is evident when coaches suggest that the ability to throw strongly is necessary for an outer circle fielder but they do not rate upper body strength and power as a desirable attribute. This is a limitation of the use of expert opinion surveys for research purposes. It also suggests that coaches may not understand the physical qualities which produce the desired performance result (i.e. a strong throw), a fact which should be kept in mind and addressed when conveying research results to coaches.

Conclusions

The results provided insight into the factors which coaches and players believed were important attributes for each fielding category for each format of the game. Agility emerged as the most important physical characteristics for wicket-keepers, close and inner circle fielders, and the second most important attribute for outer circle fielders behind speed. However, no attributes were given an importance value of less than three

on the Likert scale, suggesting that none can be considered unimportant for any fielding category.

Several emergent themes recurred throughout the survey including the importance of specific techniques and movement patterns, anthropometric characteristics and mental factors. The importance of mental factors on performance was emphasised repeatedly, particularly for the wicket-keeper and close fielders. This information provides insight into some of the demands associated with wicket-keeping and fielding. The findings of this survey can provide good indicators for the assessment of players' suitability for different positions, for the development of training programmes, and could be of assistance to coaches in selection of players and in providing guidance to the players. The information also highlights some areas that require further research.

Chapter 5 - Methodological issues concerning video analysis in cricket

Prelude

From the previous chapters, a higher level of understanding around fielding and wicket-keeping has been developed. However, it is obvious from these chapters there are certain areas that need further investigation for example, event coding the type of movement and skills implicit in fielding and wicket-keeping. Prior to engaging in such analyses, we need to have some understanding of the limitations of the technology being used to gather the information. Generally, for a measurement system or research instrument/technology to be accepted for use in empirical research it must be proven to be reliable and the validity of the system established by comparing results against a "gold standard" system. It was thought that collecting footage from the side-line of a cricket match might be a more appropriate method for video analysis as compared to broadcast television footage. Therefore, the purpose of this chapter was to compare the reliability and validity of video analysis, using televised footage and video footage collected from the side-lines in order to determine which form of footage is most acceptable for performance analysis research.

Introduction

Cricket is a game steeped in tradition, however it has slowly but surely been evolving over recent times to match popular demand. Shorter, more audience-appealing formats of the game have been created (ODI and Twenty20 cricket), and with them technology such as Hawkeye (Hawkeye Innovations Ltd., 2015) and the Decision Review System (DRS) (International Cricket Council, 2013) are being adopted for use during the game. Performance analysis aims to advance understanding of game behaviour with a view to improving future outcomes (McGarry, 2009). Performance analysts are being employed by professional teams in order to analyse their own and opposition teams to gain understanding of tactics and performance strength and weaknesses. For example it is widely used by team sports such as Australian Rules Football (Appleby & Dawson, 2002; Dawson et al., 2004) and Rugby League (Sirotic et al., 2009). This practice is slowly being adopted by cricket teams; for example, West Indies Cricket use the performance analysis software SportsCode (2008) and NZC have developed their own bespoke software Feedback Cricket (FeedbackSport, 2006) which is also used by the England cricket team. Video analysis is widely used in sports and exercise in a variety of contexts, including player tracking, event coding and movement analysis (Mytton, Archer, Thompson, Renfree, & St Clair Gibson, 2013). Analysts can provide insight and feedback throughout a match, by capturing video footage as play takes place, using either the televised footage or collecting their own footage using purposefully placed cameras. A great deal of video footage that is used for performance analysis in sport is from televised footage (J. J. Williams, 2007). Footage is collected from multiple cameras and angles, with broadcast footage changing from camera to camera in order to follow the ball. However, using such an approach it is quite likely that some of the fielding activity will be missed due to the changing camera views following the ball.

Given that video analysis is a relatively new practice in sports science and particularly in cricket, some consideration and investigation of the practicalities of its use in cricket is warranted. The purpose of this study therefore was to investigate and discuss the merits and limitations of video analysis in cricket by comparing two different types of video footage of the same match; televised footage and footage collected by the author using a specific setup of cameras. In particular, issues of reliability, validity and practicality were investigated.

Methodology

Subjects

The subjects ($n = 22$; average age 27.7 ± 4.0 years) were New Zealand and England international cricket players who took part in an ODI match (Eden Park, Auckland, 2013). The university ethics committee (AUTEC) was consulted; no ethics approval was needed as data collection was taking place in a public place with no interaction or interference with players.

Equipment

Four video cameras (2 x Sony Handycam, 2 x JVC Everio) were placed around the ground (see Figure 5.1) in order to collect video footage of as much of the field as possible. Cameras one and two were set up to capture the wicket-keeper at either end of the pitch. Cameras three and four were placed on opposite sides of the pitch, in order to capture as much of the play as possible, assuming that anything missed by one camera would be visible in the opposite view.

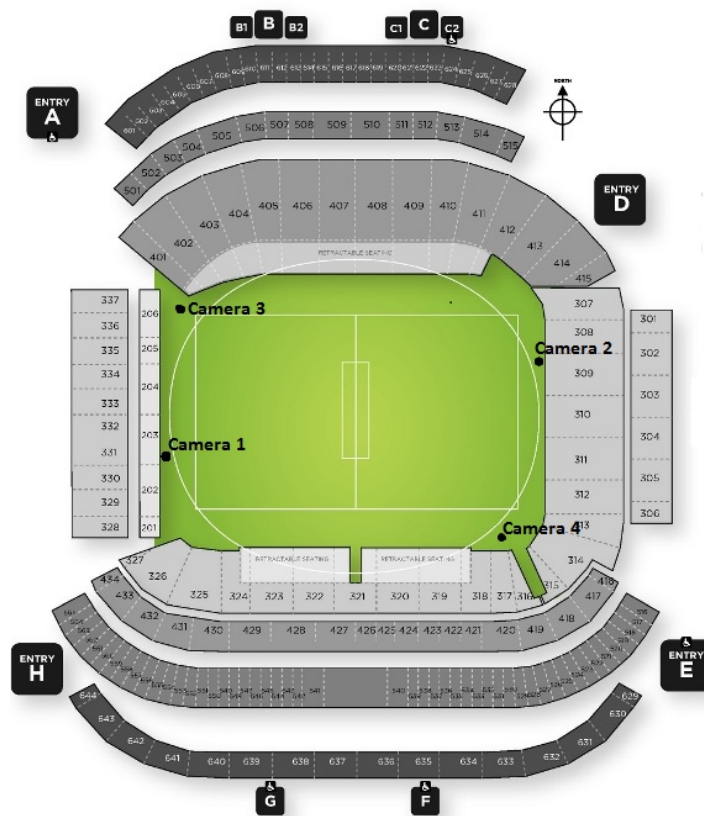


Figure 5.1: Schematic of approximate camera placement at Eden Park

The cameras were mounted on tripods and set up at a height of 1.25 m. This height was selected to ensure that the cameras did not protrude too high over the advertising boards

so as not to distract players and to avoid equipment being damaged by the cricket ball. Research assistants volunteered to operate each camera positioned around the ground. Each was provided with a notebook so that field notes could be taken (i.e. any pertinent observations, and when recording was started and stopped). To avoid large video file sizes and the potential corruption of video footage, the recording was stopped whenever there was a significant stop in play (i.e. when a wicket fell or drinks were taken). In addition to the video footage collected on the day, the televised footage was obtained from the host television broadcaster post match.

Video Analysis Methods

Some video editing was required to make the collected video ready for analysis. Video editing was performed using the software PowerDirector (Cyberlink, 2012). Given that cameras one and two were placed at either end of the crease on opposite sides of the pitch, in order to keep the wicket-keeper in view throughout the entire innings, the camera view was alternated between cameras as the play changed ends at the end of each over. This required manually cropping each video into one over segments and piecing together the alternating views over by over. Footage from cameras three and four were synchronised and 'stacked' (placed side by side) so that both video views could be viewed simultaneously. Following the initial video processing, all footage was imported onto a MacBook Pro laptop and analysed using a video analysis package (SportsCode Elite v.8.10 (Sportstec, 2008)). All coding and analysis was undertaken by one experienced performance analyst. The matrix function of SportsCode was used to export the results of each innings into Microsoft Excel for further analysis. The activities of interest (see Table 5.1) were identified from literature reviews (Chapters 2 and 3) and a survey of cricket players and coaches (Chapter 4).

Table 5.1: Selected wicket-keeping and fielding activities subjected to validity and reliability tests, including definitions.

Wicket-Keeping	Fielding
Position specific activities studied	
Crouch - Wicket-keepers' preparatory stance as the bowler runs in, technique differs due to individual preference	Field - The player retrieves the ball following a shot played by a batsman.
Lateral shuffle - Lateral movement consisting of an initial small step followed by a side skip	Misfield - The fielder makes contact with the ball but fails to retrieve
Lateral step - Movement of one foot laterally away from the sagittal plane, the other remains still	Stop - The fielder stops the ball with a foot or part of the body but does not collect it with the hands.
Missed take/reception from field - The ball makes contact with the gloves after coming past the bat or following a throw from another fielder but is not caught successfully	Missed stop - The fielder makes contact with the ball but fails to stop the ball
Reception from field - The wicket-keeper catches the ball from a throw from another fielder	Sliding stop - Descending onto one knee to slide next to the ball, allowing momentum to regain footing (Woolmer et al., 2008).
Run up to the stumps - When the wicket-keeper is standing back from the stumps, then moves up to the stumps to receive the ball from the field, usually at a jog	Run out - A fielder receives removes the bails before the batsman has made his ground, resulting in the dismissal of the batsman, either with a direct hit of the stumps with a throw from the field or by passing to another fielder.
Take - The ball has gone past the batsmen without touching the bat or gloves, the wicket-keeper catches the ball	Support run - When a second fielder moves at speed from his position in any given direction to support another player in chasing the ball.
Underarm throw - Ball is drawn back with the hand pointing to the ground, before the release of the ball.	Throw - When the ball is propelled through the air by a movement of the arm and hand. Can be underarm, sidearm or overarm.
Common activities studied	
Catch - The ball has hit the bat or gloves, and the ball is caught by the wicket-keeper, dismissing the batsman.	Catch - The ball has hit the bat or gloves, and the ball is caught by a fielder, dismissing the batsman.
Dive - When the wicket-keeper dives to one direction (usually laterally, occasionally forward) to attempt to take or catch the ball	Dive - When a fielder dives to one direction (usually laterally, occasionally forward) to attempt to stop or catch the ball
Jump - The wicket-keeper projects vertically in an attempt to take or catch the ball	Jump - The fielder projects vertically in an attempt to take or catch the ball
Sprint - When the wicket-keeper moves at speed from his position in any given direction to cut off, field or catch the ball.	Sprint - When a fielder moves at speed from his position in any given direction to cut off, field or catch the ball.

It should be noted that there were more fielding and wicket-keeping activities, however some activities (such as certain types of dismissal) may occur only once or twice, if at all during a particular match. For this reason, only the variables which repeatedly occurred during the match were used for reliability and validity testing.

Statistical Analysis

The intra-coder reliability was assessed for each activity by coding an innings from the televised footage twice, separated by a period of a month. In order to facilitate analysis, data was exported from SportsCode in 5 over segments; the data consisted of frequencies of the fielding and wicket-keeping activities. Testing the same coder's reliability is essentially a test-retest research design; therefore it was possible to use simple parametric reliability statistics. The reliability of the coding was determined by using a reliability spreadsheet (Hopkins, 2000). The spreadsheet facilitated the calculation of ICC and standardised typical error (sometimes called the standard error of measurement). The ICC and standardised typical error can be used as measures of the level of agreement between two sets of coding data by the same individual. The magnitude of the standardised typical error was evaluated using the modified Cohen scale (<0.2 , $0.2-0.6$, $1.2-2.0$, $2.0-4.0$, > 4.0 for trivial, small, moderate, large, very large respectively) (Hopkins, 2004; Smith & Hopkins, 2011).

In order to quantify the level of agreement between the coding of the two different camera views, the difference between camera views was calculated for each coded variable. This was calculated by subtracting the televised footage frequency counts for each variable from the corresponding frequency count from the collected footage for each innings and dividing by 2. This allowed the level of agreement between the televised and the collected footage to be presented as a positive or negative value. For example, if a variable was underreported by the televised footage compared to the collected footage the percentage difference would have a negative sign, and vice versa.

Results and Discussion

Wicket-Keeping

The results of the reliability analysis are presented in Table 5.2. The ICCs for all activities, apart from the lateral footwork were between 0.85 and 1.00. Variables which had an ICC of 1.00 such as types of dismissals, had very clear operational definitions and occurred comparatively infrequently in the match, and therefore there was no error associated with the coding of these activities. The crouch is a fundamental movement of wicket-keeping which occurs every delivery of the innings; while there was an ICC of 1.00 there was a small standardised typical error (0.08). This can be attributed to some human error and inattention in the coding process. However, the frequency of crouches meant that the effect of this error was trivial on the modified Cohen scale. The magnitude of the standardised errors associated with the crouch, catch, missed take/reception, jump, dive and take correspond to a trivial effect on the modified Cohen scale (<0.2).

Table 5.2: Intra-coder reliability for wicket-keeping coding

Activity	Intra-Class Correlation	Typical Error
Crouch	1.00	0.08
Catch	1.00	0.00
Missed Take/Reception	1.00	0.00
Jump	1.00	0.00
Dive	1.00	0.00
Take	0.99	0.12
Reception from field	0.99	0.11
Sprint	0.96	0.18
Underarm Throw	0.94	0.30
Run up to stumps	0.94	0.31
Lateral Step	0.83	0.54
Lateral Shuffle	0.55	1.02

The magnitude of the errors increased when it came to the movement activities of wicket-keepers. The error in the running and sprinting can be attributed to the fact there is a level of subjectivity in distinguishing between running and sprinting (0.18 and 0.30 typical error) when it is not possible to actually measure running speed. While these correspond to small to moderate effects, these results should be considered with the knowledge that these two variables are subject to interpretation by the observer. The errors increased significantly when it came to identifying the lateral footwork wicket-

keepers used; with lateral step and shuffle having standardised errors of 0.54 and 1.02 respectively. This corresponds to moderate to large effect sizes on the modified Cohen scale. While clear operational definitions for these movements were used, due to changing camera angles and views, perspective issues and speed of movement it was difficult to consistently distinguish between movement types. These errors should be taken into account when utilising results of lateral movement coding. Nevertheless, for most activities there would seem an acceptable level of reliability (Sirotic et al., 2009).

The results of comparing coded television footage to footage collected from the side-line can be observed in Table 5.3. Cameras one and two were placed on the side-line specifically to capture the footage of the wicket-keeper, therefore it was expected that the collected footage would be the most efficient to capture wicket-keeping footage. Hence the frequency of activities would be greater in the collected video footage and the difference (error) between the collected footage and the televised footage should be positive.

Table 5.3: Average difference of wicket-keeping activities from collected footage compared to television footage

Activity	Innings 1		Innings 2		Average Difference
	Collected	TV	Collected	TV	
Underarm Throw	125	77	81	40	44.5
Run up to stumps	153	119	121	97	29.0
Reception from field	112	96	94	86	12.0
Jump	9	7	2	2	1.0
Missed Take/Reception	4	3	2	2	0.5
Crouch	271	267	229	233	0
Catch	3	3	3	3	0.
Dive	0	0	4	4	0.
Sprint	1	2	3	4	-1.0
Take	34	36	14	14	-1.0
Lateral Shuffle	29	53	96	75	-1.5
Lateral Step	48	62	36	49	-13.5

Five of the eight wicket-keeping specific activities were under-reported by the televised footage compared to the collected footage, with errors ranging from 0.5 to 44.5. These errors were due to the changing camera used for broadcast footage to follow the play; it was not always possible to see the wicket-keeper after a shot had been played. This was

particularly the case for the run up to the stumps and underarm throws (29.0 and 44.5). Conversely, sprints, takes, and lateral movements were underreported by the collected footage compared to the televised footage, hence negative errors were reported. The errors associated with sprinting can likely be attributed to the human error and subjectivity in distinguishing between running and sprinting. The effect of the error is greater given that sprints are infrequently occurring events for a wicket-keeper. The greatest error was -13.5 associated with the lateral step. Distinguishing between the lateral step and the shuffle is a subjective exercise and not assisted by the placement of cameras one and two perpendicular to the batting crease. Lateral movements were directly towards or away from the cameras and therefore difficult to see on video due to camera perspective.

The cameras collecting for the wicket-keeper were positioned so that he was always in view, so the differences seen in the two types of footage can be attributed to the fact that the televised footage does not always have the wicket-keeper in view, although in this case, the average error cancelled out to zero. Catches and dives had very clear operational definitions, and occurred relatively infrequently so there was no difficulty in identifying them from both types of video footage.

Fielding

The results of the reliability testing are presented in Table 5.4. As for wicket-keeping, variables which had very clear operational definitions and occurred infrequently (such as type of dismissal) had an ICC of 1.00 and no errors associated with them. In fact, the ICC for all activities was greater than 0.85. The typical errors associated with fielding variables ranged to 0.14 (throws) to 0.41 (field), corresponding to small to moderate effects. The main source of this error can be attributed to the changing camera views and angles used in broadcast footage. This made ascertaining which player fielded the ball more difficult, as often cameras views switch to other areas of the field following a shot being played. These ICC and standardised typical error results suggest an acceptable level of reliability. However, results of coded variables with moderate effect sizes should be used in further research with consideration of the likely error involved.

Table 5.4: Intra-coder reliability for fielding coding

Activity	Intra-Class Correlation	Typical Error
Catch	1.00	0.00
Run out	1.00	0.00
Throw	0.99	0.14
Sprint	0.99	0.13
Sliding Stop	0.97	0.23
Stop	0.95	0.29
Misfield	0.94	0.25
Missed Stop	0.92	0.36
Support Run	0.91	0.38
Dive	0.91	0.37
Field	0.88	0.41

The camera set up on the side-line consisted of only two cameras to capture the fielding players, therefore one would not expect the set up to capture any more activity than the televised footage. The average differences between the innings are shown in Table 5.5.

Table 5.5: Percent difference of fielding activities from collected footage compared to television footage

Activity	Innings 1		Innings 2		Average Difference
	Collected	TV	Collected	TV	
Missed Stop	1	1	12	8	2
Run out	1	1	0	0	0
Sliding Stop	4	1	6	9	0
Catch	5	5	2	2	0
Sprint	8	8	16	17	-0.5
Throw	139	143	135	133	-1
Jump	0	0	0	2	-1
Misfield	0	2	1	2	-1.5
Support Run	2	8	4	7	-4.5
Field	177	178	175	185	-5.5
Stop	7	11	8	16	-6
Dive	7	25	16	26	-14

There were no differences between the two coding modalities for key events, such as dismissals. In fact, the results using the average difference criterion shows that there is only slight difference between the typical fielding activities, with the commercial set up showing slightly more of these activities. The average percentage differences for

frequently occurring activities (i.e. field, throw and sprints) were negligible. This was because these events had very clear operational definitions and were therefore easy to distinguish on video.

Conversely, other variables were significantly under-reported by the footage collected from the side-line. The side-line cameras used a wide view to capture as much of the field as possible and hence players appeared small in the camera view; this also meant that some variables were difficult to distinguish in the captured camera view particularly stopping and diving for the ball. The televised footage tended to focus on the spectacular activities in the field, therefore diving will be shown frequently; the cameras on the side-line were not set up to be able to focus on specific actions. The magnitude of the effect of these errors is all the greater as the occurrence of these activities is comparatively low.

While it was possible to identify basic fielding actions due to the positioning of the cameras at ground level, such positioning meant that the footage was foreshortened and players appeared very small in the field of view. This meant that it was difficult to see close detail of performance (for example, one or two handed fielding actions) and identify specific fielding positions.

Implications for Future Research

These findings suggest that there are merits and limitations to using both types of video footage for performance analysis, and provide suitable evidence for the use of video analysis, when undertaken by one, experienced analyst. Manually coding a video for analysis purposes can be a very subjective exercise, and therefore there are issues with inter-coder reliability. Current professional practice usually sees one performance analyst employed by a team, which negates this issue. However, when several analysts are involved, activities of interest to be coded must be clearly defined so as to eliminate as much subjectivity as possible when coding events. Additionally, a reliability study should be undertaken in order to quantify the level of agreement between all analysts' coding (Hallgren, 2012).

Given these results, it can be concluded that neither the televised footage nor the footage collected from the side-line are a gold standard for performance analysis using video. Although neither is a gold-standard, comparing the coding of televised and collected footage provides a point of context for video analysis. The video collected

from the side-line allowed the frequency of activities to be determined, it didn't allow the more detailed scrutiny of performance intended for this research. However, video footage as an instrument is valid provided the appropriate camera placement is used. The International Cricket Council is the world governing body for cricket which defines the rules and regulations for the game. They provide guidelines for camera placement (International Cricket Council, 2011) for broadcasting and for the DRS (see Figure 5.2).

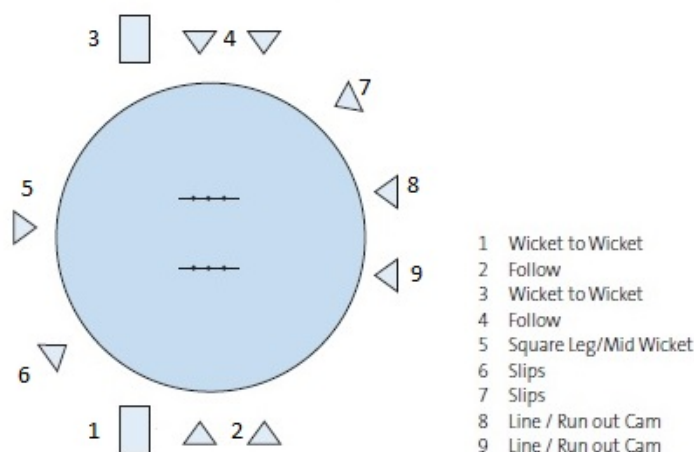


Figure 5.2: International Cricket Council generic camera layout basic TV coverage

The fact that the world governing body of the game sanctions the use of video for making umpiring decisions suggests that video footage as a research instrument is valid, provided the set up is customised for the intended use. It is therefore proposed that the gold standard camera placement for performance analysis using video would be a camera placement set up using cameras one to seven of the camera layout in Figure 5.2. Cameras eight and nine in the International Cricket Council set up would not be necessary as they focus on the lines for umpiring decisions. If an agreement between crickets governing body and broadcasters could be arranged to make this footage available free of charge for non-commercial and scientific research, such an arrangement would be beneficial for analysis of the game. Where it is not possible to gain access to the television footage, video footage can be collected from the side-line, however, some modifications to the set up used in this study are recommended. If footage is to be collected from the side-lines a slightly modified set up of the generic camera layout should be used. There should be, ideally, four cameras for the wicket-keeper, perpendicular and end on from each end. The other three cameras covering the

rest of the field should be elevated if possible, thus allowing a wider view, and eliminating issues of obstruction and foreshortening. Additionally, rather than being stationary, where possible the cameras should zoom and pan in order to see more performance detail.

The findings from this study have provided insight into issues related to reliability and validity of the use of video for performance analysis in cricket. There are issues of practicality with the proposed gold standard, therefore televised footage can be assumed to be a valid performance analysis instrument provided that limitations in terms of over- and underreporting of frequencies are taken into account. Provided that the limitations of the method and instruments are taken into consideration, video analysis of televised ODI can provide valuable insight into the performance requirements of fielding and wicket-keeping. This type of analysis could be used to identify strengths and weaknesses and prescribe appropriate training. Given the findings of this study, it has been deemed that the televised footage of ODI matches is acceptable for performance analysis studies and will therefore be used in the proceeding studies.

Chapter 6 - An analysis of the key movements and required skills of different fielding categories in One Day International cricket

Prelude

From the literature review it was found that there had been little quantification of the match demands of cricket fielding aside from time-motion analysis studies. The use of event coding is becoming an increasingly utilised tool in professional sports, as it allows the quantification of performance measures in competitive situations. The flexibility of performance analysis software packages means that any events of interest can be defined and identified from the video. Consequently, the skills and movements of interest identified from the literature review and the coach and player survey provided the foundation for this chapter. Having established the merits and limitations of using video analysis in cricket in the previous chapter, the purpose of this chapter was to undertake video analysis of ODI cricket to identify the skill and movement demands of ODI fielding.

Introduction

There are three main components to the game of cricket; batting, bowling and fielding. All players bat and field, while only some players bowl. Fielding in cricket is the on-field action of players related to collecting the ball after it is struck by a batsman. Fielding has gained considerable importance as saving of runs is an important factor in winning matches, particularly in the shorter format of the game (Saikia, Bhattacharjee, & Lemmer, 2012). However, there is a lack of research in this area, compared to batting and bowling (MacDonald, Cronin, Mills, et al., 2013).

The most prevalent type of fielding research has been time-motion analyses (Petersen et al., 2010; Petersen, Pyne, et al., 2009a; Petersen et al., 2011). These studies used GPS technology to track players' movements during the different formats of the game to quantify time spent and distances covered at different exercise intensities. However, these studies have focussed either on the bowler, or a specific fielding position; none have investigated all fielders per specific position or category. While time-motion analyses can provide physiological information, which is important for coaches and strength and conditioners to develop position-specific conditioning programs and recovery periods based on quantified game demands (Petersen, Pyne, Portus, Karppinen, & Dawson, 2009), it doesn't provide all performance related information or about the position specific demands of fielding.

Single, closed skill components of fielding performance such as throwing and catching have been investigated. Freeston and Ferdinands (2007) investigated the relationship between overarm throwing velocity and accuracy in elite and sub-elite cricketers, and found that a speed-accuracy trade-off existed. Only one study has attempted to quantify the skills associated with fielding during a cricket game (Shilbury, 1990). This study focussed on two areas: frequency of skills required in 25 defined fielding positions and analysis of fielding patterns of individual players. The frequency of these activities was recorded for each of the fielding positions, which were grouped into five 'sectors' on the cricket pitch. Shilbury (1990) reported that the wicket-keeper took the most fielding contacts (21%), followed by cover ($\approx 12\%$), mid-on and mid-off ($\approx 9.5\%$ each). However, only six multi-day games by one team from the 1986/87 cricket season were analysed and these were first class not elite international level games. Additionally, only a very limited number of activities were recorded; 'fielded ball', 'fielded ball and overarm throw', 'fielded ball and underarm throw' and 'catches and attempted catches'.

The author highlighted the need to gain a greater understanding of the skills and sub-skills required for each fielding position.

Therefore the purpose of this chapter was to investigate the match activities of fielding, including ambulatory and stationary activities in ODI cricket. Fielding performance was investigated with respect to different fielding categories and positions to establish if positional performance differences exist. The aim was to gain more understanding of elite fielding performance demands, and to address the general lack of information in this area. Understanding the playing demands of cricket fielding would be of value to coaches when designing training programmes and activities, as it would allow players strengths and weaknesses and suitability for certain fielding positions to be established.

Methods

Participants

The television footage of eight games (sixteen innings) from the 2011 ODI World Cup was obtained from the International Cricket Council. The participants were the international players who took part in the eight matches. The institution's ethics committee (AUTEC) confirmed that ethics approval was not required, as footage which had previously been publically broadcasted was analysed and therefore no verbal or physical agreement was needed with relevant parties.

Procedures

All footage was imported onto a MacBook Pro laptop and was analysed using the video analysis package SportsCode Elite v.8.10 (Sportstec, 2008). All matches were analysed by the principal investigator. For each player who fielded the ball, the fielding actions were identified and coded, including individual fielding positions which fell under the categories identified (in red) in Figure 6.1.

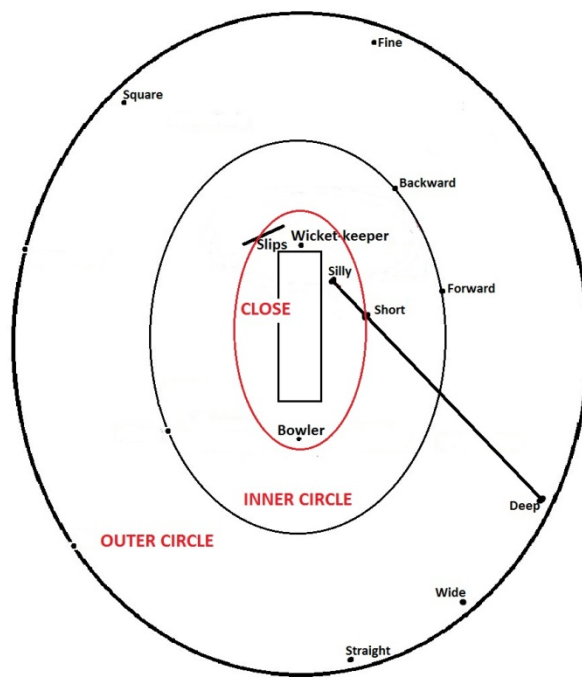


Figure 6.1: Fielding categories and permutations.

Note. See Glossary for definitions.

The fielding activities were identified from the results of a previous study (MacDonald, Cronin, McGuigan, & Stretch, 2013) and defined and validated through expert consultation with coaches (Table 6.1). This list of activities is far more comprehensive than that of the only other study to attempt to quantify fielding performance (Shilbury, 1990). In addition to the fielding activities, the 'ball in play' frequency was coded. The ball was deemed to be in play if it required intervention by a fielder or went through to the wicket-keeper. This value was required for fielding efficiency calculations.

Table 6.1: Operational definitions of match activities of cricket fielders

Activity	Type and Definition
Catch	The ball has hit the bat or gloves, and is then caught by a fielder, dismissing the batsman.
Dropped catch	The ball has made contact with the bat or gloves, the ball makes contact with the fielders' hands but is not caught.
Run out	A fielder receives and removes the bails before the batsman has made his ground, resulting in the dismissal of the batsman, either with a direct hit of the stumps with a throw from the field or by passing to another fielder.
Missed run out	A fielder fails to remove the stumps (either with a throw or with ball in hand), when the batsman is still short of his ground and would otherwise have been dismissed.
Field	The player retrieves the ball following a shot played by a batsman.
Misfield	The fielder makes contact with the ball but fails to retrieve or stop the ball cleanly.
Sliding stop	Descending onto one knee to slide next to the ball, allowing momentum to regain footing (Woolmer et al., 2008).
Underarm throw	Ball is drawn back with the hand pointing to the ground before releasing the ball.
Sidarm throw	Arm is approximately parallel to the ground when the ball is released.
Overarm throw	The ball is drawn back over the shoulder, so that it faces backwards, before the arm unwinds and throws it straight over the shoulder at the target. (Woolmer et al., 2008)
Field and throw	The fielder fields the ball and in the same action immediately throws the ball without moving from the spot where they fielded it
Sprint	When a fielder moves at speed from his position in any given direction to cut off, field or catch the ball.
Dive	When the fielder dives to one direction (usually laterally, occasionally forward) to attempt to take or catch the ball
Jump	The fielder projects vertically in an attempt to take or catch the ball
Following chase	When a second fielder moves at speed from his position in any given direction to support another player in chasing the ball.
Roll	Roll following a fielding action, usually laterally

Following the initial coding, the coded footage was reviewed, and the fielding position associated with each activity was identified. The matrix function of SportsCode was used to export the results of each innings into Microsoft Excel for further analysis.

Data and Statistical analysis

For each innings analysed the total number of balls delivered was calculated and the frequency of all variables was determined. Prior to this investigation, the intra-coder reliability for each variable was determined using a Microsoft Excel spreadsheet (Hopkins, 2000) and most variables of interest were found to have acceptable reliability with an ICC of 0.85 to 1.00 (Sirotic et al., 2009) as detailed in Chapter 5. As the games analysed all varied in duration, the total number of activities from all sixteen innings was summed; activity totals were divided by this total value to express the results as a

percentage of activity. This was to correct for the lack of equal numbers of overs per innings, normalising the data to provide a better level of comparability. Basic descriptive statistics such as mean and standard deviation were calculated for all variables for each fielding category. The total number of fields, misfields, stops and missed stops were summed to calculate total number of fielding contacts. The intensity of efforts can be calculated by dividing the total number of activities per the number of overs.

Additionally, fielding efficiency measures developed in conjunction with fielding coaches are proposed, to measure the success of fielding performance. These efficiency measures for catching, throwing and overall team fielding were defined by the following equations:

$$\textbf{Catching efficiency \%} = \frac{\textit{catches taken}}{\textit{catching chances}} \times 100 \quad \text{Equation 6.1}$$

$$\textbf{Throwing accuracy \%} = \frac{\textit{hit stumps}}{\textit{shies at stumps}} \times 100 \quad \text{Equation 6.2}$$

$$\textbf{Team efficiency \%} = \frac{\textit{Ball in play-ground fielding mistakes}}{\textit{Ball in play}} \times 100 \quad \text{Equation 6.3}$$

An expert cricket coach provided a scale (from one to three) for rating the difficulty of catches taken; ranging from easy to difficult (J. Pamment, personal communication, February 2013). An easy catch required no movement of the feet prior to catch execution, a medium catch required movement in any direction prior to taking the catch, a difficult catch required a high degree of quick movement prior to catch execution (for example a diving catch). This scale was used throughout the analysis to assess the difficulty of catches taken.

Results

The average innings duration for this sample of games was 41 ± 12 overs, with the ball in play on average $84 \pm 11\%$ of the innings. There were on average 177 ± 52 fielding contacts and 12 ± 6 fielding mistakes per innings. Overall team efficiency was $94.0 \pm 2.3\%$ ranging from 89.0% to 98.0% . Figure 6.2 is a 'heat map' showing the average number of all fielding activities per position. The activity in the field was split between the fielding categories; 20.0% close fielding, 50.0% inner circle fielding, and 30.0% outer circle fielding respectively. The positions with the most fielding activity in an ODI innings were cover, bowler, backward point, mid-off and midwicket, all of which are close or inner circle fielding positions.

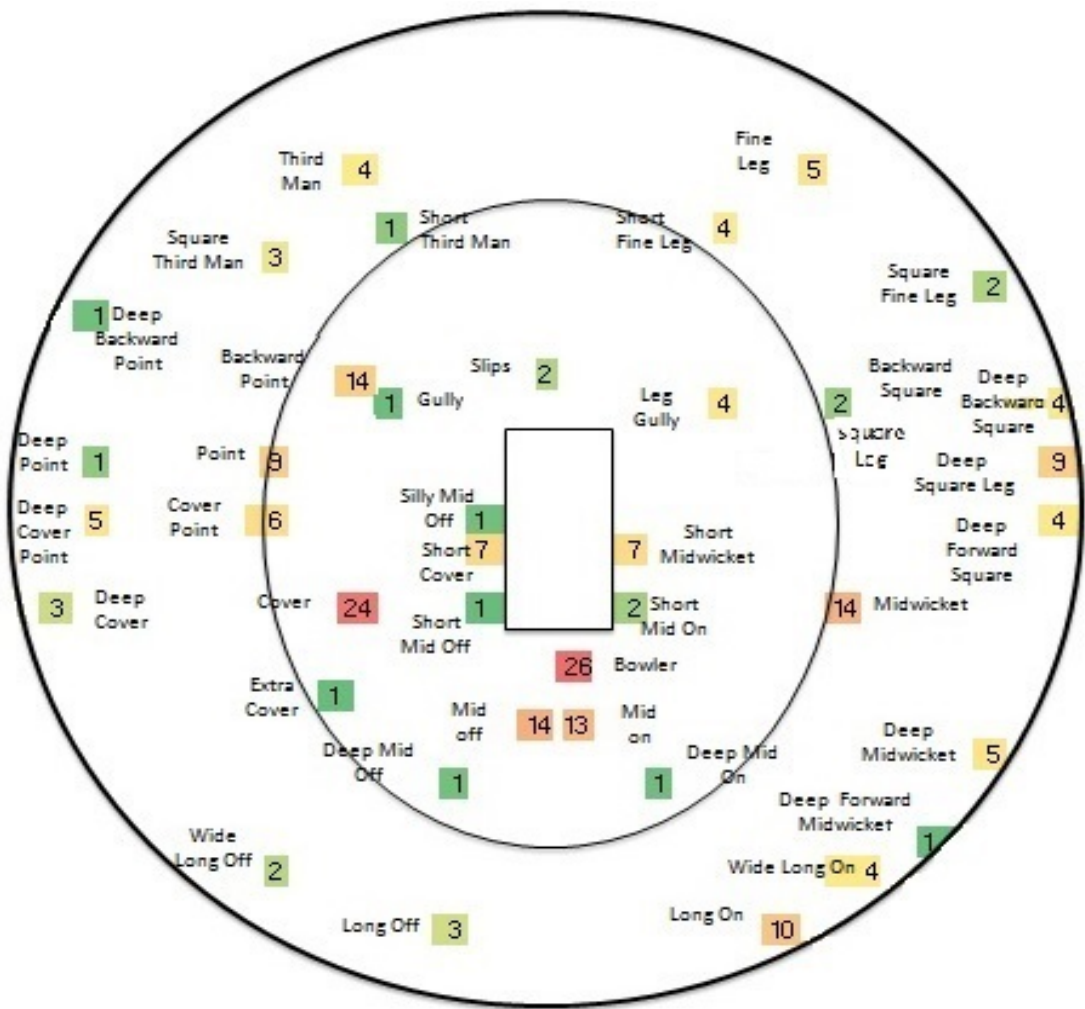


Figure 6.2: Heat map of number of fielding activity per position.

Note: Colour gradient scale: red = most contacts, green = fewest contacts.

As discussed in Chapter 2, prior to this research the only study to attempt to quantify fielding skill was that of Shilbury (1990) who analysed fielding activity of first class cricket. While there is considerable difference in the sample in terms of size, quality, and type of cricket, this is the only study available and thus is used for comparison. The distribution of fielding activity per innings by position, comparing the current results with that of Shilbury (1990) can be observed in Table 6.2.

Table 6.2: Percentage of fielding contacts per position

Position	Study	
	Current Results	Shilbury 1990 (%)
Wicket-keeper	32.4	20.9
Bowler	12.1	6.89
Cover	11.3	11.7
Backward Point	6.81	2.65
Mid-off	6.66	9.51
Mid-Wicket	6.59	5.31
Mid-on	6.34	9.45
Point	3.92	3.17
Extra Cover	2.71	1.34
Deep Mid-Wicket	2.49	0.79
Square Leg	2.07	3.65
Third Man	1.92	1.65
Deep Backward Square Leg	1.78	0.90
Slips	0.89	2.62
Backward Square Leg	0.82	1.76
Deep Mid-on	0.46	0.69
Deep Mid-off	0.32	0.45
Gully	0.25	3.00
Deep Extra Cover	0.25	0.24

In both sets of results, the wicket-keeper has clearly the most fielding activity of all of the fielding positions. It was for this reason that the wicket-keeper performance requirements have been investigated separately. The results of the wicket-keeping analysis will be presented in Chapter 7; henceforth the wicket-keeper is excluded from further discussion in this chapter.

Discussion

Cover was the fielding position that had the second most total activity in Shilbury's study; however, in this study the bowler (12.1%) had the most fielding activity, which was closely followed by the cover fieldsman (11.3%). This suggests that despite the changes seen in the game of cricket between the two studies, cover is a still vital position. In fact, aside from the bowler (a close fielding position) the top seven positions with the most fielding contacts were inner circle fielding positions, as had been found previously. The increase ($\approx 5\%$) in the bowler's involvement in fielding activity can perhaps be attributed to the fact that the 2011 sample consisted of matches played in India, where there conditions suit spin bowling during which the bowler has a lower run up speed and is more likely to be able to field off his own bowling. Additionally, it can be deduced that the fielding aspect of cricket may have a higher priority now than in the multi-day 1990 sample, due to the smaller number of overs in the game. In limited overs cricket batting and bowling 'power plays' are employed, during which period (a set number of overs) the number of fielders permitted outside the 30 yard inner circle is restricted. This is also likely a contributing factor to the greater number of inner circle fielding contacts in the 2011 sample.

Hereafter fielding performance will be discussed with respect to fielding category to investigate positional differences in performance.

Close Fielding Requirements

There were seven close fielding positions included in this analysis; the bowler, leg slip, short cover, short leg, short mid-wicket, silly mid-off and the slips (which is in fact more than one position ranging from first to fourth slips, but for the sake of this investigation were grouped into one). The bowler took the majority of all close fielding skill activity (58.4%), followed by short cover (16.4%) and short midwicket (15.8%).

Players in close fielding positions fielded the ball on average 38 times per innings, approximately 20.0% of all deliveries for which the ball was in play. Of the close fielding positions, the bowler most often fielded the ball from his own bowling, on average 23 times per innings. The tournament from which the 2011 sample was taken was held in India with conditions suited to spin bowling. This is reflected in the fact that 57.0% of all fielding of own bowling was by spin bowlers. For a spin bowler, fielding from his own bowling is less reactive due to his lower run up velocity and delivery speed. For a fast bowler, fielding or stopping the ball is particularly difficult as they are

in the middle of the follow through after a delivery; fielding activity is often a result of reflexes and quick reactions. Four catches were taken and two catches were dropped by bowlers over all 16 innings, giving this position a catching efficiency of 66.0%. One of the dropped catches was by a fast bowler in the middle of his follow through, therefore a very difficult catching opportunity.

The overall catching efficiency for close fielders was 75.0%; 12 successful catches, four dropped. Aside from the bowler, seven catches were taken by slip fielders in the eight games analysed and two catches were missed, giving a catching efficiency of 77.0%. Their proximity to the batsmen is the obvious cause of these mistakes, there is very little time to react and therefore anticipation and reflexes often play a part in successful catches. A previous study (Scott et al 2010) measured movement initiation times (defined as the time between ball projection and first movement of the hands) for slip catching; the average was 152 ± 53 ms. Although they may not have much fielding contact (5.0% of close fielding contact), slip fielding contact was usually a dismissal opportunity. Of all the catches taken by close fielders, they were either easy (42.0%) or difficult (58.0%). Despite their proximity to the batsmen the majority (10 of 12) were taken with two hands. This suggests that success in catching in close positions is attributable to preparation and anticipation rather than reactions after the ball has been played.

Close fielders were usually only required to move a segment of their body (i.e. torso, or arm) to field or catch the ball. Of all the fielding contacts performed by close fielders, 57.0% were one handed actions and 41.0% two handed. Due to their close proximity to the batsmen, movement needed to be initiated in as short a time as possible and fielders must be prepared for this movement to be in any direction. In the 16 innings analysed, close fielders were required to dive on two occasions only. This movement may be infrequent but has the possibility of dismissing a batsman by catching or stopping the ball by forming a barrier with the body.

From the results it seems that close fielders were rarely required to sprint or cover any distance at speed (only four sprints by close fielders were recorded in the analysis), these fielders rather requiring the ability to execute skills such as catching and stopping the ball from their original position very close to the batsman. It was observed that close fielders tended to keep their stance low to the ground and move upwards to field the ball

if possible. Some positions exhibited a small preparatory movement or loading phase prior to movement.

The underarm throw accounted for nearly 8.0% of close fielding activity, however this was almost solely used to pass the ball to another player between deliveries (only two of the 52 underarm throws by close fielders were throws at the stumps). In pressure situations, such as throwing for a run out, a sidearm or overarm throw was used. The throwing efficiency for close fielders on this occasion was 0.0%, as none of the four throws at the stumps resulted in hitting the stumps. There was however, one throw which was successfully collected by the bowler who executed a run out by breaking the stumps with ball in hand.

Inner Circle Fielding Requirements

Fifteen inner circle fielding positions were analysed; backward point, cover, extra cover, cover point, point, gully, leg gully, mid-off (and short and deep mid-off), mid-on (and short and deep mid-on), midwicket, short fine leg, square leg, backward square, forward square and short third man. Just over half (51.0%) of all fielding activity involved the inner circle fielders. This high percentage of involvement is likely to be in part due to the fielding restrictions in use in ODI cricket, when a limited number of fielders are permitted outside of the 30 yard inner circle during 'power play' phases of the game.

The three positions with the most fielding activity were cover (21.0%), mid-off (12.0%) and backward point (12.0%), all offside positions. These positions fielded and stopped the ball more often than any other inner circle fielding position. Over 70.0% of all inner circle fielding activity recorded involved fielding or stopping the ball. From the innings analysed, the ball was fielded by inner circle fielders on average 99 times per innings. This was achieved by either using one (30.0%) or two hands (60.0%), a foot (2.0%), or forming a long barrier with the body by diving in front of the ball (8.0%). There were on average two ground fielding mistakes per innings by inner circle fielders. The overall fielding efficiency for the inner circle fielders was 98.0%. Given that such a high proportion of fielding contacts involves inner circle fielders, it is important that the team efficiency be as close to 100% as possible to minimise potential costly mistakes.

In total, 15 catches were taken by inner circle fielders, which corresponded to a third of all the catches taken. In addition to fielding the ball frequently, backward point took six catches, twice as many as the next position (mid-off). Other inner circle positions who took catches (one each respectively) were point, gully, mid-on, extra cover, cover point

and cover. The overall catching efficiency for inner circle fielding was 88.0%, with only two opportunities being dropped by inner circle fielders. One of the dropped catches was what is called a 'sitter', a catch which otherwise should have been taken. The other was a difficult chance, with the fielder having to jump and reach high above his head. Of the catches taken, almost half (47.0%) were categorised as difficult on the catching assessment scale, 33.0% were moderately difficult, and 20.0% were easy catches. This means that the majority of catches taken by inner circle fielders required a moderate to large amount of quick movement in order to be in a position to take the catch. Despite this, all catches taken by the inner circle fielders were taken with two hands rather than one. While this may be the case for this sample, it can be inferred that the ability to be able to quickly get into position to catch the ball with two hands should be prerequisite for good inner circle fielding performance but they should be able to catch one-handed if need be.

Analysis of throwing proved that inner circle fielders employed different throwing techniques depending on the situation. If they had fielded the ball from their original position an underarm throw (19.0%) was used to pass the ball, or if they were throwing with more urgency for a shy at the stumps a sidearm throw was used (28.0%). The sidearm throw had an action which can be described as a 'flick'; observations of the coded throws revealed that the shoulder angle at release varied considerably. Over half of all throws by inner circle fielders were overarm (53.0%); often inner circle fielders had run from their original position to field the ball, and therefore had a greater distance to cover with the return throw.

It was possible to identify from the video a variety of different footwork patterns used in preparation for the return throw. The purpose of these preparatory movements was to position to form a strong base from which to throw. These footwork patterns were identified as 'crow hop', 'replace feet' and 'split step' (Woolmer et al., 2008). Following fielding the ball, the 'crow hop' is a movement which consists of a hopping action with the leading foot to form a stable base from which to throw. When using the 'replace feet' pattern, one foot was moved in towards the sagittal plane, and placed in the place of the other foot, similar to a skipping action. The split step did not cover much ground, but consisted of the movement of one foot away from the centre in order to form a wide base from which to throw. The 'split step' was the most recorded pattern (63.0% of throws), followed by 'replace feet' (25.0%) and 'crow hop' (12.0%). The choice of footwork used was dependant on how much time the fielders had to prepare and how far

they had to throw. There also appeared to be a degree of personal preference when it came to throwing technique. Fielders' anthropometry and individual strengths and weaknesses appeared to contribute to individual technique selection. However, the fielders did not always have the time to set a position to throw after fielding the ball; 10.0% of the recorded throws by inner circle fielders were from an unbalanced position; 4.0% of balls were thrown with the player still on their knees having fielded the ball.

Players in inner circle fielding positions are often in a position with the potential to affect a run out; in this sample, three run outs involving inner circle fielders took place. The throwing efficiency for inner circle fielders was 30.0%; only 13 of the 44 throws at the stumps were successful. The throws at the stumps were predominately overarm (50.0%) and sidearm (39.0%), indicating that the underarm throw is not generally used when throwing for speed and accuracy. The poor efficiency for inner circle fielders is like due to the fact that the inner circle covers a large amount of the pitch, therefore a player on the edge of the circle can be almost 30 m away from the stumps but is still expected to be able to hit the stumps. From this sample, it is clear that in this sample throwing efficiency needs to be improved.

From the results of the movement analysis it can be concluded that inner circle fielding position requirements necessitate explosive movements such as diving and sprinting. For example, inner circle fielders had to dive or slide to stop the ball an average eight and two times per innings respectively. While they have greater amount of reaction time for decision making and movement initiation than close fielders, inner circle fielders have greater ground to cover. Fielders in the inner circle sprinted on average 16 ± 5 times per innings. The length of the sprint depended on how strongly the batsman had hit the ball and whether a fielder had been able to get a hand to it to take some momentum off the ball. In addition to the sprints recorded, inner circle fielders on average performed two support runs per innings. A support run is a sprint, defined by the fact that the fielder is running in support of a primary fielder; they may be required to field the ball in tandem or perform the return throw if the primary fielder is unable to do so.

Outer Circle Fielding Requirements

The outer circle field consisted of 21 different positions outside of the 30 yard circle. Outer circle fielders were involved in 30.0% of all the fielding activity recorded. The positions with the most total activity were long on (14.0%), deep square leg (13.0%) and deep forward square and deep midwicket (7.0%) respectively.

Players in outer circle fielding positions were involved in on average 52 ± 21 fielding contacts per innings. There were only six ground fielding mistakes including in all total ground fielding recorded for outer circle fielders; giving an overall fielding efficiency of 99.0% for outer circle fielders. Of these fielding contacts, 74.0% of them were two handed fielding actions, 22.0% one handed. 4.0% of outer circle fielding involved forming a barrier in front of the ball, by either diving or performing a sliding stop. Outer circle fielders were usually required to move from their original position to field the ball. Therefore these positions prepared to field by walking in towards the circle from their initial position, from which point they could move in any direction as deemed appropriate. Due to their distance away from the batting crease, outer circle fielders had the greatest time in which to move to field the ball, but also the greatest distances to cover. Outer circle fielding positions were required to sprint an 8 ± 5 times per innings; sprints occurred less frequently than for inner circle fielders but they had greater distances to cover. It was observed that outer circle fielders had to sprint from a few metres to approximately 30 m in order to field, either towards the boundary chasing the ball, or around the edge of the boundary to get in position to cut the ball off. Following the sprint, the fielders often had to perform explosive movements such as a dive or a jump to field the ball; they rarely had the opportunity to stop and position themselves to perform their skill.

In total, 17 catches were taken by outer circle fielding positions; the most catches taken by one position was four, by long on and deep square leg. Outer circle fielder catches comprised 37.0% of all catches taken. Analysis of the catches from the video showed that outer circle fielders are subject to a variety of catching conditions and pressures. The majority of the catches taken (76.0%) were rated two on the catching difficulty scale, requiring a moderate amount of movement prior to taking the catch. This is most likely due to the fielding restriction in ODI cricket, limiting the number of fielders permitted outside the inner circle. Often the batsman had miscued the ball high into the air and the fielders had plenty of time to position themselves for the catch. Three of the outer circle catches were more difficult and hence spectacular to watch; for example one catch was taken by deep midwicket, who ran half way around the boundary to catch it on the run, when it looked to be going for 6 runs. Three catches were dropped by outer circle fielding giving a catching efficiency of 85.0%. All of the catches taken by outer circle fielders were taken with two hands; in the case of the dropped catches, on all three occasions the fielders managed to get two hands to the ball but failed to secure the

catch. Observations from the video analysis showed that the dropped catches were the result of fielders misjudging the distances when positioning to take the catch.

Outer circle fielders most often performed a return throw immediately having fielded the ball; this was coded as 'field and throw' in the video analysis. Due to their distance away from the batting crease, outer circle fielders were required to return the ball quickly in order to concede as few runs as possible. To achieve this, they overwhelmingly used the overarm throwing technique (87.0%). The remaining 13.0% of throws were side arm throws; outer circle fielders rarely employed the underarm throw. Unlike the other fielding categories who used the overarm throw technique when throwing under pressure, outer circle fielders are always under pressure to return the ball as quickly and efficiently as possible. Even when passing to another fielder, the distances between them are so large that an overarm throw is required even to pass to another fielder.

The footwork used to position to throw appeared to vary due to a combination of influences including individual technique preference and circumstances of the fielding action. Twenty five percent of outer fielding throws used a 'crow hop' to place a stable front foot from which to propel a throw as fair as possible. Alternatively, some fielders used the 'replace feet' technique (35.0%). When circumstances did not permit a great deal of movement to prepare to throw, a split step was used (34.0%) to form a strong base from which to throw. Four percent of the throws by outer circle fielders were coded as being from an unbalanced position, the remaining 1.0% the fielders threw when still on their knees having fielded the ball. Occasionally, the primary fielder was not in a position to return the ball (usually due to having dived full length to stop it), and therefore the ball was passed to a supporting fielder who then executed the return throw. Due to the distance, outer circle fielders rarely had direct throws at the stumps; just three throws from outer circle fielders occurred in the sample. Of these, one was successful giving a throwing efficiency of 33.0%. While infrequent, direct hits of the stumps from the outfield are possible, and therefore outer circle fielders must be prepared to throw for speed, distance and accuracy.

Conclusions and Implications for Future Research

The results of the video analysis allow conclusions to be drawn regarding the match performance requirements of fielders with respect to each fielding category. This

information can be used to make recommendations in terms of training and assessment of players.

Close Fielding

Good reaction times and catching ability are vital requirements for close circle fielding. Therefore it would be beneficial to have some measure of these fielders' decision making and movement times. An acyclic measure of multidirectional leg power most likely would give insight into strengths and weaknesses of their movement ability and might be integrated with the movement time measure to determine movement capability. Calculating catching efficiency retrospectively from game footage can provide a measure of catching ability. In depth analysis of the footage can be used to understand the determinants of successful and unsuccessful catches thus providing coaches with valuable information to improve technical ability of this position. Close fielders often employ an underarm throw when there is no pressure to return the ball, however, in high pressure situations such as attempting a run out close fielders need to be able to overarm throw at the stumps with speed and accuracy. Testing this skill from a static position with little reaction time should simulate the pressure seen in match conditions and will assist in improving throwing accuracy in close fielding positions.

Inner Circle Fielding

From the results of the inner circle analysis it can be inferred that inner circle fielders need to have a wide variety of fielding skills and attributes. The video analysis has demonstrated that inner circle fielders' performance requirements ranged from taking sharp catches with little reaction time similar to close fielding, to sprinting relatively large distances to field the ball. A certain degree of athleticism will be necessary to perform the explosive movements required in the inner circle. While there is currently no valid cricket agility test, some measure of a player's agility would be useful in determining suitability for fielding in the inner circle. All three throwing techniques are used by inner circle fielders therefore aspects such as technical weaknesses and implications for injury must be taken into consideration when designing throwing assessments. Throwing assessments should assess movement time (the time taken to set to throw) as well as throwing speed and accuracy. Throwing ability should be assessed from both stable and unbalanced positions to simulate match conditions as much as possible.

Outer Circle Fielding

Fielding for an outer circle fielder can most accurately be described as a chain of movements and skills which lead to the ball being fielded, rather than a discrete event. Outer circle fielders cover the most distance of all the fielding positions, therefore ideally players in these positions should be fast, at up to distances of 40 metres. Using tall fielders on the boundary rope when possible would prove to be advantageous, as their height provides an advantage when jumping to prevent the ball going over the boundary. A strong throwing arm is a pre-requisite for fielders in the outer circle, as there is a large distance to cover with the return throw. If a timely throw is returned while the batsmen are running between the wickets, there is the potential to dismiss the batsman through a run out. Usually this is done by passing to another fielder, although the best outer circle fielders can hit the stumps directly from distance.

This study demonstrated that there are positional differences in cricket fielding and it can be concluded that players with certain attributes will be suited to fielding in different areas of the field. This should be taken into consideration when selecting assessments and prescribing training.

Chapter 7 - Key movements and skills of wicket-keepers in One Day International cricket

Prelude

Throughout this research, it has been reiterated that the wicket-keeper is a specialist position within the fielding unit, but has not been afforded a great deal of attention in terms of empirical research. As with the fielding chapter, wicket-keeping specific skills and movements have been identified via a literature review and online survey. Once more there is a need to use event coding to develop a better understanding of the movement and game demands of the wicket-keeper. Developing such understanding can inform the assessment, program and skill development of the wicket-keeper to better effect. Therefore, the purpose of this chapter was to identify the skill and movements demands of wicket-keeping in ODI cricket through video analysis of ODI cricket.

"The central figure on the field must always be the man behind the stumps. Not only does he have the opportunity to make more catches than anyone else, but he delivers the coup de grâce in the majority of run outs, and he is also responsible for the stumpings. He can transform the whole appearance of the fielding side, camouflaging the poorer returns and adding colour to the proceedings."

Trevor Bailey, (1968), (as quoted by Lemmon, 1990)

Introduction

Cricket is considered unique as three formats are played at international level (Petersen et al., 2010); Test (5 day match), ODI (50 overs for each team), and Twenty20 cricket (20 overs each). The shorter formats of the game in particular are becoming increasingly lucrative for players, as there are leagues around the world which essentially allows players to play year round. However, compared with other international sports, cricket has not enjoyed the same research attention regarding the physiology or physical demands of match play (Duffield & Drinkwater, 2008). There are three main components to the game of cricket; batting, bowling and fielding; most published cricket literature has focussed on batting and bowling. This chapter focuses on the skills and movements associated with wicket-keeping in ODI cricket.

Time-motion analysis is thought to be important for coaches and strength and conditioning practitioners to develop sport-specific conditioning programs and to tailor recovery periods based on quantified game demands (Petersen, Pyne, Portus, Karppinen, et al., 2009). Since the advent of GPS technology in sport, there have been numerous studies (Petersen, Pyne, et al., 2009a, 2009b; Petersen et al., 2011) using GPS technology to quantify demands in terms of time spent and distances covered at different exercise intensities. A limitation of these studies is while they provide information about the time spent and distances covered at various exercise intensities (physiological demands), they provide little information of the movement patterns and skills specific to the wicket-keeper (biomechanical/technical demands). One study (Shilbury, 1990), investigated the skills associated with 25 field positions of one elite Australian cricket team. In this study it was found that the wicket-keeping position was involved in about 21.0 % of the considered activities, nearly twice as much as the second most involved position, that of cover (12.0 %).

Despite the noted importance of this position, only two peer-reviewed articles have specifically investigated wicket-keeping, both of which investigated particular aspects

of wicket-keeping technique, such as stance (Plunkett et al., 2005) and footwork (Rosen & Bower, 2006). Plunkett, Salter and Moore (2005) investigated movement efficacy and forces on the knees of three different stances used by wicket-keeping, full crouch, half crouch and the touch. Several footwork patterns were identified by Rosen and Bower (2006); a notable conclusion was that wicket-keepers used a variety and combination of footwork patterns according to situations and personal preference. These studies provide information regarding single aspects of wicket-keeping technique, but provide little insight as to the important biomechanical/technical demands associated with wicket-keeping. Given these limitations, the purpose of this study was to identify the key movements (including directional information) and skills required for wicket-keeping at the ODI level. The findings should provide the information that guides the assessment, coaching and conditioning of wicket-keepers.

Methods

Participants

The television footage of eight games (sixteen innings) from the 2011 ODI World Cup was obtained from the International Cricket Council. The participants were the wicket-keepers who took part in the eight matches. Ethics approval was not required, as footage which had previously been publically broadcasted was analysed and therefore no verbal or physical agreement was needed from players.

Procedures

The activities of interest were identified using the results of a literature review and information seeking survey of cricket players and coaches as detailed in Chapter 4. For the sake of this study, the activities were categorized into either movements or skills (Table 7.1). Clearly skills and movements are not completely independent of each other; however they are examined in this way to provide a clear direction for practical applications. All footage was imported onto a MacBook Pro computer and analysed using a commercially available video analysis package (SportsCode Elite v.8.10 (Sportstec, 2008)). The matrix function of SportsCode was used to export the results of each innings into Microsoft Excel for further analysis.

Table 7.1: Operational definitions of skills and movements of interest

Activity	Definition
Take	The ball has gone past the batsmen without touching the bat or gloves, the wicket-keeper catches the ball
Missed take	The ball has travelled past the bat or gloves without touching them, makes contact with the wicket-keepers gloves but is not caught
Catch	The ball has hit the bat or gloves, and the ball is caught by the wicket-keeper, dismissing the batsman.
Dropped catch	The ball has hit the bat or gloves, the ball makes contact with the wicket-keepers gloves but is not caught
Reception from field	The wicket-keeper catches the ball from a throw from another fielder
Missed reception from field	The ball makes contact with the gloves following a throw from another fielder but is not caught successfully
Run out	The wicket-keeper receives the ball from a throw, and removes the bails before the batsman has made his ground, resulting in the dismissal of the batsman
Missed run out	The wicket-keeper fails to catch the ball and remove the stumps, when the batsman is still short of his ground and would otherwise have been dismissed
Stumping	The batsman has advanced down the pitch, missed the ball, the wicket-keeper takes the ball and removes the bails resulting in the dismissal of the batsman
Missed stumping	The batsman has advanced down the pitch, missed the ball, the wicket-keeper fails to take the ball and remove the bails, which would have resulted in the dismissal of the batsman
Sliding stop	Descending onto one knee to slide next to the ball, allowing momentum to regain footing (Woolmer et al., 2008)
Underarm throw	Ball is drawn back with the hand pointing to the ground, before the release of the ball.
Sidearm throw	Arm is approximately parallel to the ground when the ball is released.
Overarm throw	The ball is drawn back over the shoulder, so that it faces backwards, before the arm unwinds and throws it straight over the shoulder at the target (Woolmer et al., 2008)
Field and throw	The wicket-keeper fields the ball, and in the same movement immediately throws the ball, without moving from the spot where they fielded it
Crouch	Wicket-keepers' preparatory stance as the bowler runs in, technique differs due to individual preference
Run up to the stumps	When the wicket-keeper is standing back from the stumps, then moves up to the stumps to receive the ball from the field, usually at a jog
Dive	When the wicket-keeper dives in one direction (usually laterally, occasionally forward) to attempt to take or catch the ball
Jump	The wicket-keeper projects vertically in an attempt to take or catch the ball
Chase/sprint	The wicket-keeper moves in any given direction at speed to cut off or catch the ball
Roll	Roll following a fielding action, usually laterally
Lateral step	Movement of one foot laterally away from the sagittal plane, the other remains still
Lateral shuffle	Lateral movement consisting of an initial small step followed by a side skip

Data and Statistical Analysis

All matches were coded by the principal investigator, establishing the frequency of each activity in each innings. To assess intra-coder reliability of the game activities the same ODI match was coded twice during piloting, separated by a period of six weeks in order to decrease the retention of information (Sirotic et al., 2009); the ICC was calculated using an Excel spreadsheet (Hopkins, 2000). The ICC for all variables bar lateral footwork was greater than 0.85.

Due to the fact that the matches were of varying duration (i.e. differing number of overs), the total number of activities from all sixteen innings was summed; activities were divided by this total value to express the result as a percentage of total innings activity. This was done in order to assess which activities occurred the most frequently for an elite wicket-keeper, while also taking into account that some of the innings sampled did not last the designated 50 overs.

Results and Discussion

In order to assess performance, the wicket-keepers' total activity in the innings was divided into two categories, movement and skills, and assessed per number of deliveries. The mean occurrence and standard deviation of the activities of interest for sixteen wicket keeping innings of ODI cricket can be observed in Tables 7.2 and 7.3.

Movements

The most significant observation is that for a wicket-keeper, the crouch, a repetitive vertical movement, is a *sine qua non* activity. Put simply, the crouch is a fundamental part of the wicket-keepers' performance; he will crouch for every delivery of the innings. The average number of crouches in the 16 innings was 252, which reflected the fact that some of the innings analysed did not last the allocated 50 overs (= 300 crouches). The wicket-keeper is the only fielding position to experience such repetitive actions in the vertical plane. As well as crouching, the wicket-keeper also has to be able to jump vertically, following the crouch; however, jumps occurred on average, just three times per innings.

Table 7.2: Wicket-keeping movement analysis

Movements	Mean Per Innings	Standard Deviation	% of total movement activity
Lateral Step	77.81	40.55	44.85
Lateral Shuffle	53.19	19.73	30.66
Run up to stumps	26.56	16.29	15.31
Chase/sprint	10.19	20.99	5.87
Jump	3.00	2.00	1.73
Dive	2.50	1.37	1.44
Roll	0.25	0.58	0.14

Following the crouch, 75.0% of the movements required of wicket-keepers during an innings are lateral steps and shuffles, indicating that lateral movement is also important for wicket-keepers. Further analysis of the lateral movements, indicated that the movements required were almost equally distributed between moving towards the left (44.4%) or right (43.1%). The remaining 12.5% of coded lateral movements resulted in no whole body movement in either direction; close observation of the video showed that they were in fact small movements of one foot, like a trigger movement prior to rising from the crouch. Whether or not the lateral movement was a step or a shuffle appeared to be due to personal preference and the circumstances of the delivery. Despite the number of lateral movements being equally distributed in either direction, just over half of the number (55.0%) of missed takes and catches occurred moving to the left. It would seem in this sample of wicket-keepers that there was a deficiency in skill execution when moving to the left, a finding which could guide future practice.

In the event of inaccurate bowling, or deviation of the ball from its trajectory, explosive movements are required in which the wicket-keeper needs to cover a relatively large distance to get to the ball as quickly as possible (Plunkett et al., 2005). The most explosive lateral movement, the dive, occurred on average two to three times per innings. Close observation of the video footage revealed that prior to executing the dive, players often moved one foot laterally away from the sagittal plane, in order to provide a solid footing from which to push off to dive in the opposite direction (pre-loading). It seems that wicket-keepers do not in fact employ lateral dives (2.5 ± 1.3) as often as might be expected. There are a couple of possible explanations for this; it may be due to players not having sufficient leg strength qualities to initiate an explosive lateral movement or conversely, a wicket-keeper might have such good footwork that he may not need to dive to cover the large amount of ground necessary. Otherwise, it may be

due to a technique preference; a previous study (Rosen & Bower, 2006) has shown that wicket-keepers employ a variety of footwork patterns when moving laterally to collect the ball. These patterns were found to be combinations of stepping and shuffling rather than diving. Observations made during this analysis were that the wicket-keepers used three different crouching techniques as described by Plunkett, Salter and Moore (2005), which were the full crouch, half crouch and 'touch and move' stance. Additionally, the catches which resulted in the dismissal of batsmen, resulted from the wicket-keeper using a variety of footwork patterns, including shuffling, side steps and jumps, similar to those described by Rosen and Bower (2006).

These results and observations indicate that a vital requirement for wicket keepers is the ability to maintain repetitive low intensity exercise; crouching and be able to move laterally, in either direction, while constantly being prepared to react and jump or dive explosively in either direction. This finding is consistent with the observations of Plunkett, Salter and Moore (2005), who stated that each of the low intensity, high repetition movements should be performed proficiently with minimal physical exertion in order to maintain a consistent standard of performance.

In addition to the vertical and lateral movement, running and sprinting occurred on average 37 times per innings. The majority of these activities were coded as 'running up to the stumps', which occurred frequently in the match, whenever the wicket-keeper is standing back from the stumps. Following the batsman's shot, the wicket-keeper has to move quickly into position behind to the stumps to receive the ball from the field and potentially, execute a run-out. The intensity of this run varied depending on how far back from the stumps the wicket-keeper was standing and the position at which the ball was fielded. This finding is a slightly larger number of sprints than has been previously found in time motion analysis studies which expressed the number of sprints per hour (5 ± 2), given that ODI innings are usually approximately four hours duration (Petersen et al., 2010). Furthermore, wicket-keepers need to be prepared to sprint to chase after a high ball. In the 16 innings sampled, chasing after a high ball occurred approximately 10 times per innings.

Skills

Table 7.3: Wicket-keeping skills analysis

Skills	Mean per innings	Standard Deviation	% of total skill activity
Reception from field	41.56	11.91	38.91
Underarm throw	31.69	10.16	29.67
Take	23.94	13.11	22.41
Missed take	2.63	1.93	2.46
Missed reception from field	2.00	0.00	1.87
Overarm throw	1.88	2.31	1.76
Field and throw	1.13	1.50	1.05
Catch	1.00	1.21	0.94
Sidearm throw	0.56	2.25	0.53
Sliding stop	0.25	0.45	0.23
Dropped catch	0.19	0.54	0.18
Stumping	0.13	0.34	0.00
Run out	0.13	0.34	0.00
Missed stumping	0.00	0.00	0.00
Missed run out	0.00	0.00	0.00

Of all the match activities, the most frequently coded skill was 'reception from field', occurring on average 41 times per innings. In fact, of all the skills which involved the wicket-keeper, catching the ball (reception from field, take and catch) when summed, comprised just less than 70.0% of total match skill activity for the wicket-keeper.

Whether the wicket-keeper is taking the ball directly from the delivery, or receiving the ball from a player in the field, they are the only player on the field with the possibility of being involved in every delivery of the innings.

In the sixteen innings coded, a total of 117 wickets fell. Of these wickets, 17.0% involved the wicket-keeper; numbering 16 catches, two stumpings and two run outs. Using a catch difficulty classification system provided by a fielding coach, the difficulty of the catches undertaken in the sample was assessed. Forty three percent of the catches were easy (Type 1) as they required no movement of the feet prior to catch. Type 2 catches required movement in any direction prior to taking the catch and also comprised 43.0% of the total catches taken. The final 14.0% of catches were difficult, requiring a high degree of quick movement prior to catch execution (Type 3).

Dropping a catch obviously means that an opportunity for the dismissal of a batsman has been squandered. In the sixteen innings analysed, three catches were dropped by

wicket-keepers. If the wicket-keeper misses a take (missed takes occurred on average twice in an innings), there is the potential that runs will be given away if another fielder is not in a position to collect the ball, or misses a stumping opportunity, although this did not occur in the matches analysed. Wicket-keeping glove-work skills (catching, taking, and receiving the ball from the field) can be quantified using a catching efficiency measure; expressed as a percentage of the successful catches and takes over the number of opportunities offered. The results of this investigation yielded a catching efficiency of 93.0%, or put more simply, wicket-keepers dropped less than one in 10 balls they were required to catch. This result has probably been distorted by the small number of matches in the sample, and the presence of poorly performing 'minnow' teams in the sample. Given the frequency of occurrence of catching type activities and the potential cost of a mistake, it can be concluded that the ability to successfully catch a ball, be it to prevent wide runs being given, or to dismiss the batsman, is the most important skill for the wicket-keeper, and thus the catching efficiency should be as close to 100% as possible.

The type of throw most predominately used by the wicket keeper was the underarm throw (around 30 per innings), employed mainly to pass the ball back to the bowler or another fielder. This was used either following a successful take from the delivery, or after receiving the ball from the field. Sidearm and overarm throws were generally used once to twice in an innings, almost certainly due to the fact that wicket-keepers rarely need to throw long distances. However, it was observed that the sidearm and overarm throws were used when the wicket-keeper was under pressure and throwing for speed was required, for example to another fielder to execute a run-out. If the wicket-keeper performed the throw in a continuous action from receiving the ball it was defined as a 'field and throw'; field and throws were mainly underarm passing to other fielders, although when the wicket-keeper had to run to field the ball and pass the ball to a fielder closer to the stumps to attempt a run out.

While the underarm throw was generally used to pass the ball between deliveries, it is also used in attacking situations when the wicket-keeper was standing back from the stumps. In addition to passing the ball to fellow fielders, the wicket-keepers also used the underarm throw when standing back from the stumps, in an attempt to perform a run out. For example, a run-out was executed by a wicket-keeper who successfully took the ball, and threw it underarm at the stumps at the other end of the crease to run out the batsman. These types of run-out opportunities are becoming increasingly common in the

shorter formats of the game, although the wicket-keeper was not involved in any of the missed run outs in this analysis. It can therefore be deduced that the ability to throw the ball underarm with fluency and accuracy is an important skill for an international wicket-keeper.

Limitations

The wicket-keeping movement analysis clearly showed that wicket-keepers need to be able to perform explosive movements over short distances in three directions. The sample size for this study was small (16 innings) and the reader needs to be cognizant of this limitation and the generalisability of these results. It must also be noted that games were coded from television footage of matches; therefore frequency values may be underestimated as due to changing camera angles it was not possible to see the wicket-keeper for the entire duration of the innings.

Practical Applications

The only other attempt to quantify the skill demands in cricket (Shilbury, 1990) quantified only four fielding activities; fielded ball, fielded ball and underarm throw, fielded ball and overarm throw, and catches and attempted catches. None of the movements which resulted in these actions were recorded by Shilbury (1990), who suggested that performance needed to be analysed in more detail. More than twenty years have passed since the publication of the Shilbury study, and the game of cricket has evolved a great deal, thus the need for this study.

The results of this performance analysis provide insight into how the training and assessment of wicket-keepers may be guided. Wicket-keeper specific training should focus on the skills which occur most frequently. With regards to the skills component of wicket-keeping, there is no doubt the most important skill for a wicket-keeper is the ability to catch the ball, be it with one or both hands, either from an almost stationary position standing close to the batsman, or following an explosive movement such as a dive or sprint. A wicket-keeping specific catching test should reflect this, and include a multitude of catching scenarios. An assessment battery may also include some measure of underarm throwing ability as the wicket-keeper successfully hitting the stumps can result in a dismissal. Wicket-keepers have very little time to react therefore skill execution given these constraints is important.

In terms of the movements associated with wicket keeping it is recommended that an assessment battery may be guided by some of the following considerations. It is clear

that the wicket-keeper must be suitably fit in order to sustain a high level of performance for the duration of the innings. To be able to perform the repetitive crouching throughout the innings, a wicket-keeper must have good lower leg strength. Squat strength or strength endurance might be a useful measure to consider. Due to the fact that the wicket-keeper performs repetitive movement in multiple planes, movement assessment should take this into account. For example, lateral movement ability should be tested following a crouch position, as this is most realistic in terms of match performance. From the video analysis it was apparent that wicket-keepers rarely needed to sprint long distances, therefore it is recommended sprint ability should be assessed over 5, 10 and 20 m. Moreover, given the wicket-keeper is the only fielder permitted to wear personal protective equipment including pads; gloves and helmet; comparing movement assessment results with equipment and no equipment may highlight the need for specific training.

Naturally the assessment battery should inform the type of strength and conditioning work that the wicket-keeper should undertake. A vital requirement for wicket-keepers is repetitive, multi-planar, low-intensity exercise with intermittent bouts of explosive movement. Given this information it would seem that a solid strength/strength endurance base in tandem with high aerobic fitness would be advantageous. Multi-planar leg strength and power both of an acyclic and cyclic nature would seem fundamental to the training of these players, the emphasis more so on lateral ability. Dedicated reactive agility and COD training with and without pads is recommended. This type of training should be interspersed with dedicated straight sprint type training of varying distances.

It should be noted that while movements and skills have been analysed and discussed separately, wicket-keeping requires the combination of both movements and skills, and therefore assessment and training which combines both movement and skill execution may best improve wicket-keeping performance.

Chapter 8 - Summary, Practical Applications and Future Research Directions

I have always maintained that although every player cannot be an all-rounder in the fullest sense of the term, there is no reason at all why all cricketers should not be able to hold their own in the field"

H.M Herman, *How's That* (1937), (as quoted in Lemmon, 1990)

Summary

The overarching question guiding this thesis was "what are the performance demands of fielding in ODI cricket?" To answer this question, peer-reviewed research was examined with respect to the physical, technical, physiological and tactical components of performance. The wicket-keeper was investigated separately from the rest of the fielders throughout this thesis. From the literature reviewed it was concluded that little was known of the performance demands of fielding and wicket-keeping, particularly in terms of the physical and technical components of performance.

To address the gaps in the knowledge, four research studies were designed. The first was a mixed-methods online survey of coaches, players and strength and conditioning coaches, which consisted of quantitative and qualitative components. The survey was designed to gather the anecdotal knowledge that coaches and trainers rely on in the absence of scientific evidence. The major findings were that coaches and players were of the opinion that there were performance differences between fielding categories, and that different attributes and skills are required in different areas of the field. Players and coaches rated agility the most important physical attribute for the wicket-keeper (4.7/5), close fielders (4.6/5), and inner circle fielders (4.8/5). Speed (4.8/5) and agility (4.6/5) were rated most important for outer circle fielders. An emerging theme for all categories was the importance of the mental aspects of the game such as positive attitude and concentration, particularly for the wicket-keeper.

The other three research studies involved the use of event coding video analysis. The first was an investigation of the validity and reliability of video analysis as a research instrument. This was achieved by comparing event coding of televised footage compared to footage purposefully collected from the side-line. The variables of interest were derived from the literature reviews and corroborated by the survey. Intra-coder reliability was determined by calculating the ICC for all variables; all but two variables were between 0.88 and 1.00 the exceptions were lateral footwork (step 0.83 and shuffle 0.55) probably due to the subjectivity of defining footwork patterns. The televised footage under-reported the frequency of wicket-keeping activity ($\approx 4.5\%$), except for lateral footwork, which was under-reported by the purposefully collected video ($\approx 13.5\%$) due to the movement being perpendicular to the camera view. Even though fielding activity was under-reported by televised footage ($\approx 4.3\%$), this footage was deemed to be most appropriate for event coding, as the collected footage resulted in a field of view that made the finer details of fielding difficult to distinguish. The use of

video performance analysis was determined to be a valid and reliable research instrument provided limitations were acknowledged and mitigated where possible.

Two performance analysis studies on fielding and wicket-keeping were carried out using televised footage of 16 innings from the 2011 ODI World Cup. The video analysis of ODI cricket has allowed the skill and movement demands of fielders and wicket-keepers to be quantified, and has expanded on the only previous study which investigated fielding skill demands (Shilbury, 1990). Wicket-keeping glove-work skills were the most performed skill activity ($\approx 69.0\%$), the quality of which was quantified using a catching efficiency measure (93.0%). Performance requirements differed between fielding positions. Overall fielding performance, as well as catching and throwing performances were quantified for close, inner and outer circle fielders respectively.

The findings from this research have contributed to the development of a comprehensive performance profile of fielding and wicket-keeping, which will be articulated in this chapter. The information provided in these profiles will integrate existing information with the new insights gained from the research undertaken in this thesis, to provide guidelines for assessment and best practice for strength and conditioning as well as cricket skills coaches. This information will be presented as stand-alone information as well as integrated into the NZC Core Playing Skills document.

Practical Applications

On the basis of the results of this research the practical implications for improving performance, assessment and training of fielders and wicket-keepers will be discussed, primarily with respect to the physical and technical components of performance; additionally, some recommendations regarding mental performance aspects will be made. The current NZC standards and practices will be reviewed on the basis of the literature review and results of the studies and improvements and novel skills assessments will be proposed.

Physical

The NZC Core Playing Skills document is a resource for players and coaches, which currently provides guidelines as to the performance requirements expected at different levels of the game, from entry level to elite. For the physical aspects of performance,

NZC have test standards of fitness qualities for fielders and wicket-keepers, as observed in Table 8.1. Where appropriate, standards have been provided for each level of competition.

Table 8.1: NZC Core Playing Skills physical recommendations

Physical Attribute	Entry Level	Intermediate	Advanced (First Class)	Expert (International)
Anthropometry	Demonstrate an understanding of the nutritional plan	Demonstrate an understanding of the nutritional plan	Sum of 8 skinfold test under 80mm.	Sum of 8 skinfold test under 80mm.
Speed - Acceleration 10m	Learn the fundamentals of: Acceleration Agility Up and running	1.80	1.78	1.76
Speed - Flying 20m		2.45	2.42	2.42
Speed - 30m		4.25	4.20	4.18
Strength	-Perfect technique 20kg Olympic Deadlift - Level 2 on the MCS	-Bodyweight 1RM Olympic Deadlift -Bench pull 1RM needs to be at 80% or better than Bench Press 1RM	-Bodyweight 1RM Olympic Deadlift -Bench pull 1RM needs to be at 80% or better than Bench Press 1RM	Bodyweight 1.5RM Olympic Deadlift -Bench pull 1RM needs to be at 80% or better than Bench Press 1RM
Olympic Lifts	-Demonstrate perfect technique on a 20kg Front Squat	-Demonstrate perfect technique on a 0kg overhead squat -Demonstrate perfect technique on a High Pull and Catch Drill	-Demonstrate perfect technique on one of the following lifts (Hang Clean, Power Clean, Snatch)	-Hang clean =0.75 x BW 1RM -Power clean BW 1RM -Snatch = 0.6 BW 1RM
Power	Linked with strength and speed	Ability to use power position in training	>7.3 m both legs bilateral triple jump -Demonstrate the use of the power position consistently within cricket environment	>7.3 m both legs bilateral triple jump -Demonstrate the use of the power position consistently within cricket environment
Aerobic Fitness - Yoyo1	17.5	18.0	18.5	18.5
Anaerobic Fitness - Max run 1s		Level 12	Level 13	Level 14
Agility	Linked to strength, speed and power	Linked to strength, speed and power	Linked to strength, speed and power	Linked to strength, speed and power

Note. MCS = Movement Competency Screen, as detailed in the doctoral thesis "Development, reliability and effectiveness of the Movement Competency Screen (MSC)", by M. Kritz, 2012.

These fitness standards are relatively generic with no differentiation in the fitness requirements for batting, bowling, fielding or wicket-keeping. For example, it could be hypothesized that fitness standards should be higher for a fast bowler, as the physical stresses and therefore the fitness requirements in all three formats of the game are higher in fast bowlers than other playing groups (Christie, 2012; Johnstone et al., 2013). However, with regards to fielding, NZC does not delineate the fitness requirements to specific fielding positions. Furthermore no such delineation has been made in the literature reviewed or comments from experts in this area. Whilst this makes sense in that all players need to bat and field, having some knowledge as to the requirements of fielding categories will assist in performance profiling and matching playing position with the physical attributes of the player. With this in mind Table 8.2 summarises information gathered from the literature review, survey and fielding and wicket-keeping event coding analysis. This table summarises the physical attributes required for fielding and wicket-keeping and the degree to which each attribute is applicable to each fielding category.

Table 8.2: Physical attributes of fielding with respect to each fielding category

Physical Attribute	Fielding Category			
	Wicket-keeper	Close	Inner Circle	Outer Circle
Anthropometry	Short, compact	Shorter in stature, lean	Athletic, ability for explosive movement	Tall, big wingspan
Sprint – 10 m	High	Low	High	Moderate
Sprint – 20 m	Moderate	Low	High	Moderate
Sprint – 30 m	Low	Low	High	High
Lateral - 3 m	High	High	Moderate	Low
Change of Direction Ability	Acyclic - High	Acyclic - High	Acyclic/cyclic - High	Cyclic - Low
Multidirectional Leg Power - Vertical	High	High	High	Moderate
Multidirectional Leg Power - Lateral	High	High	High	Moderate
Multidirectional Leg Power - Horizontal	High	Low	High	Moderate
Strength	Moderate	Moderate	Moderate	Moderate
Flexibility	High	High	High	High
Aerobic Fitness	High	High	High	High
Anaerobic Fitness	Moderate	Moderate	High	High

From these tables, a number of observations can be made regarding improving assessment, program design and subsequent performance.

Fielding Group Priorities

Due to the nature of the game of cricket, it is not possible for players to field in the same position throughout the match; fields are set depending on the batsman and bowler in at the time. Therefore, fielders should be expected to field in all fielding categories, but they will have particular strengths and weaknesses, which will lend themselves to fielding in certain positions. Currently, the NZC Core Playing Skills document does not acknowledge the degree to which physical attributes are applicable to different positions. Therefore, it is recommended that players undergo all assessments; physical strengths and weaknesses will indicate players' suitability in different areas of the field (Carr, McMahon, & Comfort, 2015).

Anthropometry

The NZC Core Playing Skills document currently recommends that advanced and elite players have a sum of 8 skinfolds under 80 mm, and that entry level players have a basic understanding of nutritional plans, recognising that a player's physical build has the potential to impact performance.

The results from the player and coach survey made it clear that there are anthropometrical qualities which are helpful for good fielding performance. For example, it is beneficial for an outer circle fielder to be tall with a large arm-span; this gives them the best opportunity to catch balls otherwise going over the boundary. Conversely, it is beneficial for close fielders and wicket-keepers to be smaller in stature, as the repetitive crouching may present implications for back injury if players are tall. Furthermore shorter fielders with lower centre of masses and shorter limbs should theoretically have better reactive ability and movement times. However, while having anthropometric characteristics that lend themselves to particular fielding positions is beneficial to performance, it would be unwise to exclude players from particular fielding positions due to their anthropometry.

Reactive Ability

Reactive ability is particularly important for close fielders who have little time for reaction and movement initiation. However, the NZC Core Playing Skills document currently does not contain an assessment of reactive ability. A possible methodology for assessing reactive ability has been previously described by Scott et al. (2000). The

assessment tested slip fielding reaction times when attempting to catch balls projected from a ball projection machine. A photoelectric timing light system and lever micro-switches were used to determine reaction time, defined as the time between ball projection and first movement of the hands. Such a test set up can be used to assess movement initiation times for each hand, allowing for the quantification of reactive ability to either side and bilaterally, in a practical setting.

It is recommended that all fielders undergo an eye test and visual acuity assessment (Zimmerman, Lust, & Bullimore, 2011); if any vision problems are detected these could be contributing factors to poor perceptual decision making performance. Sports optometrists can manufacture sunglasses with polarized colour filters which reduce glare and improve contrast sensitivity. Hand-eye coordination and reaction times can be measured and trained in isolation with the use of vision training systems such as the Sports Vision Trainer™ (Ellison, Sparks, Murphy, Carnegie, & Marchant, 2014; Erickson, 2007). There has been research which indicated the fielding performance is greatly improved when on-field training is used in conjunction with video-based systems than with on-field training alone (Hopwood et al., 2011). Online visual training has been successfully used in rugby union and football and is now being considered at a professional level in cricket, a logical step when vision training has been integrated successfully into the baseball leagues in the USA (Seiller, 2013).

Change of Direction Ability

From the results of this research it has been possible to establish that the COD requirements differ between the fielding categories. The wicket-keepers and close fielders require high acyclic COD ability to perform explosive movements from relatively static positions. Single leg squat jumps and single leg countermovement jumps have been used to assess acyclic changes of direction (Hewit, Cronin, & Hume, 2012a; Meylan et al., 2009). Given that wicket keepers and close fielders tend to start from a power position, the single leg lateral jump most closely simulates the COD requirements of close fielders and wicket keepers and would be the jump method of choice to assess and develop the acyclic COD ability of these players.

Conversely, the other circle fielders rely on cyclic COD of ability. The results of the video analysis revealed that due to their position, outer circle fielders had to perform approximately 90° changes of direction from a walking start to sprint to field the ball. An outer circle COD movement assessment test modelled on the 90° turn and sprint tests described by Hewit, Cronin, Button, and Hume (2010) would seem desirable and is

described in Figure 8.1. Qualitative video analysis methods can be used to identify critical features of the COD performance (Hewit et al., 2010) and used to improve performance in this task.

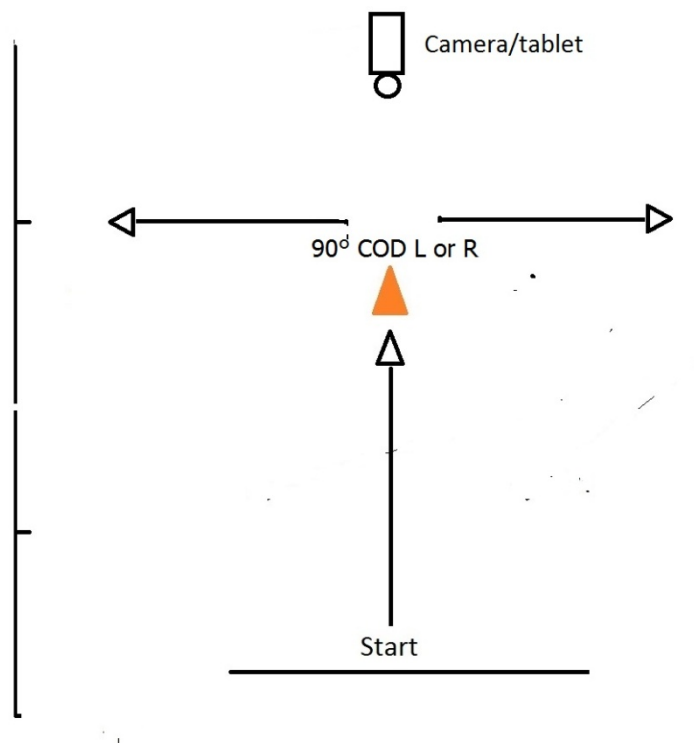


Figure 8.1: 90° change of direction movement assessment

The inner circle fielder was found to be unique in that they require proficiency in both acyclic and cyclic changes of direction. They were required to perform acyclic explosive movement such as dives and jumps and also up to 180° turns and sprints from an almost stationary position. Therefore inner circle COD ability assessment batteries must be the most comprehensive of all the fielding categories. Inner circle fielders should undergo the acyclic COD ability assessments as described for wicket-keepers and close fielders, a 90° turn and sprint COD test and an additional 180° COD assessment as illustrated in Figure 8.2.

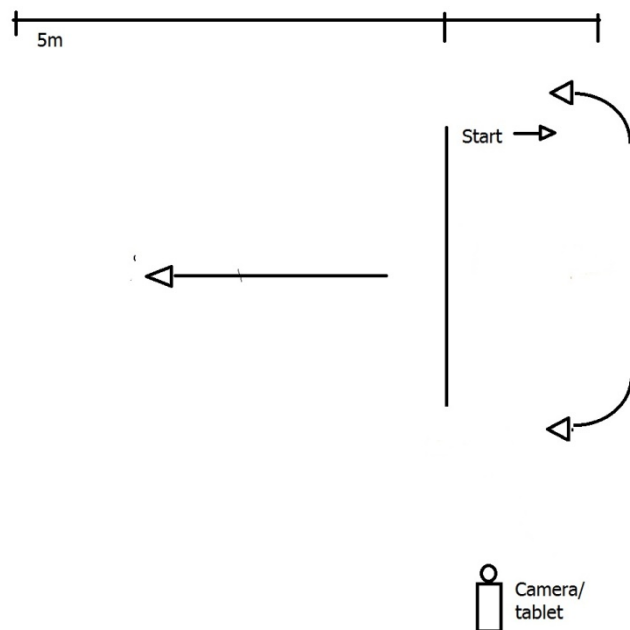


Figure 8.2: 180° change of direction assessment

Fielders should begin the 180° COD test with their heels on the start line. When ready, they make a 180° COD to the right followed by a 5 m straight sprint. The test should then be repeated so that calculated times can be averaged. The camera should then be placed on the opposite side of the start mark to assess 180° COD to the left. Movement times for COD ability can be quantified from the recordings of the trials. It is important to measure COD ability to both the left and the right; as with single leg movements, the ability to change direction with one leg is not necessarily related to ability to change direction with the other (Meylan et al., 2009). Substantial COD ability deficiency to one side will have implications for performance in the field and may guide strength and conditioning as well as technique training of the respective coaches.

Power

The bilateral triple jump is recommended in the NZC Core Playing Skills document for assessing leg power. However, it only assesses power in one plane of movement and gives no indication of a left-right differential in power output. The findings of both the survey and the video analysis studies have indicated that fielders require multidirectional leg power to move explosively in any direction to field the ball. In particular, the results of this research have determined that the wicket-keeper must perform repetitive, multi-planar, low-intensity movements, in the form of crouching and lateral footwork, interspersed with bouts of explosive movements such as diving. This low intensity, high repetition movement should be performed proficiently with minimal physical exertion in order to maintain a consistent standard of performance (Plunkett et

al., 2005). Therefore, to build a more comprehensive, multidirectional power profile for all fielding categories there is merit in considering the use of power tests with different direction of force application (Brughelli, Cronin, Levin, & Chaouachi, 2008), for example single leg jumps in vertical, horizontal and lateral directions to assess multidirectional lower limb power (Meylan et al., 2009). Assessing single leg jumps in multiple planes, both with unilateral and bilateral force production will allow a complete power profile to be developed, and left/right asymmetries to be quantified. The shared variance between countermovement jumps performed in the vertical, horizontal, and lateral planes is moderate at best with assessments being relatively independent of each other (Hewit, Cronin, & Hume, 2012b), hence each leg must be measured in multiple planes so that multi-planar asymmetries can be determined. These power profiles can be developed using measures such as height and distance jumped or with a force plate if available. Strengths and weaknesses in multidirectional leg power will have implications on other aspects of performance, for example a fielder may have good horizontal leg power (and hence sprint speed), but poor lateral leg strength. Therefore such information provides information for direction and plane specific strength and power training. Furthermore, if fielders exhibit substantial left or right asymmetries remedial programming should be prescribed as appropriate. Single leg jumps may be more appropriate for assessing power for entry level players as there are currently no power recommendations for the entry level of competition beyond the recommendations in Table 8.1. Furthermore, some thought needs to be given to the development of multidirectional leg power in the physical conditional programming of the fielders and wicket-keepers.

Flexibility

There is currently no mention of flexibility in the NZC Core Playing Skills document. This is despite the fact that the results of the video analysis of fielding indicated that close fielders have to exhibit a high level of flexibility. Due to their proximity to the batsmen they have no time to reposition, and hence may take catches low to the ground, or high above their heads without moving their feet. It is therefore recommended that some evaluation of flexibility is added to the physical testing procedures; however, careful consideration must be given as to whether this is static or dynamic flexibility and which muscle groups should be assessed. Also the strength and conditioning coach needs to consider the placement of such training in the weekly schedule of players.

Technical

Currently the NZC Core Playing Skills document recommends certain levels of proficiency in the physical aspects of performance, however, beyond descriptions of the desired qualities there are as yet no methods of quantifying the technical component of performance. Using the catching, throwing, and fielding efficiency measures previously defined in Chapter 7 would be a simple method of quantifying performance measures for teams and individuals in competitive matches throughout a season.

$$\text{Catching efficiency \%} = \frac{\text{catches taken}}{\text{catching chances}} \times 100 \quad \text{Equation 8.1.}$$

$$\text{Throwing accuracy \%} = \frac{\text{hit stumps}}{\text{shies at stumps}} \times 100 \quad \text{Equation 8.2}$$

$$\text{Team efficiency \%} = \frac{\text{Ball in play-ground fielding mistakes}}{\text{Ball in play}} \times 100 \quad \text{Equation 8.3}$$

However, what is currently missing from the NZC Core Playing Skills documents are methods of assessing fielding technical skills so that strengths and weaknesses may be quantified and players may be matched to positions most suited to their skills. Proposed methods for assessing catching and throwing performance are detailed in this section.

Catching

From the previous chapters it is clear that while all fielders have to perform the same skills, there are differences in technical requirements between categories. For example all players must be able to catch the ball, but the skills and attributes required to successfully take the catch differ between close slip fielders and players on the boundary. Therefore, it is important that catching assessments are designed to assess catching demands in all areas of the field.

A slip catching test incorporating a reaction time assessment has been previously described by Scott et al. (2000); this test procedure is recommended for assessing slip and close catching skill. The catching assessment proposed by Scott et al. (2000) assessed performance using a catching scale such as that described by Wickstrom (1983) to score performance (Table 8.3).

Table 8.3: Wickstrom catching scale

Outcome Score	Description
5 - Clean catch	The ball is contacted and retained by hands
4 - Assisted Catch	The ball is juggled and retained by the hands
3 - Hand Contact	The ball contacts the hand but is dropped
2 - Upper body contact	Upper body (but no hand contact)
1 - Lower body contact	Lower body (but no hand contact)
0 - No ball contact	No cricket ball contact

If a catching drill consisted of 10 catches, the maximum possible score using this scale would be 50. Using a score system to quantify performance provides a simple method of between and within player skill comparisons and monitoring performance progress over time. The test schematic used by Scott et al. (2000) provides a method of assessing slip catching performance in a controlled setting. However, due to the varied and often spectacular nature of catches taken in the inner and outer circle fields, it would be difficult to fully simulate the types of catches taken while conducting a controlled reliable test. Therefore it is proposed that catching analysis for fielders is assessed by performing retrospective analysis taken in competitive matches. The catches can be assessed with adapted Wickstrom scale detailed in Table 8.5. Recording the outcome score of each catch along with the positions in which the player was fielding when they took the catch and their catching efficiency will allow analysis of ability in different fielding positions. Furthermore the video footage will allow the coach to provide technical advice where necessary.

Throwing

From the previous chapters it is apparent that throwing requirements differ between fielding categories both in distance to throw and technique used (Table 8.4). For example, inner circle fielders use any throwing technique in an attempt to hit the stumps, whereas outer circle fielders are required to overarm throw with speed and accuracy in order to return the ball to the crease as quickly as possible. Therefore it is necessary to use throwing assessments which can be applicable to all areas of the field. However, no such throwing assessments are currently detailed in the NZC Core Playing Skills document.

Table 8.4: Recommended throwing proficiency for each fielding category.

Fielding Category	Distance	Throw Type
Wicket-keeping	10, 20	Underarm, Sidearm
Close	10	Underarm, Sidearm
Inner Circle	10, 20	Underarm, Sidearm, Overarm
Outer Circle	20, 35	Sidearm, Overarm

There are commercial throwing assessment systems, such as the Pitch Vision Fielder Kit (miSport Holdings Ltd, 2009) which assess fielding performance by recording the total time taken to perform a fielding task which includes fielding the ball and a return throw at a target. This system allows between and within fielder assessments to be performed. However, the cost of the system and the associated equipment may limit the accessibility of such systems to all levels of cricket. Figure 8.3 illustrates a simple, cost effective throwing schematic, which assesses throwing as a closed-task skill and can be used for all fielding categories and throwing techniques. The video analysis of wicket-keepers revealed that wicket-keepers occasionally removed their outer glove when attempting to throw for accuracy, therefore the wicket-keeper should be assessed wearing full gear and with the outer glove removed.

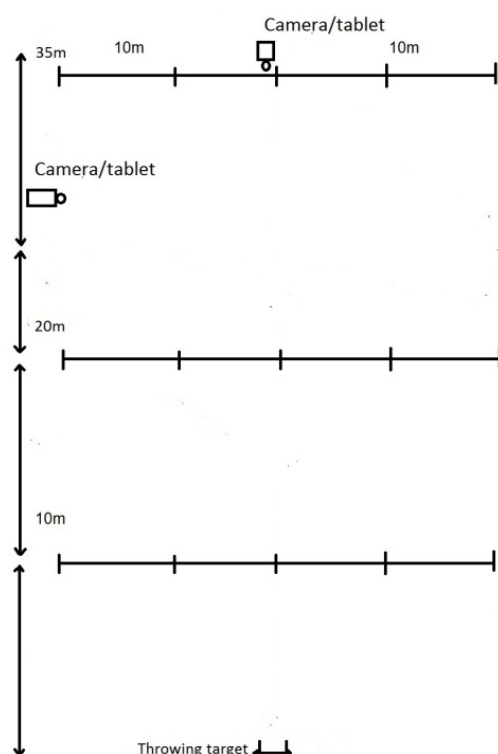


Figure 8.3: Throwing assessment schematic

Using this set up, static throwing ability can be evaluated from three distances (10, 20 and 35 m) from the target; 10 throws at each distance. Two throws should be taken from

each mark on the line to change the angle at which the fielders have to aim at the stumps. Figure 8.5 illustrates a throwing target as used by Freeston and Ferdinands (2007) to assess throwing accuracy.

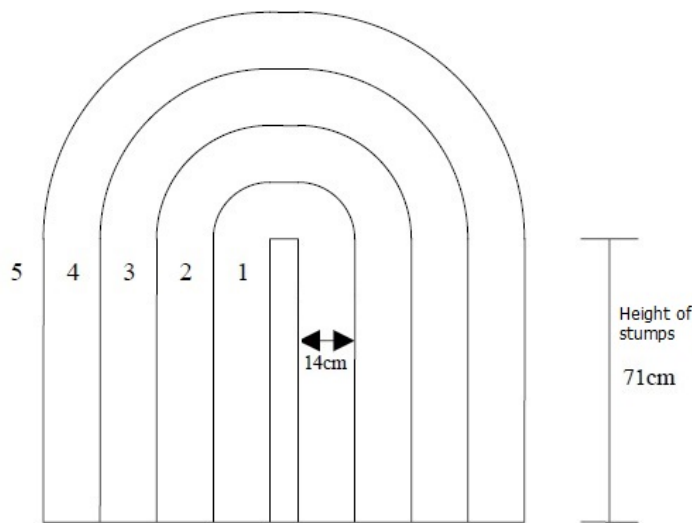


Figure 8.4: Throwing target schematic

Note: Adapted from "Progressive velocity throwing training increase velocity without detriment to accuracy in sub-elite cricket players: A randomized controlled trial" by J. Freeston and K. Rooney. 2008. *European Journal of Sports Science*, 8(6).

The target (Figure 8.4) should be set up directly opposite the throwing lines; a tablet or camera should be placed behind the thrower with the target in view so that throwing success can be determined from the video retrospectively. Videoing the performance will also permit movement time, defined as time from first ball contact to point of ball release to be determined. The target allows an inverse score system to be used to evaluate throwing accuracy; the lower the score, the more accurate the throwing. If ten throws are taken from each distance, the maximum possible (worst score) is 50 points.

The test schematic can be altered to assess dynamic throwing ability, with the fielder required to run a set distance to the ball, and then field and throw at the target. Measurements including movement time to ball, ball collection to ball release, and ball release to hitting target can be measured from the video footage. The findings of the fielding video analysis supports previously findings (Elliott & Anderson, 1990), that fielders, particularly those in the inner circle are sometimes required to throw from an unbalanced position, therefore this should be simulated in a fielding throwing assessment. The researcher recommends that players are assessed at all distances; player scores at different distances and throw types will indicate their throwing ability in different fielding categories.

Mental

The importance of mental factors on sports performance has been recognised in cricket research (Weissensteiner, Abernathy, & Farrow, 2009; Weissensteiner, Abernathy, Farrow, & Gross, 2012) and is recognised in the NZC Core Playing Skills document. The core mental skills identified by NZC were routines, decision-making, performance flags, concentration, coach-ability and adaptability; recommendations around performance preparation, performance focus, reviewing performance and world class performance were also made.

With regards to this research, one of the most significant findings of the survey of players and coaches was the contribution of mental qualities to fielding performance. This included mental qualities such as desire to be involved, concentration and anticipation. From the results of the survey the mental attributes important for fielding performance and the degree to which they are thought important for different fielding positions are displayed in Table 8.5.

Table 8.5: Mental attributes of fielding and wicket-keeping performance

Mental Attributes	Fielding Category			
	Wicket-keeper	Close	Inner	Outer
Anticipation	High	High	Moderate	Low
Cue scanning	High	High	Moderate	Low
Reactive Ability	High	High	High	Low
Decision Making	High	High	High	Low
Routines	High	High	High	High
Leadership	High	Low	Low	Low
Concentration	High	High	High	High

From this table, a number of observations regarding the mental aspects of performance can be made. Due to their position close to the batsman anticipation and cue scanning are particularly important for the wicket-keeper and close fielders. Inner circle fielders are not positioned as close to the batsmen, however one of the findings of the survey was that the best inner circle fielders anticipate the trajectory of the ball well, rather than just reacting to it.

When the bowler is running into bowl, all fielders must be concentrating and prepared for the ball to come to them, no matter where they are placed in the field. The routines used to prepare to field may differ between fielding categories but are equally important. In response to the survey one player said, "just tell myself to get involved and this keeps me alert. My routine if this is one is an attitude to want the ball which

creates my sense to ready to move and exercise". Outer circle fielders described physical routines such as walking in as the bowler is running up to bowl.

Wicket-keeping

"It is impossible to estimate too highly the qualities that make up a good wicket-keeper. It demands the quickest of eye, the staunchest of nerve, the steadiest of purpose, the most unflinching of resolution."

R.A. Fitzgerald (1866) as quoted in Lemmon (1990)).

Although mental qualities are important for all players, especially at the international level, this quotation provides evidence that it has been long known that mental qualities are a significant contributing factor to wicket-keeping performance. This fact is supported by the findings of the investigative survey, where coaches and players clearly stated that there are mental attributes which lend themselves to wicket-keeping performance. These included a desire to be constantly involved, 'bags of energy' and the ability to concentrate. The wicket-keeper needs to display leadership qualities, as their unique position in the field allows them lead the fielding unit and to provide insight to the captain regarding tactical decisions. While it is possible to assess the physical qualities and skills required for successful performance, these mental factors are more difficult to quantitatively assess. Nevertheless, it would be beneficial if coaches can recognize these traits in all players, and use this knowledge so that potential wicket-keepers can be identified as early as possible.

Physical

Movement Ability

Horizontal movements are routinely assessed in the form of straight sprint speed tests, over 10 to 30 metres. However, the findings of the wicket-keeping video analysis determined that the majority of wicket-keeping movement is in a lateral direction; currently there is no method of assessing wicket-keeping lateral movement efficiency. The movement required of wicket-keepers is position specific; starting from a crouch they have to use anticipatory cues and react to the ball to move laterally either to the left or right. This lateral movement can be achieved through a series of steps and shuffles (personal preference determining individual patterns) or through explosive dives. A testing procedure for assessing wicket-keeping footwork and diving efficiency is proposed below (Figure 8.5). The purpose of these tests is to determine the efficacy of wicket-keeping footwork and diving, and the degree to which reactive ability impacts footwork efficiency. Thereafter strength and conditioning coaches can devise training methods to improve movement efficiency specific to the findings of the test.

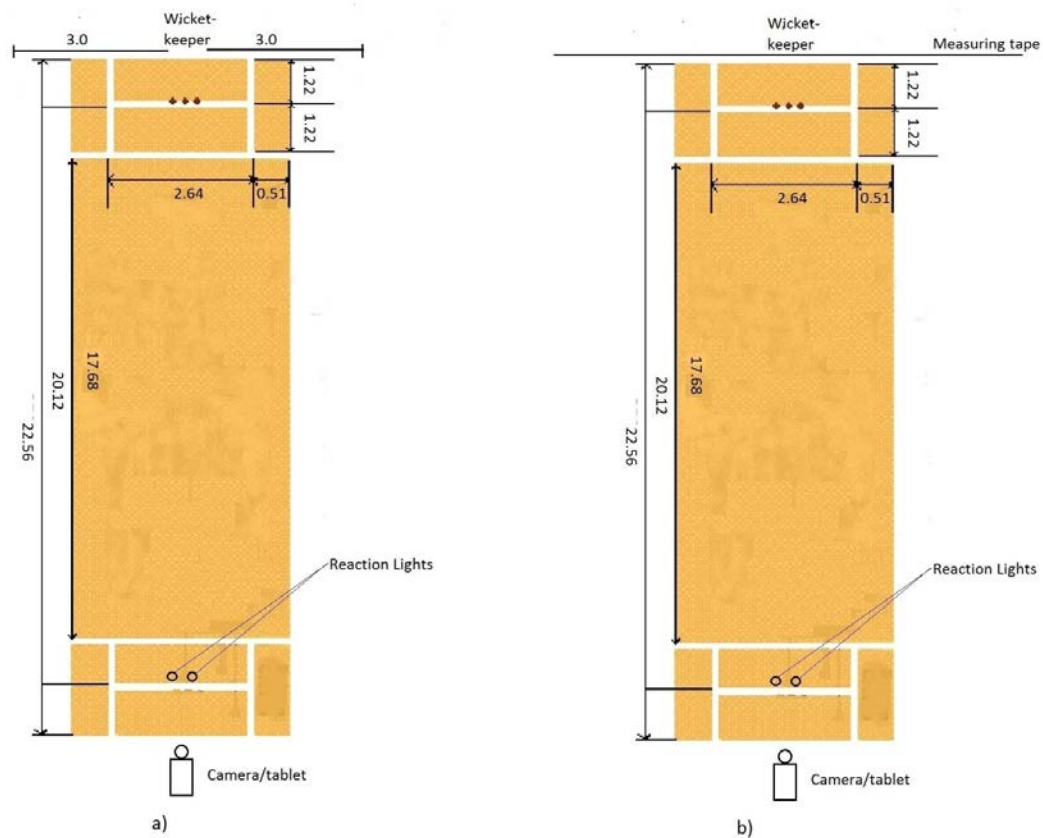


Figure 8.5: Test set up for assessing wicket-keeping a) lateral footwork and b) lateral diving

Lateral footwork will be assessed using the time taken to cover 3m in a lateral direction either side of the stumps; the maximum distance travelled from the stumps will be the measure of diving ability. Wicket-keepers should be fully familiarised with testing procedures, and given sufficient practice trials prior to testing. Full wicket-keeping protective equipment should be worn when undergoing testing. Recording the assessments with either a camera or tablet allows times to be quantified, visual feedback to be provided to wicket-keepers, and further technical analysis to be performed if desired. Such assessments provide better diagnostic value to guide the strength and conditioners programming to better effect.

To assess lateral footwork, the wicket-keeper assumes the power position and moves laterally (with their preferred footwork technique) 3 m in reaction to either the left or right light being illuminated. Trials shall be in a random order to prevent anticipation. Five trials to either side should be collected and averaged to provide movement time to either side. The time between the light being first illuminated and the wicket-keepers' first movement is defined as reaction time and can be calculated from the video footage. The total time taken for the wicket-keeper to move laterally 3 m is the movement time.

As such, this test enables profiling of the wicket-keepers reaction and movement times in the lateral direction and once more better diagnosis for exercise prescription.

Diving to field a ball is relatively uncommon in the field, but nonetheless can occur in any position, but more so in the wicket keepers as denoted in the video analysis. As such methods to profile diving ability have been detailed for the wicket keeper but theoretically could be used across positions. One measure of diving performance is the distance achieved those with greater dives theoretically better able to make catches and save runs. Wicket-keepers must start behind the centre of the stumps and dive as far as possible in response to either the left or right light being illuminated; the distance of the dive will be measured from the furthest point of the wicket-keeper to touch the ground. The wicket-keeper is allowed to move to their outside foot prior to the diving. Five trials to each side are to be collected in random order to minimise anticipation and averaged to calculate maximum diving distance to each side. The reaction time itself can be calculated from the video, as the time between the reaction light first illuminating and first movement of the wicket-keeper. The total movement time is the time from first light illumination to the conclusion of the wicket-keepers' dive. The movement times provides a measure of the velocity of movement if used in tandem with the dive distance. To be able to dive far would seem important but to be able to do the movement quickly would seem especially advantageous.

This test is designed to use minimal and easily accessible equipment; if reaction lights are unavailable other cues such as a visual or audio signal from a tester may be used, provided that they are easily identifiable or audible in the recorded footage so that movement and reaction can be measured. As such, this test enables profiling of the wicket-keepers reaction and movement times as well as diving distance in the lateral direction. Due to the requirements of the game (bowler's preference or handedness of the batsman) wicket keepers will move differentially left or right. It is therefore important that in the assessment of wicket-keeping movements, movements in both directions are assessed so that any movement asymmetry can be established and quantified, and remedied if thought important. Wicket-keeping movement capability assessed using these methods can be summarised in a table as below (Table 8.6).

Table 8.6: Wicket-keeping movement capability

Movement	Left	Right	% Difference
Footwork			
Reaction Time (s)			
Movement Time (s)			
Diving			
Distance (m)			
Reaction Time (s)			
Movement Time (s)			

Technical

The wicket-keeper is unique in that they are the only fielder who has the potential to be involved in every delivery of the innings and the only fielder who is permitted to wear gloves by the Laws of Cricket (Marylebone Cricket Club, 2010). Their role within the fielding unit is also unique; it is their responsibility to catch the ball directly from the bowler if the batsman does not play a shot, catch dismissal opportunities and receive returning throws from other fielders.

Wicket-keeping glove-work (catching, taking, and receiving the ball from the field) performance in matches can be quantified using catching efficiency measures; expressed as a percentage of the successful catches and takes over the total number of opportunities offered as seen in Table 8.7. These efficiency measures should be recorded for each match throughout a competitive season to monitor wicket-keeping performance.

Table 8.7: Wicket-keeping efficiency table

Wicket-Keeping Efficiency		Offered	Taken	%
From Bowler	Takes			
	Chances			
From Field	Takes			
	Totals			
	Catching Efficiency			

The wicket-keeper's positioning behind the stumps will vary depending on the type of bowler (i.e. spin or fast) and whether the batsman on strike is left or right handed. Therefore, wicket-keeping ability should be assessed for both standing back and standing up to the stumps. Methods for quantifying wicket-keeping glove-work ability standing up and standing back from the stumps in training are detailed below.

Wicket-keeping ability standing up to the stumps

This test requires the use of a ball projection machine, a barrier (e.g. a box) to place in front of the wicket-keeper to create a batsman simulating blind-spot. A camera or a tablet should be placed behind the bowling machine to record the assessments.

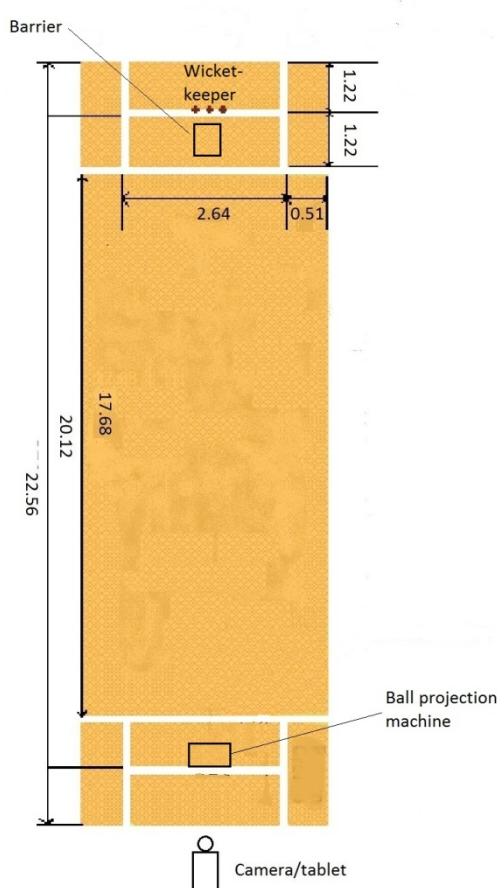


Figure 8.6: Wicket-keeping standing up to the stumps assessment

The wicket-keeper is to assume their usual power position and stance standing up to the stumps. The bowling machine should be set up so that balls are delivered down the leg side (as if for a right handed batsman), with the ball pitching on a determined length.

The ball speeds utilised shall be as described in Table 8.8, which outlines the classification of bowling type, adapted from West and Justham (2008).

Table 8.8: Bowling classification

Bowler Classification	Transit time (ms)	Ball velocity kmh⁻¹	Ball velocity (ms⁻¹)
Express	439	145	40.2
Fast	493	129	35.8
Fast-medium	657	96	26.8
Slow-medium	986	50	13.9

Note: Adapted from "The development of a novel cricket bowling system: recreating spin and swing bowling deliveries at the elite level", by A.A. West and L. Justham, 2008, *Journal of Physics: Conference series*, 108. The transit time is a guide of the time (in milliseconds) between the ball being released to reaching the wicket-keeper.

Starting at 50kmh⁻¹ balls will be projected down the leg side; the wicket-keeper must take the ball and release it immediately to prepare for the next ball. Five balls will be projected at the wicket-keeper in succession with 15 seconds between each ball for the wicket-keeper to resume their crouch stance. If the wicket-keeper successfully catches 5 of the 5 deliveries he is deemed to have passed at the speed. The ball delivery speed is then increased in 5 kmh⁻¹ increments, and the test repeated. The test is over when the wicket-keeper fails to take 5 of 5 takes at a given speed. Their score is the last speed at which they were successful (e.g. 75kmh⁻¹ right hand bat). The test procedure is then to be repeated as if for a left-handed batsmen.

Wicket-keeping ability standing back from the stumps

For this test, the stumps and barrier at the wicket-keepers end should be removed, so the ball may be projected straight at the wicket-keeper. Fifteen x one metre marks are measured back from the crease as shown in Figure 8.7.

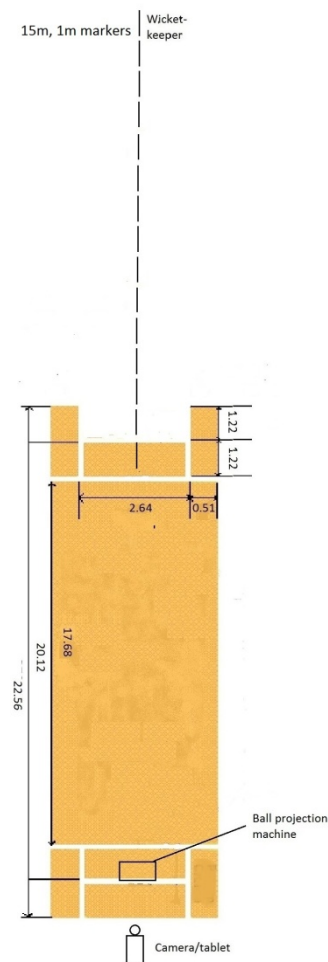


Figure 8.7: Wicket-keeping standing back from the stumps assessment

The wicket-keeper is to start standing 15 m back from the stumps. The bowling machine should be set to bowl at 80 kmh^{-1} , pitching on a good length. Five balls in succession (with 15 seconds between balls), will be projected at the wicket-keeper, who must catch each one, release it and prepare for the next. If the wicket-keeper catches 5 of 5 balls he is deemed to have passed at that distance and moves forward one metre to the next and the test is repeated using the same ball speed. The test is over when the wicket-keeper fails to take 5 successful catches at that distance. The wicket-keepers final score will be the first distance at which 5 of 5 takes were successful (e.g. standing back catching range, 80 kmh^{-1} at 3 m). Depending on the test being used (i.e. outdoor cricket pitch or indoor training facility), the ball may not carry to the wicket-keeper standing back at 15 m, and in this case the wicket-keeper should be moved forward. The test surface used should be recorded along with results.

Conclusions

The tests and recommendations made in this chapter and throughout this thesis should contribute to further understanding fielding and wicket-keeping performance and thereafter progress the development of these players by the strength and conditioning coach, given the enhanced diagnostic and specificity of the suggested tests. It is recommended that the tests and improvements detailed in this thesis be added to the NZC Core Playing Skills documents and integrated into practices where feasible. To fully monitor and evaluate performance, it is recommended that players be assessed periodically throughout the season. The reader should also be cognizant that many of the tests proposed measure physical qualities in isolation, but they do not operate in isolation; multidirectional leg power will have implications for COD and movement ability. For example, if a wicket-keeper had good lateral leg power but poor lateral movement ability, this would indicate a technical issue rather than a physical deficiency.

Noteworthy is the lack of an agility test, a fact which was reiterated by coaches in the survey results. Young and Farrow (2006) proposed a deterministic model of agility, which was broken into perceptual and decision-making factors, and COD factors (Figure 8.8).

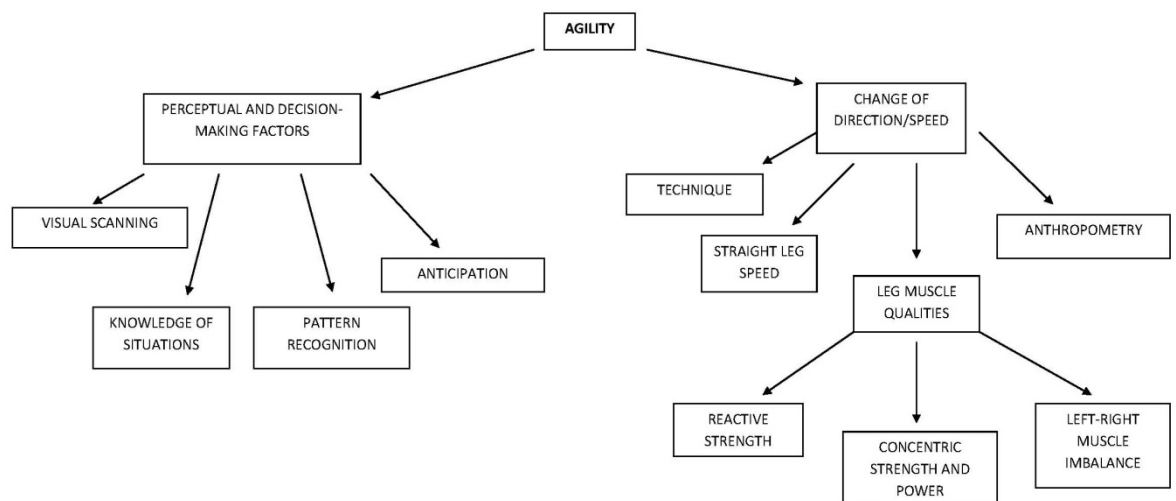


Figure 8.8: Deterministic model of the components of agility

Note. Figure adapted from "A review of agility: practical applications for strength and conditions" by W. Young and D. Farrow, 2006, *Strength and Conditioning Journal*, 28(5).

Such a model may be used to inform the development of cricket specific fielding agility tests that identify player strength and weaknesses and provide insight into focus areas for coaching and conditioning. While there is currently no valid cricket specific agility test, the recommendations made in this chapter provide methods of measuring individual components that contribute to overall agility.

Perceptual decision making factors are a vital component of agility, as are other mental factors, such as attitude, concentration and anticipation to overall fielding performance. While these mental factors are more difficult to assess than physical aspects of performance, their importance must be acknowledged. Ideally, coaches will be able to recognise the mental qualities important for fielding performance.

In order to assess the core technical skills, efficiency calculations were defined to evaluate catching, throwing and overall fielding performance during matches. They can be used to assess both individual and team performances. In the absence of a reliable training based catching assessment individual catching performance can be video analysed retrospectively using a scale to quantify the quality of the catch. A simple method of assessing throwing performance from all areas of the field was proposed. The findings of this research identified the wicket-keeper as a specialist position with unique skills. A wicket-keeping glove-work efficiency measure and movement assessment tests were proposed to quantify wicket-keeping ability. This series of recommended tests should allow strengths and weaknesses in core skills to be identified.

Limitations

The findings of this study have been limited by a number of factors which must be acknowledged. The camera placement for the validation study (Chapter 5) was limited by restrictions placed by the match organisers and venue. It can be hypothesised that video footage of a higher quality could have been collected had these restrictions not been in place.

The video analysis studies in Chapters 6 and 7 were carried out with a sample of eight matches from one tournament. It would have been preferable to include all matches from the tournament to have greater sample sizes from which to draw conclusions. The sample was drawn from one tournament, held in certain playing conditions. Ideally, matches played in other locations would have been added to the sample for analysis.

Future Research Directions

The purpose of this thesis was to establish the performance demands of fielding and wicket-keeping in ODI cricket with the aim of providing recommendations for assessing and improving performance. The studies in this thesis have contributed to addressing the gaps in the knowledge of physical, mental and technical performance requirements in fielding and wicket-keeping.

It was determined that there were differences in performance requirements between different fielding positions and that assessments and training should be individualised taking these differences into consideration. The logical continuation of this research would be to undertake reliability studies for the novel testing procedures introduced in this section. However, the design of current and future assessments should be carefully considered, and not limited to the assessments proposed in this thesis. While video analysis usually involves video cameras, the technical assessments proposed in this research were designed so that mobile devices such as an iPad or tablet may be used for recording. The use of such readily available technology makes performance analysis available to all levels of cricket. Validity and reliability using such mobile technology in performance analysis should also be undertaken.

The findings of this research have improved knowledge regarding the performance requirements of fielders and wicket-keepers and if suggestions are integrated into the current NZC Core Playing Skills documents there will be opportunities to gather further data around the listed competencies. Where possible it is recommended that physical, technical and mental performance profiling is undertaken at all levels of the game so that national normative standards can be established. The development of national normative standards for age groups and different competition levels of cricket will further increase the understanding of the performance requirements of the game, assist talent identification and enhance player development.

The research undertaken in this thesis used a mixed methods approach to inform strength and conditioning practice, with this final chapter attempting to integrate the findings of the performance analysis into tangible strength and conditioning information. There is no doubt that some of the suggestions and recommendations made in this research would benefit from critique by experts in the area so that the assessment and training suggestions may be further refined.

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Glossary of terms

Definitions and explanations of words or phrases not defined in the text

Ball in play - The ball was deemed to be in play if it required intervention by a fielder or went through to the wicket-keeper.

Fielder - is one of the 11 players who compose the fielding side. This definition includes not only both the bowler and the wicket-keeper but also nominated players who are legitimately on the field of play acting as substitutes. 0

Fielding Side - the side currently fielding, whether play or taking place or not

Field of Play - the area contained within the boundary edges.

Fielding Permutations:

Silly - very near batsman

Short - near batsman

Deep - further from batsman

Wide - further from line of pitch

Fine - straight nearer line of pitch

Square - near line of batsman's crease

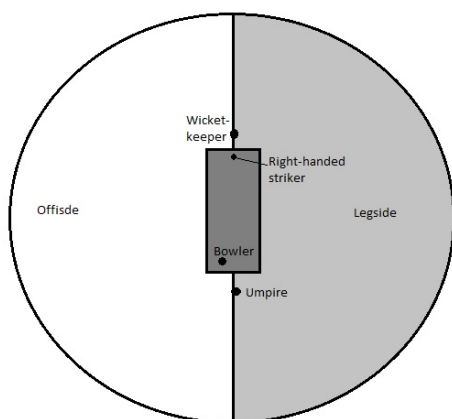
Backward - behind batsman's crease

Forward - in front of batsman's crease

Hand - for the batsmen or wicket-keeper shall include both the hand itself and the whole of a glove worn on the hand.

Inner field - the area of the field contained by the 30 yard inner circle rope.

Offside/Legside - See diagram below. Reversed for left-handed striker.



Outfield - the part of the field of play between the inner circle rope and the boundary rope

Appendices

Appendix 1 - Abstracts form published journal articles

Chapter 2 - Performance demands of fielding in cricket

Cricket is played in three formats at elite level; Test, One Day and Twenty20. Fielding is an important component of cricket, as all players are obliged to field. However, there is a paucity of literature on fielding compared to that on batting and bowling. This article reviews the available literature in terms of technical, tactical, mental, physiological and physical factors important to fielding, in order to identify gaps in knowledge and to better understand the performance requirements of fielding in cricket.

Chapter 3 - Performance demands of wicket-keeping in cricket

Cricket is unique in that three formats of the game, of varying duration and intensity are played at elite level; Test, One Day and Twenty20 (T20) cricket. The wicket-keeper is a vital member of the fielding side; the only player who could be involved with every delivery of the innings. Despite this, there is a paucity of literature on wicket-keeping, with most research having focused on fast bowling and batting. This review is principally concerned with identifying the performance demands associated with wicket-keeping and the conditioning of these cricketers. To appreciate the performance demands of wicket-keeping, an integrated approach has been taken where the mental, technical, physiological, physical and tactical requirements of wicket-keeping are discussed. From this information recommendations are made and suggestions for future research detailed.

Chapter 4 - A survey of the performance demands of cricket fielding and wicket-keeping

Little is known of the performance demands of fielders and wicket-keepers in cricket, therefore the purpose of this study was to investigate the performance demands of fielding and wicket-keeping through an online survey of players, coaches and strength and conditioning coaches (n=41). The mental, physical and technical aspects of performance were explored with respect to wicket-keepers, close, inner and outer circle fielders. The importance of physical characteristics for each position was determined for each format of cricket respectively. However, more detailed analysis was undertaken for One Day International cricket, from which emerging themes were also identified. Agility emerged as the most important physical characteristic in ODI cricket for all but the outer circle fielder, for whom speed was the most important attribute. Understanding

the performance demands of fielding and wicket-keeping should allow more appropriate training and conditioning to be prescribed.

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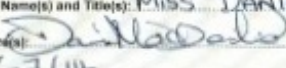
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Appendix 3 - Ethics Approval



AUTEC

SECRETARIAT

16 November 2012

John Cronin

Faculty of Health and Environmental Science

Dear John

RE: Ethics Application - 12/293 Fielding and wicket-keeping in cricket: A performance analysis and strength and conditioning perspective.

Thank you for submitting your application for ethical review. I am pleased to advise that the Auckland University of Technology Ethics Committee (AUTEC) approved your ethics application at their meeting on 12 November 2012, subject to the following conditions:

1. Provision of a revised response to section E. of the application which greater reflects the focus, context and nature of the research;
2. Clarification of whether female cricketers will be invited to participate. AUTEC noted that the questionnaire was gender specific;
3. Provision of further information relating to the response to section H.9.2 of the application;
4. Provision of a revised Information Sheet to include;
 - a. Inclusion of the AUT logo;
 - b. Advice relating to point 3 above;
 - c. Advice about who is funding the researcher's study.

This approval is for the questionnaire phase of the research only. Please submit an application for subsequent phases for approval by AUTEC.

Please provide me with a response to the points raised in these conditions, indicating either how you have satisfied these points or proposing an alternative approach. AUTEC also requires copies of any altered documents, such as Information Sheets, surveys etc. Once your response

is received and confirmed as satisfying the Committee's points, you will be notified of the full approval of your ethics application. Full approval is not effective until all the conditions have been met. Data collection may not commence until full approval has been confirmed. If these conditions are not met within six months, your application may be closed and a new application will be required if you wish to continue with this research.

To enable us to provide you with efficient service, we ask that you use the application number and study title in all correspondence with us. If you have any enquiries about this application, or anything else, please do contact us at ethics@aut.ac.nz.

I look forward to hearing from you,

A handwritten signature in dark ink, appearing to read 'Rosemary Godbold', with a stylized, flowing script.

Dr Rosemary Godbold

Executive Secretary

Auckland University of Technology Ethics Committee

Cc: Danielle MacDonald dani.macdonald@aut.ac.nz, Mike McGuigan

Appendix 4 - Participant Information Sheet



SPORTS PERFORMANCE
RESEARCH INSTITUTE, NEW ZEALAND
AN INSTITUTE OF AUT UNIVERSITY

INFORMATION FOR PARTICIPANTS

Participant information sheet 30/10/12

An Invitation

My name is Danielle MacDonald and I am a PhD student at AUT University. I have scholarships from New Zealand Cricket and High Performance Sport New Zealand. I love cricket, and have focused my academic research on cricket throughout my studies. I invite you to take part in a survey which will form part of my PhD thesis. My supervisors are Dr. John Cronin and Dr. Mike McGuigan at AUT University and Dr. Richard Stretch, who is based in South Africa.

The aim of this study is to investigate the various components which comprise fielding and wicket-keeping performance. This information will assist in the development of a cricket fielding performance testing battery and will benefit athletes and coaches alike by assisting in improving performance, developing national benchmarks and coach education. We would be very grateful to you if you could take the time to participate in this survey. Please know that your participation is entirely voluntary and you will not be disadvantaged by not participating.

What is the purpose of this research?

The purpose of this study is to gather information regarding the performance requirements of fielding (wicket-keeper, close, inner and outer). The acquisition of this knowledge will help the development of a robust series of tests so that fielding skills can be quantified and measured. Eventually, we will seek to publish this research in a scientific journal such as the Journal of Sports Sciences or the International Journal of Performance Analysis in Sport.

How was I identified and why am I being invited to participate in this research?

You have been identified as a potential participant of this research because you are a cricket player, coach or strength and conditioning coach involved in first class cricket. Only people who meet these criteria are eligible to participate in this study.

What will happen in this research?

The online questionnaire will take a maximum of half an hour for you to complete. There are closed as well as open questions which give you the opportunity to elaborate on your responses about the physical, technical and mental aspects of fielding and wicket-keeping. The types of questions you will encounter will include; drop down boxes, check boxes, ranking, and open text questions. You are asked to please select or tick which boxes are relevant. For open text box questions please type your answer in. We would like you to answer as many questions as you can as your knowledge and experience in this field is important to us.

What will happen to my data?

This study will form a chapter of my PhD thesis and an academic publication from this data set will be sought. The data collected will only be used for the purpose for which it has been collected. No individuals will be identified. Only summary data will be reported. De-identified results from this survey may be stored on the AUT-Millennium Campus for a period of 6 years following the completion of this study. We feel that it is important to store this data as it may inform future research. Once the student has completed her doctorate and the 6 year storage period is over data will be destroyed.

What are the benefits?

This study will help to improve our understanding of the performance requirements of fielding and wicket-keeping in cricket. Such information will benefit athletes and coaches when training and in matches.

How will my privacy be protected?

This study has complete anonymity. The researchers will not know you as a participant.

What are the costs of participating in this research?

There are no costs you to participate in the research except for your time.

What opportunity do I have to consider this invitation?

The survey link will be active for a period of one month, during which time you are welcome to consider the invitation to take part in this research.

How do I agree to participate in this research?

By completing the questionnaire you have consented to participate in this research project. This also means that you have read and understood all the information contained in the participant information letter and have clarified any details prior to starting the research project.

Will I receive feedback on the results of this research?

If you would like to view the findings of this research please copy and save the URL address below. You will be able to access the results using this URL address in approximately four months time.

www.sprinz.aut.ac.nz/research-results

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Prof. John Cronin, john.cronin@aut.ac.nz , Ph (+64) 9 921 9999 ext 6902

Concerns regarding the conduct of the research should be notified to the Executive Secretary, AUTEK, Dr Rosemary Godbold, rosemary.godbold@aut.ac.nz, 921 9999 ext 7772

Whom do I contact for further information about this research?

Researcher Contact Details:

Danielle MacDonald, Sport Performance Research Institute New Zealand, School of Sport and Recreation, AUT University, Auckland, New Zealand dani.macdonald@aut.ac.nz

Project Supervisor Contact Details:

Professor John Cronin, Sport Performance Research Institute New Zealand, School of Sport and Recreation, AUT University, Auckland, New Zealand john.cronin@aut.ac.nz

Dr. Richard Stretch, Summerstrand Campus South, Nelson Mandela Metropolitan University, PO Box 77000, Port Elizabeth 6013, South Africa richard.stretch@nmmu.ac.za

Prof. Mike McGuigan, Sport Performance Research Institute New Zealand, School of Sport and Recreation, AUT University, Auckland, New Zealand mike.mcguigan@aut.ac.nz

"12/293 A survey of the performance demands of fielding and wicket-keeping. Approved 16 November 2012"

Appendix 5 - Survey Instructions for Participants

The survey consists of 6 sections. Each section contains question regarding the physical, technical and mental aspects of fielding and wicket-keeping. All participants are to complete Section 1, and then complete the section/s, which apply to you role in cricket. For example, a player-coach would complete the sections relevant to his fielding positions and the coach section. Please remember that these questions are asking for your own personal opinion on these topics.

Throughout this survey, anthropometry is defined as the measurement of the human body, and therefore includes such things as height, mass and body type or compositions e.g. % body fat or sum of skinfolds. Agility is defined as a rapid whole body movement that usually involves a perceptual decision making component to affect a COD.

For the purpose of the technical questions, fielding skill has been broken down into four components; pre-movement, movement, catch, and throws. For each component, please describe the skills, attributes and any other observations regarding fielding ability in each position.

‘Pre-movement’ in this instance refers to the preparation or set-up for fielding at each position (i.e. before the batsman plays a shot). ‘Movement’ should be in regards to the movement initiated in response to the ball. Catch refers to the specifics related to that position e.g. hand position. Throw refers to the type of throw and the technical cues associated with that motion.

Appendix 6 - Survey Questions

Section 1: Demographics

General

1.1 Are you a: (Please select all that apply)

- ☐ Player
- ☐ Ex-player
- ☐ Coach (please specify, e.g. fielding, bowling)
- ☐ Strength and Conditioning coach

1.2 What is your age?

Range: 16 – over 75

1.3 How many years have you been involved in

- a) Any cricket
- b) Professional cricket

1.4 What country are you from?

Range: Afghanistan to Zimbabwe

1.5 What formats of cricket are you involved in? (please select all that apply)

- ☐ T20
- ☐ One Day
- ☐ Multi-day/Test

1.6 Which are you involved in the most? (Pick one)

- ☐ T20
- ☐ One Day
- ☐ Multi-day/Test

1.7 What is the highest level of cricket you have been involved in? (Select one and specify whether T20, OD, or multi-day/Test)

- ☐ U19
- ☐ U21
- ☐ First Class
- ☐ International

Players only:

1.8 Do you consider yourself a specialist: (Players only)

Checkboxes:

Bowler

Batsman

All-rounder

Wicket-Keeper

Section 2: Wicket-Keepers

Physical

2.1 How important are the following physical qualities for a wicket-keeper? (1 - 5, least to most important), for T20, ODI and Multiday cricket.

Aerobic Fitness

Anaerobic Fitness

Upper body strength/power

Lower body/strength /power

Core strength power

Speed

Agility

Other

2.2 Please comment on any other physical qualities, including anthropometry, which you think are ideal physical attributes for a wicket-keeper?

2.3 Do you have a physical routine prior to each delivery? If so, please describe this routine and how long this routine lasts?

2.4 Do you have/have you had any injuries which your believe have come about as a result of your wicket-keeping?

Technical

2.5 What technical factors/cues are important determinants of elite wicket-keeping performance?

Pre-movement	Movement	Catch	Throw

2.6 What crouch technique do you use:

a) Standing Up:

Full Crouch, half crouch, touch and move

b) Standing Back:

Full Crouch, half crouch, touch and move

2.7 Why do you use this/these techniques? (i.e. is it a personal technical preference, or due to an injury etc)

2.8 Do you use the same technique when facing fast or spin bowlers? Yes, No. If not, why and what techniques do you use?

2.9 How did you become a wicket-keeper? (i.e. were you identified as a potential wicket-keeper by a coach)

2.10 As a wicket-keeper what is your position in the batting order?

Mental

2.11 Do you have a mental routine prior to each delivery? If so how long does this routine last?

2.12 Please describe your mental routine prior to each delivery.

2.13 Is there anything else you would like to add?

End of wicket-keeper section

Section 3: Close Fielders

Physical

3.1 How important are the following qualities for close fielders? (1 - 5, least to most important), for T20, ODI and Multiday cricket. (1 - 5, least to most important), for T20, ODI and Multiday cricket.

Aerobic Fitness

Anaerobic Fitness

Upper body strength/power

Lower body/strength /power

Core strength power

Speed

Agility

3.2 Please comment on any other physical qualities, including anthropometry, which you think are ideal physical attributes for a close fielder?

3.3 Do you have a physical routine prior to each delivery? If so, please describe this routine and how long this routine lasts?

3.4 Do you have/have you had any injuries which your believe have come about as a result of your fielding position?

Technical

3.5 What technical factors/cues are important determinants of elite close-fielding performance?

Pre-movement	Movement	Catch	Throw

3.6 Do you have a mental routine prior to each delivery? If so how long does this routine last?

3.7 Please describe your mental routine prior to each delivery.

3.8 Is there anything else you would like to add?

End of close fielder section

Section 4: Inner circle fielders

Physical

4.1 How important are the following physical qualities for an inner circle fielder? (1 - 5, least to most important), for T20, ODI and Multiday cricket.

Aerobic Fitness

Anaerobic Fitness

Upper body strength/power
Lower body/strength /power
Core strength power
Speed
Agility

4.2 Please comment on any other physical qualities, including anthropometry, which you think are ideal physical attributes for an inner circle fielder?

4.3 Do you have a physical routine prior to each delivery? If so, please describe this routine and how long this routine lasts?

4.4 Do you have/have you had any injuries which your believe have come about as a result of your fielding position?

Technical

4.6 What technical factors/cues are important determinants of elite inner circle fielding performance?

Pre-movement	Movement	Catch	Throw

Mental

4.7 Do you have a mental routine prior to each delivery? If so how long does this routine last?

4.8 Please describe your mental routine prior to each delivery.

4.9 Is there anything else you would like to add?

End of inner circle fielder section

Section 5: Outer-circle fielders

Physical

5.1 How important are the following physical qualities for an outer circle fielder? (1 - 5, least to most important), for T20, ODI and Multiday cricket.

Aerobic Fitness

Anaerobic Fitness

Upper body strength/power

Lower body/strength /power

Core strength power

Speed

Agility

5.2 Please comment on any other physical qualities, including anthropometry, which you think are ideal physical attributes for an outer circle fielder?

5.3 Do you have a physical routine prior to each delivery? If so, please describe this routine and how long this routine lasts?

5.4 Do you have/have you had any injuries which your believe have come about as a result of your fielding position?

Technical

5.5 What technical factors/cues are important determinants of elite outer circle fielding performance?

Pre-movement	Movement	Catch	Throw

Mental

5.6 Do you have a mental routine prior to each delivery? If so how long does this routine last?

5.7 Please describe your mental routine prior to each delivery

5.8 Is there anything else you would like to add?

End of outer fielder section

Section 6: Coaches and Strength and Conditioning Coaches

Physical

6.1 How important are the following physical qualities for a wicket-keeper. (1 - 5, least to most important), for T20, ODI and Multiday cricket.

Aerobic Fitness

Anaerobic Fitness

Upper body strength/power

Lower body/strength /power

Core strength power

Speed

Agility

6.2 Please comment on any other physical qualities, including anthropometry, which you think are ideal physical attributes for a wicket-keeper?

6.3 What test/s would you use/recommend to assess each of these qualities for the wicket-keeper?

	Tests
Aerobic fitness	
Anaerobic fitness	
Upper body strength/power	
Lower body strength/power	
Core strength/power	
Speed	
Agility	
Other qualities	

6.4 What technical factors/cues are important determinants of elite wicket-keeping performance?

Pre-movement	Movement	Catch	Throw

6.5 How important are the following physical qualities for a close-fielder(1 - 5, least to most important), for T20, ODI and Multiday cricket.

Aerobic Fitness

Anaerobic Fitness

Upper body strength/power

Lower body/strength /power

Core strength power

Speed

Agility

6.6 Please comment on any other physical qualities, including anthropometry, which you think are ideal physical attributes for a close fielder?

6.7 What test/s would you use/recommend to assess each of these qualities for a close fielder?

	Tests
Aerobic fitness	
Anaerobic fitness	
Upper body strength/power	
Lower body strength/power	
Core strength/power	
Speed	
Agility	
Other qualities	

6.8 What technical factors/cues are important determinants of elite close fielding performance?

Pre-movement	Movement	Catch	Throw

6.9 How important are the following physical qualities for an inner-circle fielder. (1 - 5, least to most important), for T20, ODI and Multiday cricket.

Aerobic Fitness

Anaerobic Fitness

Upper body strength/power

Lower body/strength /power

Core strength power

Speed

Agility

6.10 Please comment on any other physical qualities, including anthropometry, which you think are ideal physical attributes for an inner circle fielder?

6.11 What test/s would you use/recommend to assess each of these qualities for an inner circle fielder?

	Tests
Aerobic fitness	
Anaerobic fitness	
Upper body strength/power	

Lower body strength/power	
Core strength/power	
Speed	
Agility	
Other qualities	

6.12 What technical factors/cues are important determinants of elite inner-circle fielding performance?

Pre-movement	Movement	Catch	Throw

6.13 How important are the following physical qualities for an outer-circle fielder? (1 - 5, least to most important), for T20, ODI and Multiday cricket.

Aerobic Fitness

Anaerobic Fitness

Upper body strength/power

Lower body/strength /power

Core strength power

Speed

Agility

6.14 Please comment on any other physical qualities, including anthropometry, which you think are ideal physical attributes for an outer-circle fielder?

6.15 What test/s would you use/recommend to assess each of these qualities for an outer-circle fielder?

	Tests
Aerobic fitness	
Anaerobic fitness	
Upper body strength/power	
Lower body strength/power	
Core strength/power	
Speed	
Agility	
Other qualities	

6.16 What technical factors/cues are important determinants of elite outer-circle performance?

Pre-movement	Movement	Catch	Throw

6.17 Within each of the fielding categories (Close, inner, outer) do you find that there is large variability in the skills and attributes required between specific fielding positions? For example, for inner-circle fielding is there a difference between skills needed at gully and mid-on?

Yes/No

Please elaborate

6.18 Is there anything else you would like to add?

Thank You! Thank you for your participation in this survey. Your response is very important to us. We appreciate the time and effort you have put in to complete this survey.

Regards

Dani MacDonald

Appendix 7 - Video analysis code windows

Fielding code window

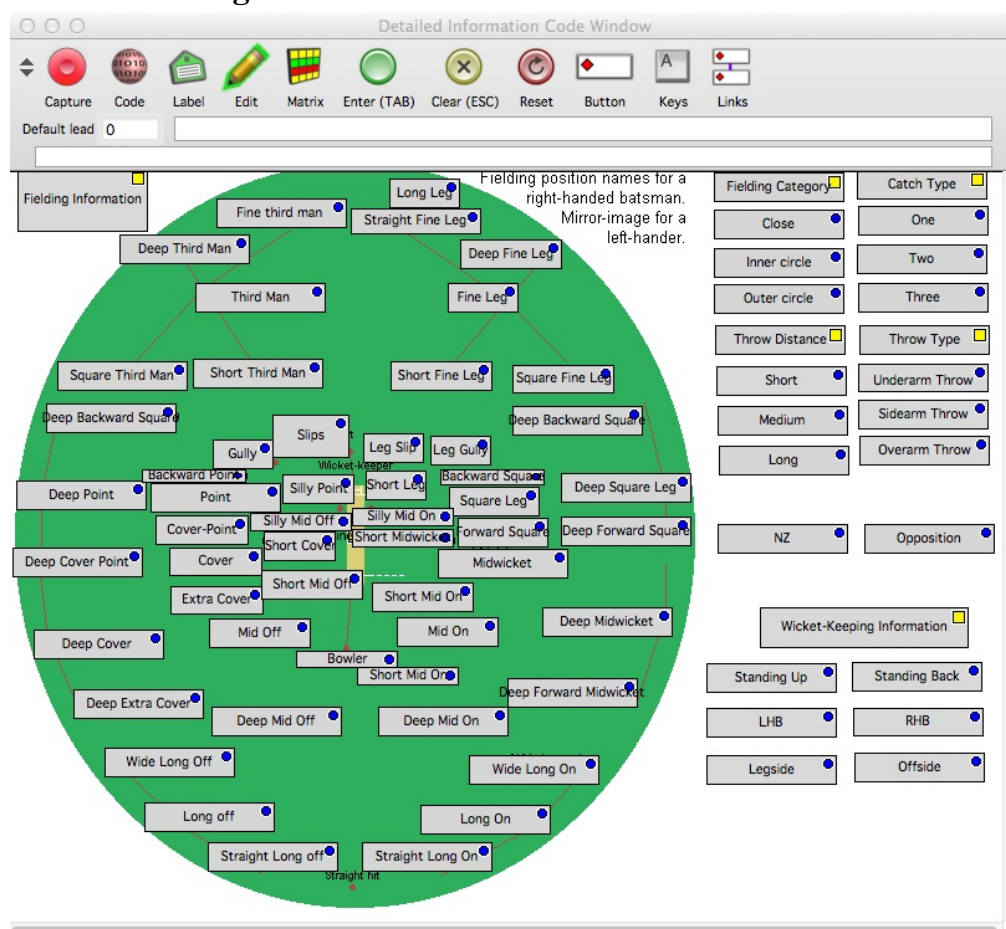
Fielding Code Window

Capture Code Label Edit Matrix Enter (TAB) Clear (ESC) Reset Button Keys Links

Default lead 0

Movements	Skills	Catch Type	Fielding Category
<input checked="" type="checkbox"/> Sprint S	<input checked="" type="checkbox"/> Missed Catch	<input type="radio"/> One	<input type="radio"/> Close
<input checked="" type="checkbox"/> Following chase	<input checked="" type="checkbox"/> Dropped Catch	<input type="radio"/> Two	<input type="radio"/> Inner circle
<input checked="" type="checkbox"/> Dive	<input checked="" type="checkbox"/> Missed Stop	<input type="radio"/> Three	<input type="radio"/> Outer circle
<input checked="" type="checkbox"/> Lateral Shuffle	<input checked="" type="checkbox"/> Runout		
<input checked="" type="checkbox"/> Lateral Step	<input checked="" type="checkbox"/> Stumping		
<input checked="" type="checkbox"/> Jump	<input checked="" type="checkbox"/> Missed Runout		
<input checked="" type="checkbox"/> Roll	<input checked="" type="checkbox"/> Missed Stumping		
<input checked="" type="checkbox"/> Sliding Stop	<input checked="" type="checkbox"/> Field and throw F		
	<input checked="" type="checkbox"/> Misfield		
	<input checked="" type="checkbox"/> Field		
	<input checked="" type="checkbox"/> Underarm Throw	<input type="radio"/> Short	<input type="radio"/> Underarm Throw
	<input checked="" type="checkbox"/> Sidearm Throw	<input type="radio"/> Medium	<input type="radio"/> Sidearm Throw
	<input checked="" type="checkbox"/> Overarm Throw	<input type="radio"/> Long	<input type="radio"/> Overarm Throw
	<input checked="" type="checkbox"/> Over Throw		<input type="radio"/> NZ
			<input type="radio"/> Opposition

Detailed fielding code window



Wicket-Keepering Code Window

◀ ▶
 Capture
 Code
 Label
 Edit
 Matrix
 Enter (TAB)
 Clear (ESC)
 Reset
 Button
 Keys
 Links

Default lead

<div>Movements <input type="checkbox"/></div> <ul style="list-style-type: none"> Chase (Sprint) Crouch C Dive Lateral Shuffle Lateral Step Jump Run Up To Stumps R Sliding Stop Roll 	<div>Skills <input type="checkbox"/></div> <ul style="list-style-type: none"> Take Missed Take Catch Dropped Catch Runout Missed Runout Stumping Missed Stumping Reception from Field Missed Reception from Field Field and throw Underarm Throw U Sidearm Throw Overarm Throw 	<div>Information <input type="checkbox"/></div> <table border="0" style="width: 100%;"> <tr> <td>Standing Up </td> <td>Standing Back </td> </tr> <tr> <td>LHB </td> <td>RHB </td> </tr> <tr> <td>Legside </td> <td>Offside </td> </tr> </table> <div> Wicket Highlights</div> <div>NZ </div> <div>Opposition </div>	Standing Up	Standing Back	LHB	RHB	Legside	Offside
Standing Up	Standing Back							
LHB	RHB							
Legside	Offside							

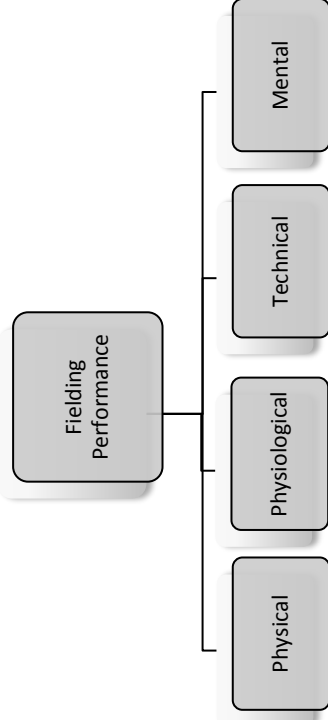


Appendix 8 - Technical Notes

Fielding Technical Note

The purpose of this document is to provide information and scientific evidence to inform best practice, training and conditioning for fielding. The existing fielding literature and two research studies have provided the information for this

T20



Time-motion analysis is the most prevalent type of fielding research. TMA results indicate differences in performance requirements between formats.

Walking	2263 ± 629	2419 ± 708	3286 ± 726
Jogging	621 ± 135	616 ± 272	1532 ± 361
Running	137 ± 44	147 ± 62	377 ± 156
Striding	166 ± 62	159 ± 89	497 ± 316
Sprinting	155 ± 71	90 ± 73	416 ± 265
Total Distance	3342 ± 759	3430 ± 883	6106 ± 981
Sprints			
Number (#)	8 ± 4	6 ± 4	23 ± 14
Mean sprint distance (m)	18 ± 5	15 ± 4	17 ± 4
Maximum sprint distance (m)	43 ± 15	34 ± 12	54 ± 23
Maximum sprinting speed (m.s⁻¹)	8.5 ± 0.9	7.9 ± 1.2	8.6 ± 1.1
High Intensity Efforts			
Number	34 ± 11	34 ± 17	98 ± 43
Mean effort duration (s)	3.1 ± 0.3	2.6 ± 0.3	2.8 ± 0.4
Recovery between (s)	116 ± 37	134 ± 73	45 ± 21

Table 1: Time-motion analysis (TMA) of fielding



Other Findings

Table 2: Comparison of fielding activity distribution from Shilbury (1990) and MacDonald et al. (2013)

Position	Study	
	Shilbury 1990 (%)	MacDonald 2014 (%)
Format	Multi-day first class	ODI
Wicket-keeper	20.92	32.29
Bowler	6.89	12.12
Cover	11.65	11.3
Backward Point	2.65	6.81
Mid-off	9.51	6.66
Mid Wicket	5.31	6.59
Mid-on	9.45	6.34
Point	3.17	3.92
Extra Cover	1.34	2.71
Deep Mid Wicket	0.79	2.49
Square Leg	3.65	2.07
Third Man	1.65	1.92
Deep Backward Square Leg	0.9	1.78
Slips	2.62	0.89
Backward Square Leg	1.76	0.82
Deep Mid-on	0.69	0.46
Deep Mid Off	0.45	0.32
Gully	3	0.25
Deep Extra Cover	0.24	0.25

Shilbury (1990) attempted to quantify the performance demands of fielding positions. He identified four fielding skills categories; **fielded ball, fielded ball and throw, fielded ball and underarm return, and catches and attempted catches.**

Other studies have investigated:

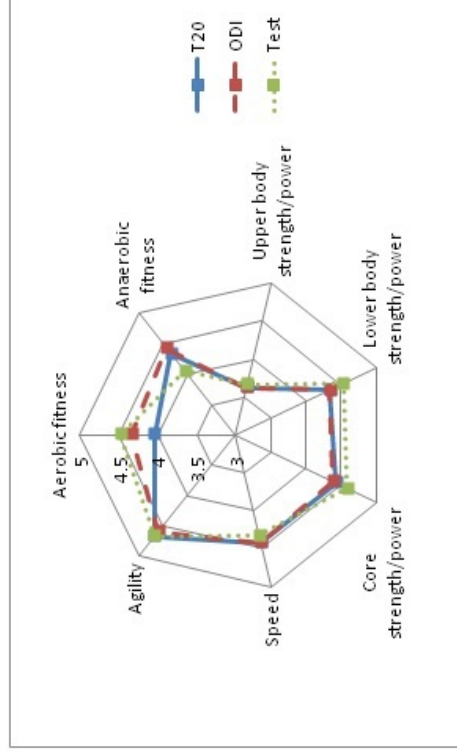
The effect of ball colour and light levels on slip catching performance - **no significant differences in slip catching performance due to ball colour or light levels**

The effect of a video-based training intervention on fielding performance - **a video-based fielding training intervention, resulted in greater improvement in performance when combined with on-field training, than on-field training alone.**

Using a statistical model to retrospectively assess performance - **proposed statistical methods**

Close Fielding

Figure 3: Findings from survey - Importance of physical characteristics of close fielders



2011 ODI WC Video Analysis Findings

- Approximately 20% of all deliveries were fielded by close fielders.
- The **bowler** took the majority of all close fielding skill activity (**58.4%**), followed by **short cover (16.4%)** and **short midwicket (15.8%)**.
- On average, bowlers fielded off their own bowling 19 times per innings.
- Of the 45 catches taken in the 16 innings sample the most by any one position was the **slips cordon** with **eight catches**.

2011 ODI WC close fielding catching efficiency:

$$= (\text{Catches Taken} / \text{Catches offered}) * 100$$

$$= (13/17) * 100$$

$$= \mathbf{76\%}$$



Key Emergent Themes

Preparation for Movement:

- Wide stance
- Split step
- Trigger Movement

Ideal Anthropometry:

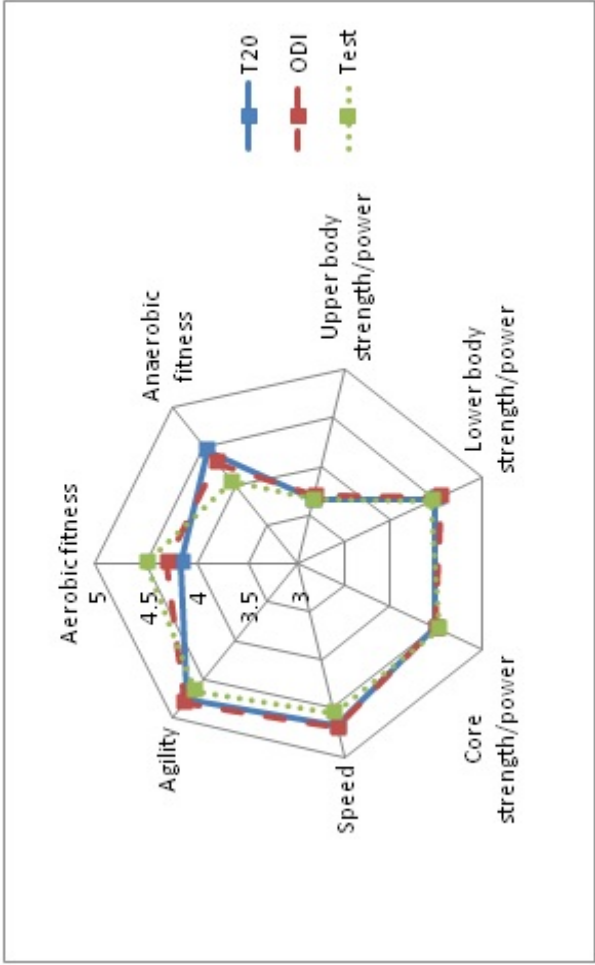
- Shorter in stature
- Lean but muscular
- Ability for explosive movement

Mental Factors:

- Concentration
- Focus
- Attitude
- Routine oriented

Inner Circle Fielding

Figure 4: Importance of physical characteristics for inner circle fielding.



Key Emergent Themes

Footwork:

- Preparation
- Balance
- Timing

Mental Factors:

Technique:

- Catching - safe hands

2011 ODI WC inner circle fielding catching efficiency:

$$= \frac{\text{Catches Taken}}{\text{Catches offered}} \times 100$$

$$= \frac{18}{22} \times 100$$

$$= 81\%$$



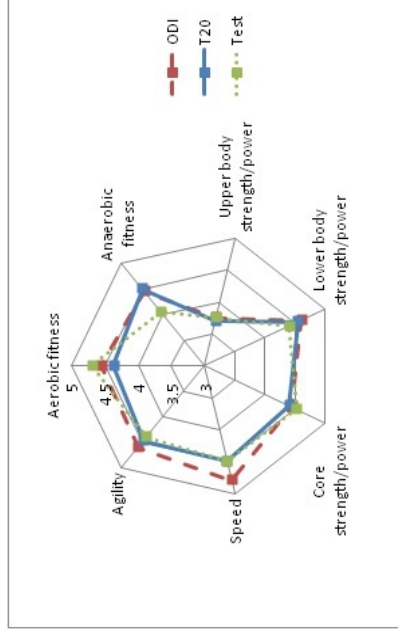
2011 ODI WC Video Analysis

Findings

- Approximately 50% of all deliveries were fielded by inner circle fielders.
- Of the inner circle positions, the three with the most fielding activity were all offside positions, **cover (21%), mid off (12%) and backward point (12%)**.
- Of the 45 catches taken in the 16 innings sample, 18 were taken by inner circle fielders.
- The most catches were taken by **backward point and mid off with 5 and 4 catches respectively**.
- **Agility**, particularly when diving, jumping and sliding is important for inner circle fielders.
- **Inner circle fielders need to have the broadest variety of skills.**

Outer Circle Fielding

Figure 5: Importance of physical characteristics for inner circle fielding



2011 ODI WC Video Analysis Findings

- Approximately 30% of all deliveries were fielded by outer circle fielders.
- The positions with the most total activity were **long on (14%)**, **deep square leg (13%)** and **deep forward square and deep midwicket (7%)** respectively.
- **11 catches** were taken by outer circle fielding positions, **deep square leg** took the most catches with **4**.
- Catches taken by the outer circle fielders ranged from the easy, requiring no movement at all, to the **spectacular**.
- Outer circle fielders were often required to **work in tandem** to return the ball as quickly as possible.
- Outer fielders are required to perform fielding skills after sprinting up to 40m.

Key Emergent Themes

Mental Factors:

- Concentration
- Attitude

Technique:

- Catching - safe hands
- Throwing - power and accuracy and distance

2011 ODI WC inner circle fielding catching efficiency:

$$\begin{aligned}
 &= (\text{Catches Taken} / \text{Catches offered}) * 100 \\
 &= (11/14) * 100 \\
 &= \mathbf{79\%}
 \end{aligned}$$

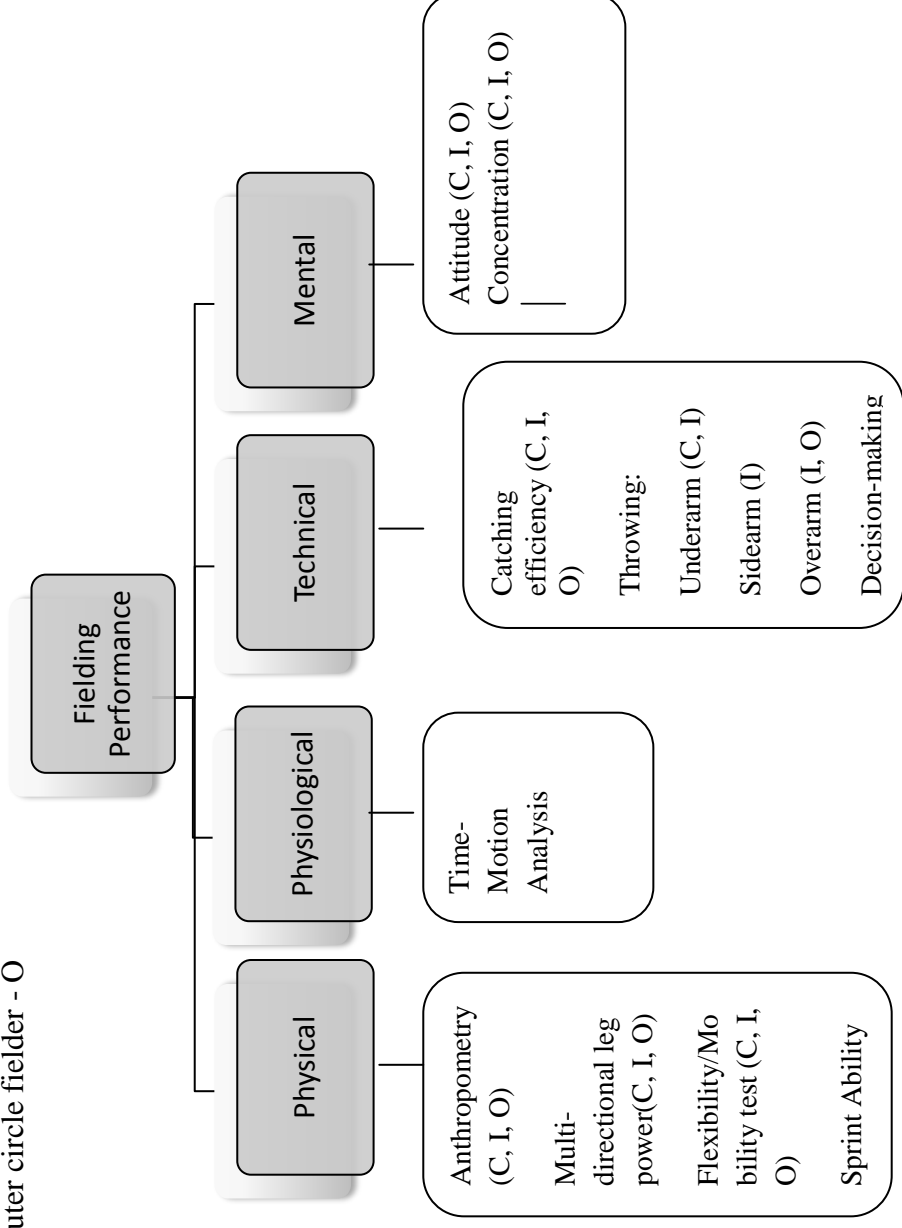
Practical Applications

Key

Close Fielder - C

Inner circle fielder - I

Outer circle fielder - O



Wicket-keeping Technical Note

D.C. MacDonald - PhD Candidate, SPRINZ, Auckland University of Technology

The purpose of this document is to provide information and scientific evidence to inform best practice, training and conditioning for wicket-keeping. The existing wicket-keeping literature and two research studies have provided the



Despite the fact that the wicket-keeper is the only player with the potential to be involved with every delivery of an innings, only two published studies to date have focussed solely on the wicket-keeper:

- D. Plunkett, C. Salter and D. Moore. (2005). The difference in efficiency of movements to the ball between wicket-keeping stances. **Australian Sports Commission.**
- B. Rosen and R. Bower. (2006). Analysis of the footwear patterns of elite wicket-keepers in cricket. **Journal of Human Movement Studies**, 51, 181-196.

Time motion analysis of wicket-keeping (Petersen et al. 2010)

Distance covered (metres/hour)	Test	ODI	T20
Walking	2135 ± 151	1913 ± 196	1587 ± 139
Jogging	523 ± 214	558 ± 104	552 ± 166
Running	51 ± 18	109 ± 16	138 ± 90
Striding	35 ± 24	97 ± 29	147 ± 77
Sprinting	23 ± 30	34 ± 21	59 ± 23
Total Distance	2767	2711	2483
Work:Rest	1:167	1:64	1:51
# of sprints per hour	2 ± 4	2 ± 1	5 ± 2
Mean sprint distance	11 ± 19	16 ± 9	13 ± 0
Max sprint distance	12 ± 9	22 ± 11	14 ± 6
# efforts per hour	12 ± 6	23 ± 4	30 ± 18
Recovery ratio (1:x)	167 ± 73	64 ± 18	51 ± 21

- Three crouch techniques were identified by Plunkett, Salter and More (2005); *crouch*, *half-crouch*, and *touch and move*.
- The full crouch technique was associated with the greatest loading at the knee, and therefore a greater range of lower limb extension was required to perform the primary lateral steps in order to take the ball. This was achieved through the use of significantly greater peak forces in the outside knee.
- There were no other significant differences in lower limb moments between stances.
- There were no significant differences between the times taken to move from the starting position for each stance.
- The type of crouch and footwear used depended greatly on individual preference.

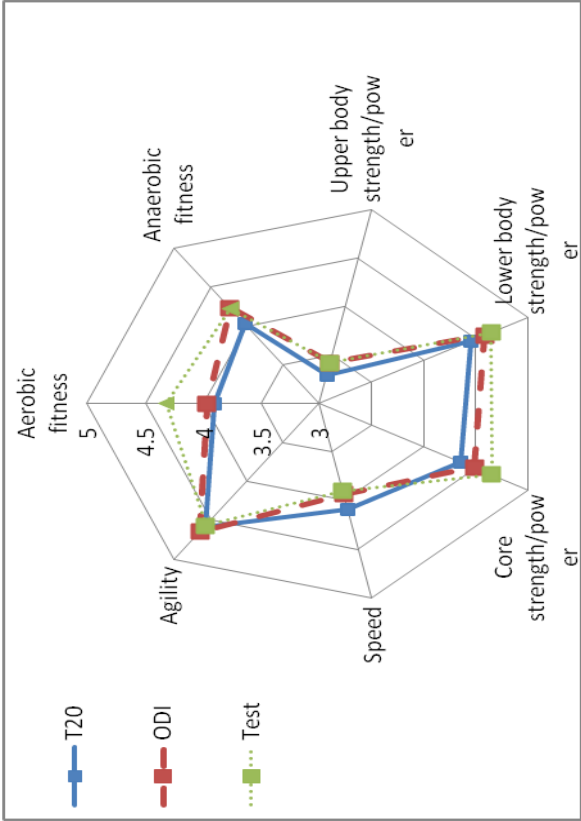
The time motion analysis does not provide any indication of the direction of movement, or any of the movement patterns specific to wicket-keeping. Therefore, two studies were undertaken in order to address the gaps in the literature:

- A survey of coaches, players and strength and conditioning coaches
- Video analysis of skills and movements of ODI wicket-keeping



Results from a Survey of the Performance Demands of Cricket Wicket-keeping

Agility, lower body and core strength/power are the most importance physical characteristics for a wicket-keeper in all formats of cricket.



There are subtle but clear differences in physical requirements for the different formats of the game. Therefore wicket-keepers training and conditioning programmes should be designed with the format of cricket in mind.

- Glovework and technique (including batting ability)
- Movement
- Stillness and stability
- Ideal anthropometry (low skinfolds)

Mental Factors and Personality

"Bags of energy"

"Desire to be involved in every ball of the innings"

"Enthusiastic"

"Narrow focus"

"Trigger word or phrase like 'stay low'"



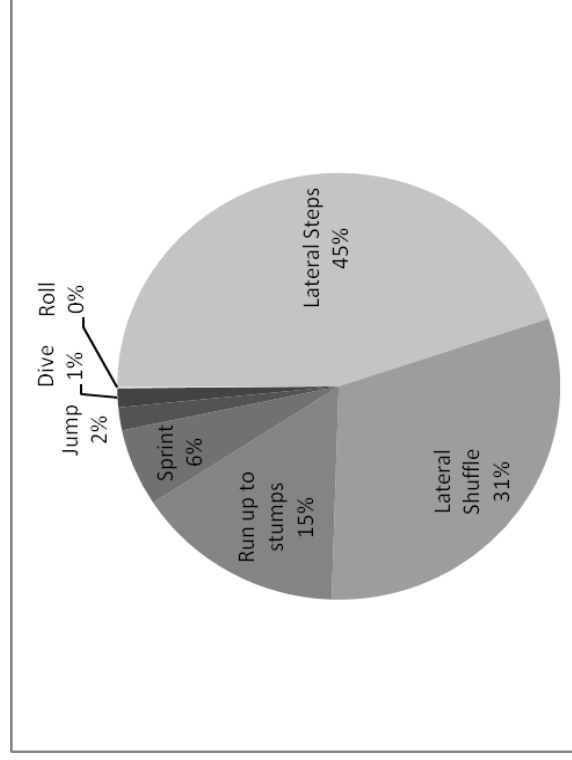
Key Movements of Wicket-keepers in One Day International Cricket

The Blackcaps' eight matches from the 2011 ODI World Cup were analysed using SportsCode™ in order to quantify the movement and skill demands of ODI wicket-keeping. Of all the fielders, the wicket-keeper had the most fielding contacts, involved in $\approx 32\%$ of all fielding activity. Movements and skills were quantified separately in order to determine the performance requirements of wicket-keepers during a match.

The majority of wicket-keeping movement is low intensity, high repetition with intermittent bouts of explosive power to travel a relatively large distance to the ball as quickly as possible.

The crouch is an indispensable, performed every ball of the innings.

Figure 2: Wicket-keeping movement activity (%)



Explosive movements comprise $\approx 5\%$ of innings activity. However lateral dives occurred on average only **twice per innings**. This may be due to not having sufficient leg strength qualities to initiate an explosive lateral movement. Or they may have quick enough footwork that they can cover the required distance without

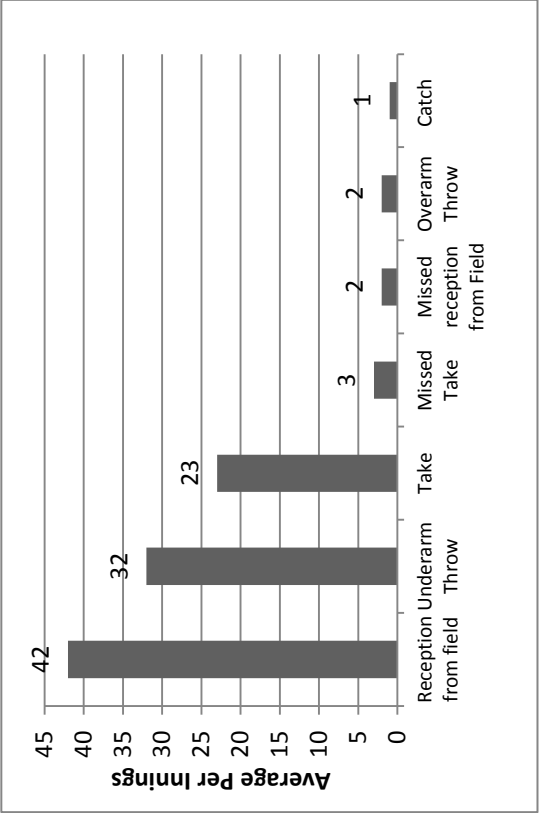
Running intensity depends on how far the wicket-keeper is standing back

- The direction of lateral movement was almost equally distributed between left and right.
- The lateral movement footwork is dependant of personal preference, physical strengths and the particular delivery.



Key Skills of Wicket-keepers in One Day International Cricket

Figure 3: Average number of key skills per innings



Of the 117 wickets which fell in the eight matches analysed, **17%** involved the wicket-keeper: 16 catches, 2 stumpings, 2 run outs.

Catch Difficulty 1 (**43%**) - required no movement of the feet prior to catch.

Catch Difficulty 2 (**43%**) - required movement in any direction prior to taking the catch.

Catch Difficulty 3 (**14%**) - requiring a high degree of quick or explosive movement prior to catch execution.

Taking the ball, be it from the field or the bowler is the most important skill for a wicket-keeper. Success can be measured using the table below.

Scorecard		Offered	Taken	Percentage
From Bowler	Takes			
	Chances			
From Field	Takes			
	Chances			
	Totals			

Practical Applications

Assessment Development

- Decision-making time – movement efficiency
- Catching efficiency
- Flexibility/mobility test
- Multi-directional leg power
- Sprint ability
- Mental

Appendix 9 - Published Articles

A review of cricket fielding requirements

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Cricket is played in three formats at elite level: Test, One Day and Twenty20. Fielding is an important component of cricket, as all players are obliged to field. However, there is a paucity of literature on fielding compared with that on batting and bowling. We review the available literature in terms of technical, mental, physiological and physical factors important to fielding, to identify knowledge gaps and better understand the performance requirements of fielding in cricket.

S Afr J SM 2013;25(3):87-92. DOI:10.7196/SAJSM.473



Internationally, three formats of cricket are played at the elite level: Test, One Day and Twenty20.^[1] All players bat and field, while only some players bowl and one person keeps wicket. Dismissing a batsman can be achieved in different ways, some specific to fielders; hence, catching and throwing are vital skills. Common requirements for these skills are speed and accuracy.^[2] As well as dismissing batsmen, the role of fielders includes saving runs, particularly in the shorter formats of the game. Therefore, optimising the movements and skills required to successfully field can have an important influence on the game. However, despite the adage that 'catches win matches', research into fielding is sparse compared with that into batting and bowling.^[3] The purpose of this review was therefore to investigate and critique the existing knowledge of fielding in cricket, with the intent of better understanding the performance demands of fielding.

Methods

For the purpose of this review, fielding performance was divided into a number of components (Fig. 1) which were systematically reviewed. Reviewed literature included peer-reviewed articles and book chapters. The requirements of the wicket-keeper are not discussed here, as the demands of this position have been reviewed previously.^[4]

The literature search was conducted using search engines (PubMed, SportsDiscus and ScienceDirect). The search terms 'fielding', 'wicket-keeping', 'catching', 'cricket' and other related terms were used in various combinations to search for articles. The reference lists of articles found were assessed to extend the search. As fielding was the focus of this review, articles specifically focussing on the wicket-keeper were excluded from the review. Additionally, cricket-relevant chapters from edited books were included.

Technical

In cricket, the playing field is not of fixed dimensions. According to the laws of the game, 'the playing area shall be a minimum of 150 yards (137.16 m) from boundary to boundary square of the pitch, with the shorter of the two square boundaries being a minimum of 70 yards (64.01 m)'.^[5] Due to the large and varying size of the playing field, the skills of fielding in cricket will vary

considerably depending on where fielders are placed. Here, the fielding positions have been categorised as close (e.g. slips and short leg), inner-circle and outer-circle (Fig. 2).

Shilbury^[6] researched the frequency of fielding skills for 25 defined positions, and the fielding patterns of individual players of an 'A'-grade cricket team playing first-class multi-day cricket. The data were divided into four skill categories: fielded ball, fielded ball and throw, fielded ball and under-arm return, and catches and attempted catches. The author reported the frequency and skills required in 25 fielding positions. The positions which featured the most were cover (12%), mid off (10%) and mid on (9%), respectively.

Cover has traditionally been considered a position that requires good attacking skills, such as being able to move towards the ball, field and throw quickly, often from unbalanced positions.^[6] However, only 13% of cover's fielding contacts required attacking skills; the majority of actions were defensive

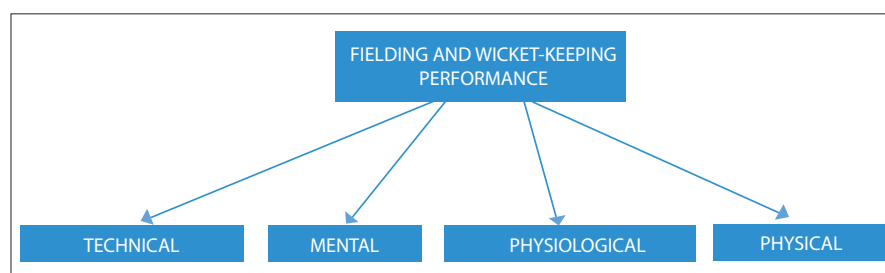


Fig. 1. Aspects of fielding performance.

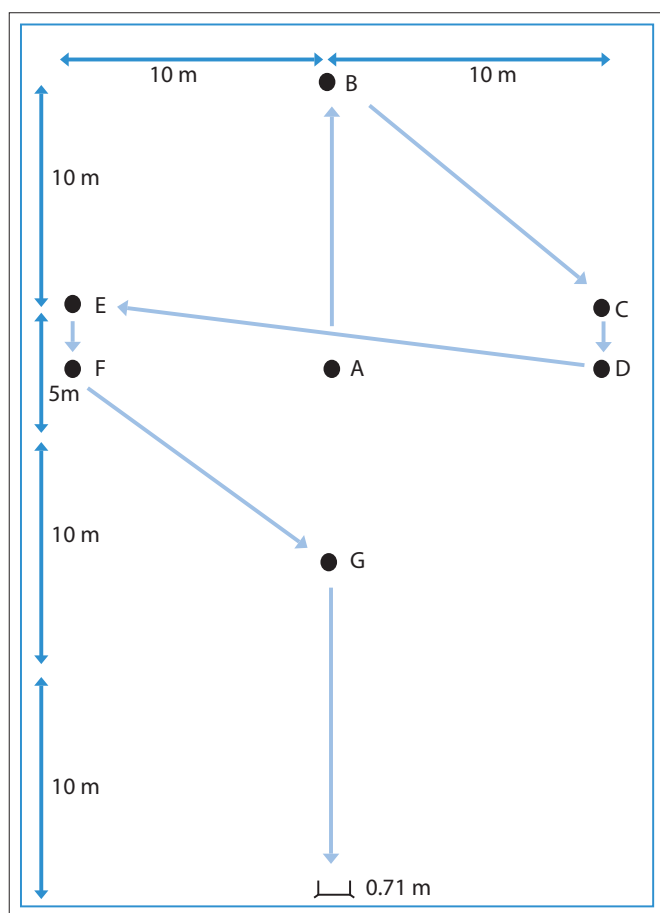


Fig. 2. Pitch map showing the different fielding categories.

and required practically no diving or lateral movements. This finding is not consistent with conventional wisdom.

Shilbury's study is dated (1990), and included data from only six domestic games. Given the developments in the game since the 1990s, research based on a larger number of international matches would be more appropriate and useful. These findings will assist the development of assessment and training protocols for the different formats of the game at the highest level.

In One Day cricket, matches began to be played into the night, and the ball colour was changed from red to white to be seen better under floodlights. Scott *et al.*^[7] investigated the effect of light levels and ball colour on catching, particularly for slip fielders in simulated field conditions. Photoelectric timing gates were placed in front of a ball projection machine and lever micro-switches were placed on the thighs of the players to establish reaction times to balls projected at a speed of 20 m/s over a distance of 8.4 m. The speed was considered representative of the demands of slip-catching performance, and was the upper limit of speeds safe for use under laboratory conditions. Catching performance was scored using a scale adapted from Wickstrom,^[8] which rated catches from 0 (no ball contact at all) to 5 (clean catch). After performing a 2 (ball) x 3 (light level) analysis of variance (ANOVA), no significant effects were noted for catching performance and movement initiation times for ball or light levels. The authors concluded that the change in ball colour or diminishing light levels were not detrimental to performance. However, the sample

size was very small ($n=5$), which may account for the lack of statistical significance. Also, the testing protocol required players to assume a standing position that may not be normal under game conditions.

The effect of a visual-perceptual training programme on fielding in cricket has been investigated using a test-retest design involving a 6-week training intervention.^[9] The tests involved an *in situ* fielding test, and athletes were required to react (predict and move in the direction that the ball was hit) to a life-sized video projection of a batsman hitting strokes, with the video occluded at the point of ball contact. The video was filmed from the perspective of three different fielding positions: extra cover, mid on and mid off. Moving in the correct direction for each video assessed decision accuracy.

The training group underwent an additional three perceptual training sessions per week in addition to the on-field training programme undertaken by the control group. The training group performed significantly better than the control group in the two tests. It was concluded that while 6 weeks of regular on-field training may lead to improvements in fielding performance, greater advantages could be gained when it is combined with visual perceptual training sessions.

A fielder's ability to throw a ball over considerable distance with speed and accuracy, if aiming for a run out, requires excellent throwing technique.^[10] The requirements are specific for the different field positions. The slips mostly intercept a fast moving ball coming off the edge of the bat and reaching them below chest height.^[11] They have little need for throwing long distances. In-fielders require good reactive ability to catch a ball falling from above their heads and strong over-arm throwing ability^[3] to attempt run-outs. Outfielders often have to cover a considerable distance, so sprinting ability is vital, and they need to throw accurately over long distances.^[6] Good techniques are not only essential to win matches; they also minimise the risk of injury.^[2]

Synchronised high-speed video cameras^[11] have been used to study the biomechanics of throwing. Distinguishing different throwing techniques has led to the identification of important performance variables.^[11] The relationship between over-arm throwing velocity and accuracy in elite and sub-elite cricketers was investigated using a specifically designed throwing test.^[8] A speed-accuracy trade-off was detected. Subjects improved accuracy scores at velocities of 75 - 85% of maximal throwing velocity. Senior elite players performed better than other groups. No research into side- or under-arm throwing in cricket has been found. Using the correct technique is crucial for success; the lack of empirical data in this area limits the development of optimal training programmes.

For skills development, player selection and talent identification, it is important to correctly test for skill and movement efficacy. This can assist a coach in detecting strengths and weaknesses in performance and in identifying the specific training needs of the individual.^[12] Stretch and Goslin^[12] devised a set of cricket skills tests, encompassing all components of the game. With regards to fielding, the majority of run-outs occur between 10 m and 35 m,^[13] and these were the distances tested in the fielding test (Fig. 3).

At point A, the fielder was required to catch a thrown ball, over-arm throw at the target and then move as quickly as possible to point B. At points B, C, D, E, and F, the fielder was required to pick a ball up from the ground and over-arm throw at the target; point G required a pick up and under-arm throw at the target, followed by a final sprint to



Fig. 3. Schematic of the fielding test used by Stretch and Goslin.^[12]

the target. The timer started when the fielder touched the first ball and ended when he had run through the target. A time penalty (3 s) was given if he dropped the balls or a throw did not go through the target at any time during the test.

The authors and coaches also used their knowledge of the game to determine, subjectively, the players' potential success in a match.^[12] The validity of the fielding tests was tested by comparing the objective tests to the subjective opinion of coaches. The relationship between the objective fielding test scores and the subjective fielding evaluation was low ($r=0.47$; $p<0.05$); however, the sample size was relatively large ($n=155$), hence the authors decided that the lower correlation was acceptable. The diagnostic utility of this test could be questioned, given the composite nature of the test i.e. many skills assessed within one test.

Mental

Cricket requires inordinate physical skill and mental aptitude, including the ability to

concentrate intensely for very long periods, for which a high level of physical fitness cannot fully compensate.^[14] Fielders have to concentrate on every ball of the innings, regardless of their positions. They have to be able to maintain concentration for the entire duration of an innings (ranging from approximately 90 minutes in a T20 innings to a total of 6 hours per day in a Test match), through changing conditions as play progresses through the day. However, studies on the mental aspect of cricket have focussed on batting only;^[15-17] no research, to the authors' knowledge, has addressed the mental aspects of fielding.

Physiological

The most prevalent approach to quantifying the physiological demands of cricket is time-motion analysis using global positioning satellite (GPS) units. Rudkin and O'Donoghue^[18] performed 27 observations of a fielder positioned at cover point, during first-class multi-day games. They used the CAPTAIN time-motion analysis system to define seven

movement classes: stationary, walking, shuffling (rapid non-running movement of the feet), jogging, running, low-intensity fielding and high-intensity fielding. It was found that the cover point fielder spends the majority (94.2%; standard deviation (SD) ± 2.4) of match time in stationary activity and walking, while high-intensity activities represented just 1.6% (SD ± 0.8) of movement activity. It was concluded that first-class fielding entails less high-intensity exercise than other team sports such as hockey and soccer. However, the conclusions are of limited value, as only one fielding position was analysed.

Time-motion studies could help develop knowledge of positional differences in workload between the different formats of cricket, allowing conditioning coaches to prescribe game-specific training programmes.^[1] Petersen *et al.*^[1,19,20] have conducted several studies using GPS technology, investigating physiological demands of performance in the three different formats of the game. Unlike in the study by Rudkin and O'Donoghue,^[18] five movement categories were established (standing/walking, jogging, running, striding and sprinting) and the three different cricket formats were investigated.

Table 1 summarises time-motion analyses for each format of cricket. In summary, it seems that fielding intensity is greatest in a T20 match and fielders covered approximately the same distances in One Day and Test cricket.

Petersen *et al.*^[19] tested the validity and reliability of three commercially available sports GPS units to monitor cricket-specific movement patterns. They found disparate and inconsistent measures for the validity and reliability of low- and high-intensity activities. They advised that conditioning coaches should be aware of the likely under-reporting of high-intensity activity and over-reporting of low-intensity efforts when using GPSs in training. All studies detailed thus far fail to document the physiological demands of the different fielding positions because generally, fielders, without distinction, are compared with bowlers and batsmen.

Physical

The physical aspects of performance have been investigated with respect to injury incidence and prevention, particularly for fast bowling and throwing, but little investigation into the physical aspects of fielding has taken place. In this section, physical aspects such

Table 1. Summary of findings from time-motion studies by Petersen *et al.*^[19,20]

Variable*	Quantifying positional movement patterns in Twenty20 cricket ^[19]	Study	
		Comparison of player movement patterns between ODI and Test cricket ^[20]	
		ODI	Test
Position	Fielders (<i>n</i> =14)	Fielders (<i>n</i> =17)	Fielders (<i>n</i> =25)
Distance per hour (m), mean (\pm SD)			
Walking (0 - 2.0 m/s)	3 286 (\pm 726)	2 419 (\pm 708)	2 263 (\pm 629)
Jogging (2.0 - 3.5 m/s)	1 532 (\pm 361)	616 (\pm 272)	621 (\pm 135)
Running (3.5 - 4.0 m/s)	377 (\pm 156)	147 (\pm 62)	137 (\pm 44)
Striding (4.0 - 5.0 m/s)	497 (\pm 316)	159 (\pm 89)	166 (\pm 62)
Sprinting (\geq 5 m/s)	416 (\pm 265)	90 (\pm 73)	155 (\pm 71)
Total distance (m)	6 106 (\pm 981)	3 430 (\pm 883)	3 342 (\pm 759)
Time (s)			
Walking and jogging	3 263 (\pm 187)	3 504 (\pm 46)	3 496 (\pm 30)
Running, striding and sprinting	275 (\pm 146)	91 (\pm 45)	104 (\pm 30)
Sprint			
Number	23 (\pm 14)	6 (\pm 4)	8 (\pm 4)
Mean sprint distance (m)	17 (\pm 4)	15 (\pm 4)	18 (\pm 5)
Maximum sprint distance (m)	54 (\pm 23)	34 (\pm 12)	43 (\pm 15)
Maximum sprinting speed (m/s)	8.6 (\pm 1.1)	7.9 (\pm 1.2)	8.5 (\pm 0.9)
High-intensity efforts			
Number	98 (\pm 43)	34 (\pm 17)	34 (\pm 11)
Effort duration	2.8 (\pm 0.4)	2.6 (\pm 0.3)	3.1 (\pm 0.3)
Recovery between (s)	45 (\pm 21)	134 (\pm 73)	116 (\pm 37)

SD = standard deviation; ODI = One Day International.

* Values are expressed as mean (\pm SD).

as anthropometry, strength, speed and aerobic and anaerobic fitness will be considered.

Anthropometry

Several studies have investigated the anthropometric profile of first-class cricketers,^[21-25] mostly by comparing groups of players, such as batsmen, bowlers or all-rounders. The measures used mass and stature measurement and the sum of seven skin folds (biceps, triceps, subscapular, supra-iliac, abdominal, thigh and medial calf). Portus *et al.*^[25] extensively researched the characteristics of Australian players. However, these findings are probably not valid globally given ethnic differences in stature. While other physical attributes would be considered when deciding where to place players in the field, certain anthropometric characteristics may make players suited to specific positions. Nevertheless, the anthropometry for specific fielding positions has not been explored.

Aerobic and anaerobic fitness

With modern cricket, players can be expected to tour for up to eleven months of the year; therefore, physical fitness is increasingly

important. The only study^[26] that focussed specifically on the calorific energy demand of cricketers was performed in 1955, and its validity in representing the demands of modern players would seem problematic.

More recent research has indicated that cricketers generally rely on aerobic energy supply and that the rates of energy expenditure of cricket are relatively low; with the exception to this being fast bowlers during a bowling spell^[21,26] and fielders sprinting after the ball. This generalisation is supported by the findings of time-motion analyses.^[1,19,27]

The multi-stage fitness test is recommended to test aerobic power as it is inexpensive, easy to administer and applicable to many team sports with respect to the stop, start and change-of-direction movement patterns.^[24] One study^[14] showed that cricketers had a higher shuttle run number when compared with rugby union players, with a $\text{VO}_{2\text{max}}$ of ~ 60 ml/kg/min. Johnstone and Ford^[21] established physical fitness profiles of cricketers grouped into bowlers and batsmen (*n*=15) using this test. The authors recorded the number of completed shuttles (12.4; SD ± 0.9), end heart rate (190.4 bpm; SD ± 11.2) and predicted the $\text{VO}_{2\text{max}}$ (54.9 ± 3.7). The researchers

concluded that the VO_{2max} results of cricketers were superior to that of the general population.^[21] These results are comparable with the normative data presented for cricket players in *Physiological Tests for Elite Athletes*.^[25]

Anaerobic fitness has generally been tested using repeated sprint tests. Johnstone and Ford^[21] found that running speed for each of the groups was similar, although the bowlers achieved moderately better results (1.5%) in maximal repeated sprint tests than the batsmen. Sprint tests in cricket have typically varied in distance (10 - 40 m); therefore, it is difficult to compare results between studies. Johnstone and Ford^[21] recommended that the future assessment of cricket-specific speed should use short distances of 5 - 15 m, because these may be associated with higher levels of match-winning fielding performance. However, sprint testing over a large range of distances may be justified because the size of the pitch that players will have to cover varies in distance depending on fielding position.

In summary, cricket players require a high level of aerobic fitness in order to play for up to 6 hours per day, with intermittent, short bursts of high-intensity effort that requires contribution from the anaerobic energy system. Whether these demands differ as a function of fielding position has not been researched. It may be that a position such as slips with potentially less aerobic demands may benefit from greater doses of high-intensity reactive training. Nevertheless, given the length of the international cricket season and the tour demands of cricketers, superior aerobic fitness will assist players in recovery and sustaining performance at the highest level.

Strength, power and speed

Upper body

The results of studies on strength and power profiles of cricketers have so far been ambiguous and seem to lack logical or face validity. Johnstone and Ford^[21] for example, measured upper-body strength and power using a medicine ball throw and timed press-up tests. There were marked differences between batsmen and bowlers; the batsmen were superior in the timed press-up tests, but the bowlers produced greater backward throws. However, the significance of these results and their relation to performance is unclear. There is no research on specific fielding positional demands, nor have normative data for each fielding position been established. Nevertheless, it appears that different strength requirements may be needed for different fielding positions (e.g. the throwing demands of an outfielder v. a slip fielder).

Lower body

Leg strength and power are important for cricket fielders as they contribute to the speed and agility required for fielding. However, there has been little research on the lower-body strength profile of cricketers. Johnstone and Ford^[21] tested lower-body strength and explosive power using a counter-movement jump and repeated vertical jump test. The authors suggested that tests such as the counter-movement jump give an indication of slow stretch-shortening cycle performance, and found that there were negligible differences between bowlers and batsmen. Bourdon *et al.*^[24] also recommended a series of tests for profiling the physical fitness of elite cricketers, the lower-body tests included a vertical double-leg jump, abdominal strength stage test, straight sprint speed (10, 20 and 40 m) and a run 3 agility test. While the abdominal stage test is

lauded as particularly important for fast bowlers, the authors noted that batsmen and fielders would benefit from good abdominal strength during long periods in the field or at the batting crease.

The leg-power demands of fielding are little understood; however, a study comparing cricketers with rugby players found no significant differences in leg press, bench press and 35 m sprints.^[14] For example, there is little logic in using only a vertical jump test when research and observation show that fielders need to move in all directions and consequently need multi-directional lower-leg strength and power. Correctly assessing the multi-planar movement ability of fielders should lead to better training programmes.

Conclusion

There is a paucity of scientific information on the performance demands of fielding across all the areas of interest discussed in this review article, i.e. technical, physical, etc. There seems to be little appreciation of the technical requirements related to different fielding positions. From the scant literature available, it is possible to deduce that cricket fielding is, in general, a low-intensity activity that requires intermittent bursts of explosive movement. However, conventional wisdom on several aspects of the game is not supported by scientific evidence. Given that fielding is an essential component to winning matches, the lack of research in this area is disconcerting. A systematic research programme covering all components of all game formats would be beneficial.

Existing knowledge could be complemented by obtaining the considered opinions and insights of coaches and players and by carrying out detailed video and notational analyses. The results would provide greater insight into the skill and movement requirements associated with the different field positions. This information would also provide a framework for the design of fielding-specific assessments, which should enable the development of more focussed training, conditioning and coaching protocols. This should enhance fielding performance and contribute to the ultimate goal of winning matches.

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Wicket-Keeping in Cricket: A Literature Review

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ABSTRACT

Cricket is unique in that three formats of the game, of varying duration and intensity are played at elite level; Test, One Day and Twenty20 (T20) cricket. The wicket-keeper is a vital member of the fielding side; the only player who could be involved with every delivery of the innings. Despite this, there is a paucity of literature on wicket-keeping, with most research having focused on fast bowling and batting. This review is principally concerned with identifying the performance demands associated with wicket-keeping and the conditioning of these cricketers. To appreciate the performance demands of wicket-keeping, an integrated approach has been taken where the mental, technical, physiological, physical and tactical requirements of wicket-keeping are discussed. From this information, recommendations are made and suggestions for future research detailed.

Key words: Cricket Fielding, Crouching Technique, Reactive Decision-Making, Sport-Specific Fitness, Visual Perception

INTRODUCTION

Cricket is a sport widely played throughout the Commonwealth. It has developed throughout the years and is unique in that three formats of the game are played at the elite level: Test, One Day and T20 cricket [1]. As with many sports, within cricket there are different performance and skill requirements depending on playing position, which can be categorised as batting, bowling and fielding.

In terms of fielding, these skills vary considerably, from the wicket-keeper and slips, who mostly intercept a fast moving ball coming off the edge of the bat and reaching them below chest height, to outfielders who primarily try to catch a ball falling from above their heads [2]. Common requirements for fielding skills are speed and accuracy, particularly in the

shorter forms of the game, as dropped catches or missed throws at the stumps can mean the difference between winning and losing a match. Therefore optimising the movements and skills required to successfully field and keep wicket can potentially have an influence on the outcome of a game. However, despite the adage that ‘catches win matches’, research into fielding in cricket is sparse compared to that for batting and bowling [2].

A strong performance from the wicket-keeper is essential to the success of the team. His actions can positively and actively contribute to the early dismissal of the opposing team [3]. The wicket-keeper’s role in cricket is unique in that he is the only player who has the potential to be involved in every delivery of the innings. This observation was supported by Shilbury [4] who reported that the wicket-keeper played a central role in cricket, taking approximately 21% of all fielding contacts in the six games analysed. In some matches the wicket-keeper was involved in as many as eight of the ten dismissals in a single innings [5]. However, there is a paucity of literature specific to wicket-keeping. Existing knowledge pertaining to wicket-keeping has generally been limited to coaching literature and for the most part this has been based on anecdotal evidence and the advice of former wicket-keepers and coaches [5].

Given this, the purpose of this literature review is to better understand the performance demands associated with wicket-keeping. To achieve this, wicket-keeping performance has been broken down into a number of components (Figure 1), which will be addressed systematically throughout the paper. The literature reviewed for this article is principally peer-reviewed research with the inclusion of one book chapter from an edited book. It is hoped that such an approach will help the reader to understand the performance requirements of a wicket-keeper and guide the conditioning and development of these players to better effect.

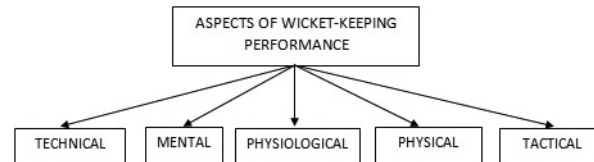


Figure 1. Aspects of Wicket-Keeping Performance

TECHNICAL

The techniques associated with wicket-keeping can be divided into two phases, pre-movement and movement, and are subsequently discussed in this section.

PRE-MOVEMENT - CROUCH

High repetition of explosive, powerful, lateral movement is required for wicket-keepers to effectively take deliveries from bowlers. In addition to this, wicket-keepers also have to field balls returned from other fielders. Therefore the movements required to take stock deliveries should be proficient and require as little physical exertion as possible. The Australian Institute of Sport [3] published a document investigating the efficiency of movements by wicket-keepers starting from three different crouch positions: the full crouch, semi-crouch and the touch and move stances (Figure 2).

The full crouch was reported as the position most used by wicket-keepers, possibly because of its successful use by past players. However, the full crouch requires the knees to be held in a static position at full flexion, which results in higher compressive forces on the



Figure 2. Side Views of Full-Crouch (Resting Position), Semi-Crouch and Touch and Move (Power Positions) Respectively (Produced by the author)

knees than more upright stances. It can be postulated that the semi-crouch and touch and move stances could be associated with reduced incidence of injury [6]. The full crouch is deemed to be a resting position used prior to moving into what is called a power position (loading phase), which are the semi-crouch, touch and move stances. The power position should only be held for a maximum of two seconds to ensure the power within the muscles is not lost before movement. Therefore, the three parts from the stance to the movement phase starts with the resting position (full crouch or a standing position), then into the power position (semi-crouch or touch and move), then into the movement stage towards the ball.

The purpose of the Plunkett et al. [3] study was to investigate the efficiency of side-to-side movement of wicket-keepers and the loading on the lower limb joints resulting from the three different crouch positions. Plunkett et al. [3] used 14 male cricketers who played in either under-14 or under-13 competitions. None of these players were specialist wicket-keepers and therefore had received little technical coaching in this position; however, they were old enough to have the coordination and physical maturity to be able to keep wicket. After pre-testing for power capabilities, the participants were assigned to three groups corresponding to each of the set-up positions, so that the results seen would be due to the different stances rather than variation in physical capabilities and coordination ability. The participants underwent a two-week training protocol during which they completed a mean 678.0 ± 60.8 repetitions of specific wicket-keeping skills. Following the training, wicket-keeping skill was tested by using a bowling machine to project balls at a mean speed of $82.2 \pm 1.5 \text{ km.h}^{-1}$. The balls were projected to the wicket-keepers left or right in order to simulate stock deliveries for a left or right-handed batsman. In addition to the 14 boys tested, two elite wicket-keepers (a first class wicket-keeper using the touch and move stance and a Cricket Australia Cup representative who used the semi-crouch stance) were also tested, allowing the technique used by the young participants to be compared to the elite wicket-keepers'.

From the results, it was concluded that the full-crouch technique was associated with the greatest loading at the knee, and therefore a greater range of lower limb extension was required to perform the primary lateral steps in order to take the ball [3]. This was achieved through the use of significantly greater peak moments in the outside knee. There were no other significant differences in lower limb moments between stances. It would seem that the full-crouch was the least efficient position; however, there were no significant differences between the times taken to move from the starting position for each stance. Although suggested that players use the touch and move in order to facilitate getting to the ball (by using a countermovement), movements from the touch and move stance did not differ significantly to movements from the other two stances in any peak joint moment. The authors concluded that the semi-crouch would allow the a wicket-keeper to move to the ball proficiently, and with potential lower loading on the knees than the full-crouch, but that set-

up position should depend largely on individual preference.

The authors highlighted the fact that there needs to be more research in this area given the limited data and the experience of the subjects from which these conclusions were made.

MOVEMENT

The footwork patterns of elite wicket-keepers ($n=12$) were investigated by Rosen and Bower [5]. 'Elite' was defined as having played in at least one Sydney Cricket Association first-grade cricket team or representing any State team from under-19 level and up. The testing protocol was designed to simulate a wide, low bouncing delivery to a right handed batsman, which would require the wicket-keeper to move to the right to catch the ball. The participants were fitted with reflective markers on nine anatomical landmarks for use with a three-dimensional motion capture system.

Following practice trials, each participant completed twenty wicket-keeping movement trials. Body kinematics were captured and digitised in real time to obtain three-dimensional coordinates. From the results, a number of footwork patterns were identified, which were then split into primary and secondary footwork patterns. The primary footwork patterns were identified as ipsilateral take-off, contralateral take-off and jump take-off (Figure 3); secondary footwork patterns were identified as the lateral shuffle and crossover step. In each of the figures, the bold feet marked L and R represent the crouch position, bold feet marked with numbers represent primary footwork patterns and outline feet represent secondary footwork patterns. The numbers indicate the order the feet were placed in.

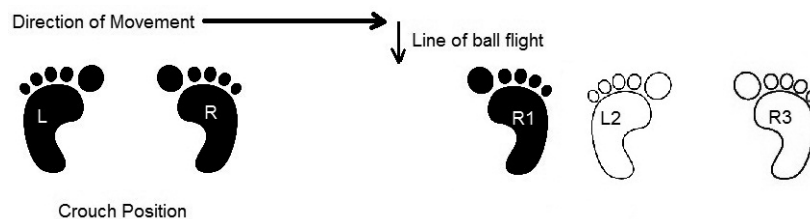


Figure 3a. Ipsilateral Take-Off

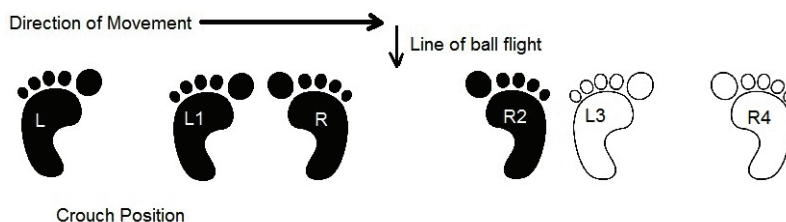


Figure 3b. Contralateral Take-Off

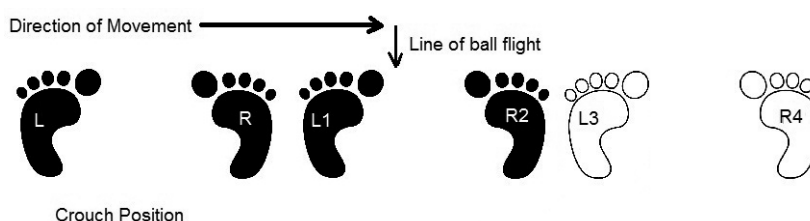


Figure 3c. Jump Take-Off

Figure 3 is adapted from findings from Rosen and Bower [5].

The ipsilateral take-off was the primary footwork pattern which was most frequently used by wicket-keepers; the average first step length was 54.5 ± 27.5 cm. The large variation between the placements of the feet indicated great variation between participants, which could be attributed to differences in stature, individual muscular strength, timing and speed of footwork.

The second most common movement sequence was the contralateral take-off, which consisted of a lateral step with the foot on the opposite side of the body from the intended direction of movement. This group of wicket-keepers appeared to have the widest crouch position, although no significant differences ($p < 0.05$) were observed [5]. The third primary footwork pattern incorporated a jump from the subjects' crouch position, similar to a split step in tennis.

Of the twelve participants, only half exhibited the same footwork pattern throughout the five selected trials while the others used a combination of multiple footwork patterns. It was concluded that the secondary footwork patterns allowed the wicket-keeper to continue the lateral movements initiated in the primary footwork phase and that the crouch position did not differ between subjects, irrespective of which movement pattern they used. Additionally, the wicket-keepers continued their movements after successfully catching the ball, indicating that rhythm and timing are vital to successful catching performance behind the stumps.

This study focused specifically on the wicket-keeper and the movements specific to this position, but there were some limitations which should be noted. The sample size was very small ($n=12$) due to the limited numbers of elite wicket-keepers and this may be why no significant differences were found in some results. The use of markers on the body meant that the participants could not wear the personal protective equipment usually worn when keeping wicket. However, the subjects were asked to comment on whether their movements felt similar to when they wore their pads and the general consensus was that their movements felt the same whether or not protective equipment was used. Additionally, due to limitations in laboratory space the ball projection machine was placed relatively close to the wicket-keeper, therefore for safety reasons ball projection speeds were lower than usually seen in elite competition. As a result of this, the wicket-keepers did not have the usual visual cues from the bowler which they normally use to determine the direction of ball trajectory and when to initiate their movement. The authors attempted to rectify this by giving the subjects a countdown before the ball was released. They were however able to maintain a reaction time between the ball release and contact with the wicket-keepers of 0.7 seconds, which is realistic in respect to match-like conditions.

Given the paucity of research in cricket, and the fact that moving and diving laterally are important movements for successful wicket-keeping, findings from other sports may be of value in understanding how to optimise these movement patterns. There is the potential for much to be learnt from sports such as tennis [7, 8], volleyball [9, 10], and football [11].

MENTAL

A five-day Test match is quite literally a test for all players, requiring them to perform and concentrate for considerable periods of time. This is true especially for the fielding side, which may spend all day in the field, often under adverse weather conditions; i.e., extreme heat. Players have to be able to switch their minds off in between deliveries in order to preserve their concentration. Such is the nature of cricket that the smallest lapses in concentration and resulting errors can mean the difference between a caught or dropped catch and a win or loss.

Perceptual-cognitive skills are an important characteristic of expert sport performance, researchers identifying that experts outperform novices in anticipation and decision-making tasks in a variety of sports [12]. Wicket-keepers have to utilise the same visual cues as a batsman to process information from the bowler's movements and from the trajectory of the ball. The wicket-keeper also has to keep a close watch on the batsman and his position in order to take advantage of any stumping opportunities. The ability to process these various pieces of information in order to make decisions has been addressed by several studies.

In fast-action dynamic sport environments, an athlete's ability to identify advanced sources of information facilitates early decision making and allows time for an appropriate response to be organised [13]. The nature of anticipatory cue utilisation in wicket-keeping was investigated using 12 male wicket-keepers sorted into 2 groups: expert and non-expert. A four-stage temporal occlusion paradigm including pre-ball release and ball flight information was used and the subjects were required to predict the position the ball would bounce. From the analysis of radial, lateral and depth accuracy information, Houlston and Lowes [13] found that there were no significant differences between the expert and non-expert groups, and emphasised the importance of time in terms of successfully predicting ball landing position. However, it was also established that experienced wicket-keepers strategically select visual cues, with lateral information taking precedence over depth information.

Given the paucity of wicket-keeper specific literature, insights derived from the analysis of the decision making process in other sports may be beneficial. Similar research has been conducted in tennis [14, 15], which is also a fast-action dynamic sport. Farrow and Abernethy [14] and Williams et al. [15] showed that with an increase in skill level, there was enhanced ability to search for and utilise cues from earlier occurring events in the display [15]. Tennis researchers have also made use of temporally occluded video to investigate training anticipatory skills through the use of video-based perceptual training [14, 15]. In a study investigating difference between implicit and explicit learning use in tennis, the implicit learning group improved their prediction accuracy after appropriate training. These findings on the decision-making process in tennis provide additional support for similar type research for wicket-keeping.

The effect of visual-perceptual training on the fielding performance of skilled cricketers was investigated by using twelve highly skilled cricketers from the Australian Institute of Sport Centre of Excellence [12]. All participants were selected to play at senior international level within six months of the conclusion of the study. The study used a test-retest design, which included a six-week training intervention. Both groups participated in the same on-field training programme for the six weeks. Additionally, the test group undertook three video-based perception training sessions per week. Despite no significant differences between the test and control group at pre-testing, the test group scored significantly higher than the control group at post-testing for decision accuracy. The results indicate that six weeks of on-field training combined with visual-perceptual training can lead to improvements in the fielding performance of skilled cricketers above those of on-field training alone [12]. While the study focused on inner circle fielders who have longer to react than wicket-keepers, the value of visual perceptual training should be noted for wicket-keepers, and is a potential area for future study.

Visual evoked potentials (VEP), reaction times and eye dominance in batsmen and bowlers have been investigated [16]. The findings of this study can potentially be applied to wicket-keepers given that wicket-keepers stand behind the batsman and have to utilise the same visual cues. A skilled batsman picks up sufficient trajectory information during the first

100 – 150 ms of ball flight to estimate the position of the bounce and that lateral information takes precedence over depth information when making decisions [17]. This information illustrates the importance of anticipation for successful wicket-keeping performance.

In summary, perception and decision-making are vital components of cricketing success. Wicket-keepers must be able to understand and prioritise subtle visual cues in order to make decisions. Research has shown that perceptual-decision making skills can be improved using a combination of on-field and video-based training. Nevertheless very little research has focused specifically on wicket-keepers and the processing of visual information required for them to execute their skills successfully. The use of visual-perceptual training in order to improve anticipatory and reactive decision making in wicket-keeping performance is an area for future study.

PHYSIOLOGICAL

There are very few studies of the physiological demands of cricket or of the specific physiological, biochemical or anthropometric attributes of top-class cricketers [18]. However, some time-motion analyses investigating the different physiological requirements between the three formats of the game have been undertaken in recent years.

Petersen et al. [19] used GPS units and time-motion analysis to quantify positional movement patterns in T20 cricket. Players were classified as a batsman, fast bowler, spin bowler, fielder or wicket-keeper. The effect size statistic was used to assess the extent of differences between the generic fielder position and the three specialist positions (wicket-keeper, fast and spin bowlers). During the fielding innings of a T20 match distance covered by players ranged from 6.4 km (wicket-keepers) to 8.5 km (fast bowlers) with 0.1 km to 0.7 km covered at sprinting intensity. For wicket-keepers sprinting accounted for 1% of total distance covered [20]. It was reported that wicket-keepers covered substantially less distance in higher intensity efforts (sprinting, striding, running and jogging) than fielders and had twice the recovery time from high-intensity efforts as fielders (101s compared to the fielders 44 s; ES = 3.0).

In an analysis of movement patterns in the three formats of cricket, Petersen et al. [1] found that wicket-keepers covered more distance per hour in multi-day cricket (2.8 km) than in T20 (2.5 km) and One Day (2.7 km) matches. Furthermore, wicket-keepers covered a greater distance per hour in high-intensity efforts (running, striding, sprinting) in T20 (433 m) matches than in One Day (240 m) or multi-day cricket (109 m) and the recovery times were longer the longer the format of the game. During a full One Day innings the wicket-keepers travelled the least total distance of all the fielding players (9.5 km), averaging only 0.1km at sprinting intensities. Wicket-keepers covered approximately 16.6km and 3.3km in multi-day and T20 innings respectively.

While knowing the proportion of distance and time spent standing, walking, jogging, running, striding and sprinting is useful for training prescription purposes, this type of analysis gives no indication of the direction of movements nor the precise movements and joint kinematics specific to the skill of wicket-keeping. Time-motion analysis should be expanded to include the movements unique to the wicket-keeper, although some of this information will not be possible to obtain with GPS.

PHYSICAL

The physical requirements of the wicket-keeper are to a large extent decided by the physiological and technical requirements mentioned in previous sections. Recommended physiological tests for cricketers include anthropometry, sprint and agility tests, leg strength

and yo-yo intermittent recovery tests[21]. Therefore in this section the anthropometry of the wicket keeper is discussed as well as the role of aerobic and anaerobic fitness, strength, power and speed.

ANTHROPOMETRY

Data presented in the cricket chapter of “Physiological Tests for Elite Athletes” [22] reported that academy wicket-keepers ($n=13$) were shorter ($177.1 \text{ cm} \pm 3.7$) than fast ($189.2 \text{ cm} \pm 6.3$) and spin bowlers ($182.5 \text{ cm} \pm 5.6$), but taller than batsmen (168.9 ± 5.3). Wicket-keepers and fast bowlers had similar sum of 7 skin folds (triceps, subscapular, biceps, supraspinale, abdominal, thigh, medial calf), but their sum of 7 skin folds were reported to be less than batsmen and spin bowlers. There has been a more recent study investigating the physiological profile of cricketers [23], but this study grouped participants ($n=15$) into groups of bowlers and batsmen and the one wicket-keeper included was classed as a batsman.

It must be noted that the little anthropometry data available for cricket has been compiled from cricketers from South Africa [24, 25] and Australia [26], therefore the findings cannot be generalised in regards to cricketers worldwide. For example, general observations have shown that players from the Asian subcontinent have a tendency to be smaller than players of European descent. Due to the fact that cricket is a global sport practiced by people from different ethnic backgrounds, finding universally valid relationships between the different aspects of the game and the anatomy and physique of the players may be a complicated process, and researchers should be aware of this issue. Saying that, in terms of the skills required by the wicket-keeper (diving and catching low balls) and their potential involvement in every ball of an innings, being smaller in stature and carrying very little fat mass would seem advantageous.

AEROBIC AND ANAEROBIC FITNESS

Given the results summarised in the physical section of this literature review, it is clear that cricketers require a high level of aerobic fitness in order to play for up to six hours a day. Additionally, good aerobic fitness will help with recovery between days of play, heat stress and the ability to concentrate for long periods of time. However, there is a lack of peer-reviewed literature regarding the physiological profiles of professional cricketers and possible differences that may exist among on-field playing positions [23] as the majority of cricket research in this area has focused on fast bowlers.

The physiological profile of professional cricketers has been investigated by putting them through a series of field-based fitness assessments including body composition, flexibility, predicted maximal oxygen uptake, upper and lower body strength, speed and explosive power [23]. Compared with normative data, cricketers have some superior fitness parameters compared to the general population. There were also physiological differences between batsmen and bowlers (no wicket-keepers were included in this study, but in previous studies wicket-keepers have been classed as batsmen). The players' predicted maximal oxygen uptake (calculated from a multi-stage shuttle run) was found to be 54.1 ± 2.8 for bowlers and $56.1 \pm 4.5 \text{ ml.kg}^{-1}.\text{min}^{-1}$ for batsmen, respectively. It was concluded that cricket has a 'moderate aerobic endurance' component, which may relate to the movement patterns of the game as match analysis indicates that players can cover up to 15 km per day in the field, although the majority of this distance is covered at walking pace [23].

In terms of wicket-keeping, it can be postulated that their aerobic fitness may need to be superior to that of most cricket positions due to: 1) their possible involvement in every ball

during the fielding innings; 2) the mental and physical requirements setting for each delivery; i.e., the pre-movement; 3) the need to be reactively explosive in order to catch balls from the bowler or off the batsmen; and, 4) in most teams the wicket-keeper is a high-order batsmen expected to perform well with the bat (in the past the wicket-keeper was a specialist position), so the expectation is for them is to score runs and build innings.

STRENGTH, POWER AND SPEED

Leg strength and power would seem pre-requisite to successful wicket-keeping performance. However, while the movements required by the wicket-keeper have been analysed [3, 5], there has been no analysis of the strength profiles required of wicket-keepers. Leg strength and endurance would seem important given the requirements of repeating and holding the crouch position over extended durations. In terms of saving runs and enabling dismissals via catches coming off the bat, there is no doubt reactive or explosive strength and power would be beneficial. Furthermore multi-directional reactive strength and power would be advantageous as the wicket-keeper needs to be able to dive to both sides (lateral), forward (horizontal) and up (vertical) to catch the ball and enable a dismissal.

In terms of speed, having very good first-step quickness or accelerative ability would be another advantageous quality for a wicket-keeper. From match analysis it is evident that at times the wicket-keeper may be the closest fielder to the ball, therefore the ability to get to that ball quickly and prevent further runs and/or enable a run-out is extremely desirable.

In summary, there has been some research into the physical requirements of cricket. However, there is little research that has focused on the specific requirements of the wicket-keeper. Further research is needed to identify those qualities and assessments that profile wicket-keeping ability. It is thought that tests of aerobic fitness, multi-directional reactive and explosive leg power and straight line acceleration ability would form the foundation of such a testing battery.

TACTICAL

There has been no peer-reviewed literature found which investigates the tactical requirements of wicket-keeping. This is probably due to the fact that cricket tactics are often influenced by external, uncontrollable factors such as the weather, the pitch or even which batsmen are in. As previously mentioned, a wicket-keeper is the only fielder who can potentially be involved in every delivery of the innings, making it important that the tactics employed for the wicket-keeper maximise his performance and are aligned with the rest of the team.

The wicket-keeper is frequently positioned close behind the batsman and are therefore in a position to influence the match in a number of ways. Outside their basic catching role, the wicket-keeper plays a pivotal role in terms of analysis of players whether it is their own bowlers or opposition batsman in order to set field positions.

CONCLUSION

There is a paucity of published literature on the performance requirements of wicket-keeping in cricket. In order to optimise performance of the wicket-keeper, a deeper appreciation of the movement requirements is needed. For example, wicket-keeper specific movements should be documented for the duration of a game to establish the performance requirements in a competition scenario. This information needs to be integrated with existing knowledge around the mental aspects of keeping (e.g., reactive decision-making component) so that specific assessment batteries may be developed that could better guide the conditioning and

skill development of wicket-keepers. Information like this will enable a more complete understanding of the training and conditioning requirements for wicket-keepers.

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Research Article

A SCITECHNOL JOURNAL

A Survey of the Performance Demands of Cricket Fielding and Wicket-Keeping

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Abstract

Little is known of the performance demands of fielders and wicket-keepers in cricket, therefore the purpose of this study was to investigate the performance demands of fielding and wicket-keeping through an online survey of players, coaches and strength and conditioning coaches (n=41). The mental, physical and technical aspects of performance were explored with respect to wicket-keepers, close, inner and outer circle fielders. The importance of physical characteristics for each position was determined for each format of cricket respectively. However, more detailed analysis was undertaken for One Day International cricket (ODI), from which emerging themes were also identified. Agility emerged as the most important physical characteristic in ODI cricket for all but the outer circle fielder, for whom speed was the most important attribute. Understanding the performance demands of fielding and wicket-keeping should allow more appropriate training and conditioning to be prescribed.

Keywords

Cricket; Performance; Wicket-keepers; Fielding; One Day International Cricket (ODI)

Introduction

Cricket is one of the most watched team sports in the world [1], largely due to its popularity in Commonwealth countries. It is a game that has three formats (Test, One Day, and Twenty20) and all players are required to bat and field, whereas only some players bowl. Despite the importance of cricket fielding in the context of the game, there is a paucity of peer-reviewed research investigating fielding compared to the other components of the game [2,3]. The only study which has investigated fielding skills with respect to position [4] acknowledged the wicket-keeper as a specialist position within the fielding unit. However, despite this there have been only two studies investigating the wicket-keeper specifically. One study investigated the footwork patterns of wicket-keepers [5] and the other investigated the forces exerted on the knees with different wicket-keeping crouch techniques [6].

The physiology of cricket fielding has been investigated using global positioning system (GPS) units to establish the amount of time and distances covered at defined exercise intensities [7-9]. Cricket fielding has been shown to be a low intensity exercise with short bursts of high intensity efforts followed by long recovery periods

[7,10]. However, this type of data collection has failed to provide any indication of the direction of movement, which is specifically relevant for the wicket-keeper who has to crouch repetitively and be able to dive and move in all directions. The studies differentiated between player roles, identifying participants as bowlers, batsmen, and fielders. The studies differentiated between player roles, identifying participants as bowlers, batsmen, and fielders. However, in spite of the differences between the functions and requirements for the different field positions, except for the wicket-keeper no differentiation between the field positions has been investigated until now.

Cricket is generally considered to be a very traditional game, and anecdotal evidence is often relied upon in coaching and training. The paucity of research suggests a lack of knowledge as to what is required for successful fielding performance in the modern formats of the game. It is important to understand and measure the performance requirements in order to be able to improve performance. Given this lack of information and the scope of what little research there is, the aim of this study was to gather expert opinion of players, coaches, and strength and conditioning coaches regarding the performance requirements of elite fielding and wicket-keeping. In particular, the technical and physical requirements of fielding in cricket were investigated via the information collated from a web-based survey. It could be postulated that there would be variation in fielding performance requirements in the three different formats, and therefore questions were related specific to the different formats. The information collated from this study should assist in furthering the understanding of some of the performance requirements of elite cricket fielding and wicket-keeping.

Methods

Participants

As expert opinion regarding elite cricket performance was being sought, participants were included if they were involved with at least first class professional cricket (Major Association (New Zealand), State (Australia) or county cricket (United Kingdom)). In order to gather the most complete view of cricket fielding performance, participants included players (former and current), coaches and strength and conditioners.

In total, 41 people participated in the study, filling out the survey to varying degrees of completeness. Twenty two participants identified themselves as players (past and present), 19 as coaches (a mixture of head, assistant, batting, fielding and wicket-keeping) and 12 as strength and conditioning coaches. Some participants identified themselves as more than one role, and therefore will have answered questions from the perspectives of each. The online survey was designed to only show the questions relevant to each participant, based on the roles and fielding categories they provided in the demographics section of the survey. This resulted in small and unequal sample sizes for each group, as not all roles and categories applied to each respondent. The participants were all between the ages of 18 and 54 and had a mean of 10 ± 9 years involvement in professional cricket. By completing the survey, participants indicated that they had given their informed

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consent to participate in the study. The research methods employed in this study were reviewed and approved by the Auckland University of Technology Ethics Committee (12/293).

Data collection

A mixed methods research design using a survey was used to collect information of interest to the researchers. The survey was designed using the online survey platform Survey Gizmo (www.surveygizmo.com) [11]. The survey included information for participants and informed consent, a demographics and basic information section and, sections to be answered by wicket-keepers, close, inner and outer circle fielders, and coaches and strength and conditioners as applicable.

Using the over-arching research question "*what are the performance requirements of elite cricket fielding*", the content of the survey was determined by consulting researchers and cricket coaches. The survey was pilot tested before distribution; the functionality of the online survey and the content was reviewed. The consultation with cricket researchers and coaches allowed the survey's face and content validity to be established. The questions were focused on the technical, physical and mental aspects of performance in each fielding position i.e. wicket-keepers, close, inner and outer circle fielders. The overall data collection was qualitative, using a combination of closed and open questions. The questions included ranking the importance of physical fitness and attributes, where participants were asked to assign a number from one to five (1 being not important at all, 5 being very important) and short answer type questions regarding skills and physical attributes. The questions were asked with respect to each format of cricket, however, one day international (ODI) cricket is the main focus of this research and therefore the bulk of the survey analysis will focus on this format.

Survey distribution

As the participants in the study were to remain anonymous, the primary researcher did not directly contact potential participants. The invitation to participate and the link to the survey was distributed to contacts in the cricket and scientific community (including researchers and coaches), who were then ask to distribute the survey to potential participants, a technique known as 'snowballing' [12,13]. The survey was sent to contacts in New Zealand, Australia, South Africa, and the United Kingdom.

Data analysis

Answers to the survey were downloaded and collated on an EXCEL spreadsheet. As there were only forty-one respondents to the survey, for the quantitative questions all data was pooled and no sub-group analysis was undertaken i.e. coaches vs. players vs. strength and conditioning coaches. As the survey included questions which required participants to give each physical fitness component an importance ranking of one to five (one being not important, five being very important), it was possible to perform some basic analysis. With regards to the closed Likert scale questions, the mean response was calculated for each of the answers and depicted on spider plots for ease of observation and trend analysis. When interpreting these spider plots, a higher number reflects greater importance attributed to that quality. In terms of the open questions, higher order themes were identified and key points which emerged are also discussed.

Results and Discussion

Given that the purpose of this study was to identify the performance demands of fielding position with respect to different positions, the results are presented and discussed with respect to wicket-keeper, close, inner and outer circle fielding respectively.

Wicket-keeper

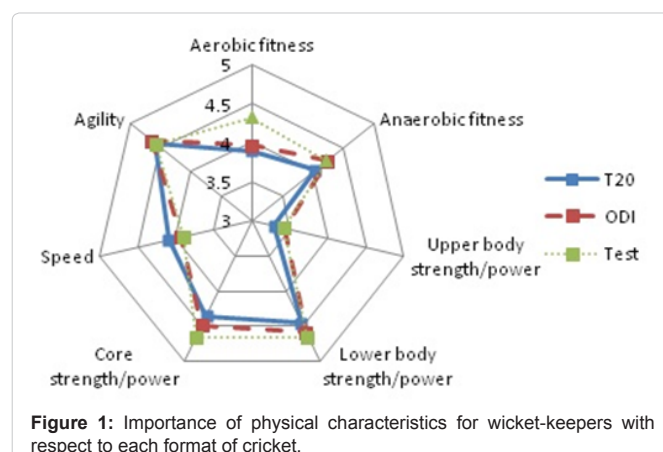
In total, 32 participants responded to the questions regarding wicket-keeping performance. The importance of each fitness characteristic with respect to each format of the game with reference to the wicket keepers can be observed in [figure 1](#). Respondents considered agility, core and lower body strength/power to be the most important physical characteristics for a wicket-keeper; however, no values were assigned an importance rating less than 3.

Agility (4.7) emerged as the most important physical characteristic for wicket-keepers in ODI cricket. In fact the three most important (> 4.2) characteristics remained the same across the three formats; agility, lower body and core strength/power. Upper body strength/power (3.4) was considered to be the least important attribute in all three formats, which was logical due to the wicket-keeper not being required to throw long distances.

Thematic analysis of ODI Cricket: Several themes emerged from the open-ended questions posed to players and coaches that can be broadly classified as skill and technique, body type and physical attributes, movement and stillness, mental factors.

Skill and technique: Of the players and coaches who responded, several highlighted the importance wicket-keeping technical ability and skills (referred to as glove work). Avoidance of injury was frequently cited when players were asked the reason for their particular crouch technique. In addition to the glove work required of wicket-keepers, in the modern game, a wicket-keeper is expected to be proficient in batting to make significant contributions to the score. Therefore, players are likely to be selected based on their batting ability, in addition to the ability to keep wicket. Of the 10 wicket-keepers surveyed, the majority (n=6) batted in the middle order, two batted in the top order and two batted in both the top and the middle order.

Body type and physical attributes: The respondents suggested that certain physical attributes would be advantageous for a wicket-keeper; the ideal being "short of stature and lean". The phrase 'low skin folds' was repeatedly used when asking about the physical



characteristics for wicket-keeping. This suggests that there is a certain degree of value placed on anthropometric measurements. One coach responded that the ideal physical attributes for a wicket-keeper would be "proprioception, speed, and agility, perfect balance of strength, power and size".

Movement and stillness: The phrase 'power z position' was used by several respondents in response to the question regarding the pre-movement for a wicket-keeper. "The Power Z position is when the knees are bent forward and the athlete is on his toes, the head is forward and the torso is obviously leaning forward as well, in essence the body forms the shape of a Z somewhat, I refer to it as the 'spring' that is coiled ready to be released!" was how the Power 'Z' position was explained by one coach, another described it as "the pre loading position a wicket-keeper gets into before they need to react". An online search of the term described the 'power z position' as "the posture that provides stability, control, power and appropriate head and hand height to a wicket keeper preparing to move into a position to take a ball" [14].

It is logical to think that movement is important for performing sport specific tasks however the importance of 'stillness' or stability prior to movement was mentioned repeatedly by players and coaches alike when asked about the technical factors of wicket-keeping. Coaching literature recommends that a wicket-keepers stance should give them the best possible sight of the ball, to watch it unblinkingly [15]. This is to enable them to have a clear view of the ball and to have a stable balance point from which they can react in any direction.

Mental factors: The importance of the mental aspect of performance emerged repeatedly from participant's responses. When players were asked why they became a wicket-keeper, several players made the point that they wanted to be involved with every ball of the innings, as they 'had bags of energy' and were 'easily distracted in the outfield'. Several players also highlighted the fact that a coach had steered them in the right direction when choosing to become a wicket-keeper. It seems that certain personality traits such as enthusiasm and the ability to concentrate for every ball of the innings might be useful for a wicket-keeper, and that it is important for coaches to be able to recognise these traits in young players so that they may be developed into a wicket-keeper.

Close fielder

In total, 21 participants responded to the questions regarding close fielding performance. The importance of each fitness characteristic for close fielders can be observed in figure 2. Respondents considered agility, core and lower body strength/power to be the most important physical characteristics for a close fielder; however, no values were assigned an importance rating less than 3.5.

Anaerobic fitness, and upper, and lower body strength/power were considered to be less important the shorter the format. In fact, upper body strength/power was comparatively the least important physical attribute from all formats of cricket (< 3.7), which is slightly surprising given that it has been demonstrated as important for cricket batting [16]. The importance of aerobic fitness increased as duration of the format increased (T20 4.1, ODI 4.3, and Test 4.5). In all three formats there was ≈ 1 point difference between the most important (agility) and least important (upper body strength/power) characteristics. No participant indicated that there were any differences in close fielding in terms of technical or mental factors between the three formats of cricket.

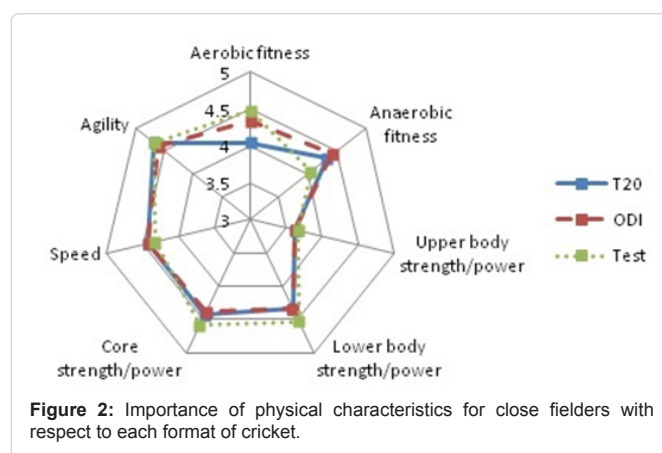


Figure 2: Importance of physical characteristics for close fielders with respect to each format of cricket.

With reference to the ODI format, agility (> 4.6) emerged as being particularly important for close fielding performance, for all formats of cricket. Speed (4.4) was the second most important characteristic for close fielders. None of the physical characteristics received a score less than 3.6, which suggests that respondents considered all physical characteristics to be reasonably important for close fielders. Upper body strength/power again emerged as the (comparatively) least important physical attribute for close circle fielders (3.6). By definition close circle fielders are placed in positions close to the batsmen, and therefore do not have any great distances to throw. However, they are usually required to return fielded balls quite quickly in order to attempt to dismiss the batsmen. This would suggest that reactive speed rather than strength is important for fielders in these close positions.

Thematic analysis of ODI cricket: Several themes emerged from the open-ended questions posed to players and coaches including preparation for movement, mental factors and body type and physical attributes.

Preparation for movement: When asked about the pre-movement phase for close fielders, several coaches highlighted the importance of the preparatory movement. Phrases such as 'wide stance' and 'split step' were used when they responded to these questions. The coaching literature refers to this as a 'trigger' movement. Jonty Rhodes, arguably one of the best fielders of the modern game, used a trigger movement which left him balanced, with weight equally spread over both feet, but also primed and energised to move in either direction as required [15].

Getting/staying low prior to movement was also highlighted. A balanced, low stance is important for close fielding. This is because it is easier to move upwards for a catch than go down for it [15]. Due to the proximity to the batsmen, players fielding in this area have very little time to react or adjust position; therefore appropriate preparation for movement is important.

Mental factors: In response to questions regarding the mental requirements of close fielding performance coaches used the words 'concentration' and 'focus', emphasising their importance. One coach said that close circle fielders need to "set position, read batsman's movement, narrow focus to contact area". The greatest fielders in the game, especially those who occupy positions close to the bat, often have highly advanced skills of anticipation. To be a good catcher requires excellent reflexes and alertness and anticipation [15].

One player commented "again it's about attitude... If you want to

be a great fielder and love it then getting ready for each ball should be natural". Another said, "Just tell myself to get involved and this keeps me alert. My routine if this is one is an attitude to want the ball which creates my sense to ready to move and exercise".

Body type and physical attributes: When asked to comment on any other physical qualities which would be ideal for a close fielder, numerous responses suggested there are ideal physical characteristics for a close fielder. On this point players and coaches seem to agree that close fielders should be "shorter in stature. Ability for explosive movement. Lean but muscular".

A player made the comment that close fielders should have "Long limbs but not excessive height"; another response said "big hands". These responses suggest that there should be anthropometric measures which would help identify players who have the potential criteria for close fielding. However, the traits mentioned are quite specific, and while having them may be seen as advantageous, it would be unwise to exclude players from this position due to anthropometric measures.

Inner circle fielder

Twenty participants responded to the questions regarding close fielding performance. The only characteristics in which there was a marked difference (1 point) in importance between formats were anaerobic (less important for ODI and Test cricket than T20) and aerobics fitness (less important in ODI cricket than the other two formats). Predictably, aerobic fitness increased in importance as the duration of the game increased (4.2, 4.3, and 4.5 for T20, ODI, and Test cricket respectively). Upper body strength/power was once again the least important attribute for all formats of cricket, being given an importance value of ≈ 3.7 between the three formats. While it is the least important attribute, this is the highest importance value provided thus far; suggesting that upper body strength/power is increasing in importance as the fielding positions move further from the batsmen (Figure 3).

In terms of the ODI format, agility (4.8) has emerged once more as the most important physical characteristic for inner circle fielding performance. However, as speed becomes increasingly important as fielders move further away from the batting crease, this is reflected in speed being given an importance value of 4.7, just 0.1 behind agility, suggesting that they are almost equally important. In fact, the only physical characteristic which was given an importance value less than 4 was upper body strength/power. Their fielding positions require inner circle fielders to stay within the 30 yard (27 m) inner circle of

the cricket field, and therefore they are not required to throw great distances.

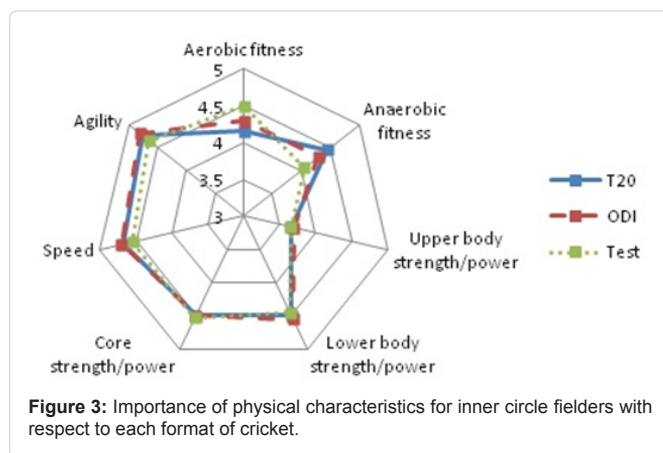
Thematic analysis: Several themes emerged from the open-ended questions posed to players and coaches that can be broadly classified as mental factors, technique and body type and physical attributes.

Mental factors: When questioned about mental routines in fielding one player responded "always attitude for me. Routine means little until you have the right attitude of wanting the ball to come to you. This to me is 90% of fielding because technique means nothing unless you want to play your role in the field." Another said "switch off after ball is bowled. Relax. Switch on as the bowler begins to approach the crease. Tell myself that this ball is coming to me". The mental component of performance appears to be a theme which is occurring for each of the fielding categories discussed thus far.

Technique - catching and throwing technique: From the responses regarding technical aspects of inner circle fielding performance, it is clear that using the correct technique for catching and throwing is important. 'Hand position' in particular was repeatedly mentioned in responses; another said "fingers up/fingers down". From these responses we can infer that there are different techniques required in different scenarios, and it is important to be able to select the correct technique. For example, coaches generally advise that fingers should be pointing upwards when taking high catches, and pointing downwards (so that the hands form a cup shape) when catching low. There are even such subtleties in taking high catches; fingers up with the palms of the hands turned towards the face is referred to as the 'English' method. The 'Australian' method of high catching uses fingers up, palms facing outwards toward the ball; this method is often used in bright conditions, so that the fielder can get a better view of the ball against the light in order to take the catch [15].

Technical considerations regarding throwing were also highlighted; coaches repeatedly suggested that players had to be quick to "realign to target" and "establish some sort of base" to be able to throw accurately. The ideal throw is thought to be an overarm baseball throw, however the nature of the game doesn't always allow for ideal technique (in fact, fielders may need to throw the ball underarm, or even backhand), therefore it is important that fielders set themselves up to throw by regaining balance and control of the body as quickly as possible. Respondents emphasised that throwing technique included the whole body, mentioning feet and hips specifically when generating throwing speed. One respondent said that inner circle fielders should be "Light on their feet with good hands, good span, and quick throw". The throw, like a bowler's action, must be smooth, grooved, fluent and repeatable [15].

Footwork: It became clear from the inner circle fielding responses, that footwork was a key part of inner circle fielding success as it was mentioned in every phase of throwing performance (pre-movement, movement, catch and throw). The timing of footwork in particular was highlighted as an important technical part of performance. In the pre-movement phase coaches recommended that players stay on the balls of their feet, with a 'stable base' or 'set position'. Another respondent said that the inner circle fielder pre-movement should be a "split position, [with] weight on balls of feet". Several different types of preparatory footwork were identified from the responses, for example split, drop jump and jump, which are trigger movements used to get in an ideal, stable position to move in any direction [15]. Descriptive words such as 'smooth' and 'efficient' were used to describe footwork and movement. Balance was another factor which



was mentioned in all phases of the performance (pre-movement, movement, catch and throw).

Outer circle fielder

Nineteen participants responded to the outer circle fielding questions. Interestingly, outer circle fielding is the only fielding category in which the most important physical characteristic was not agility and the most important characteristic was different for each format (Figure 4). The most important characteristics for outer circle fielding were lower body strength/power (4.6), speed (4.8) and aerobic fitness (4.7) for T20, ODI and Test cricket respectively. As the duration of the game increases, there is increasing emphasis put on the importance of aerobic fitness and speed when compared to other formats.

Outer circle fielding is the first and only category in which agility was not considered to be the most important physical characteristic for ODI cricket. Instead, speed (4.8) was reported to be the most important characteristic in ODI cricket, followed by lower body strength/power and agility (both 4.6) respectively.

The fact that aerobic fitness was the most important attribute (4.7) for an outer circle fielder in Test cricket is testament to the large distances they can cover, up to 14 km per day in a Test match [10]. The greater intensity and explosiveness of T20 cricket would contribute to lower body strength/power, anaerobic fitness (sprint ability) and speed being considered almost equally important for T20 outer circle fielders.

Thematic analysis: Mental factors: Players reported that they employed both physical and mental routines when preparing to field in the outfield. This included watching the ball, bowler and batsman for visual cues, and 'switching off' or relaxing between deliveries. One player explained "Switch off after ball is bowled. Relax. Switch on as the bowler begins to approach the crease. Tell myself that this ball is coming to me." Another mentioned the fact that he had a preparatory checklist he used to get ready. Anticipation was repeatedly mentioned by coaches as important for in the pre-movement phase of performance.

Technique: Given the distances in the outfield, it is importance to have a strong throw; both players and coaches agreed on this fact. One coach mentioned that "fast shoulder rotation produces a strong throwing arm". In fact, strong throwing was repeatedly mentioned as being important for outer fielding performance. Given this, the authors were surprised that upper body strength/power was consistently rated as the least important physical characteristic for fielding. However, while considered unimportant when compared to the other characteristics, it received an importance value greater than 3.4 for all fielding positions, further supporting the fact that no physical characteristic was unimportant. Additionally, a coach mentioned that an outer circle fielder should be fast across the ground. One respondent also mentioned flexibility as an important attribute for an outer circle fielder to have.

Further Discussion

Comparing the importance of physical attributes for all positions on the same plot allows the relative differences in importance to be observed (see Figure 5).

Agility, aerobic fitness and core strength and power were considered almost equally important for all fielding positions. This suggests that all fielders require a certain level of agility and

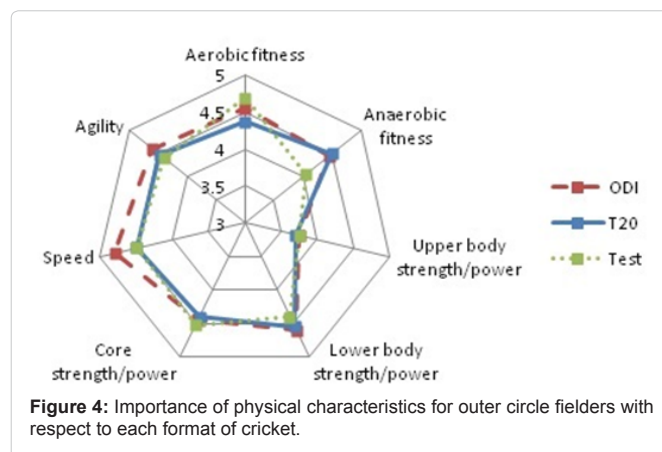


Figure 4: Importance of physical characteristics for outer circle fielders with respect to each format of cricket.

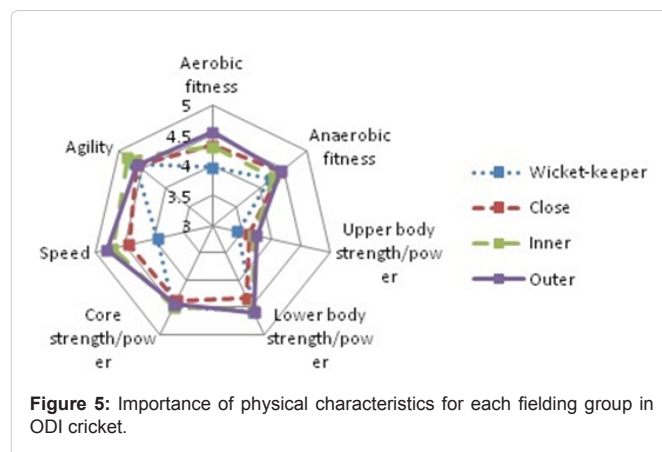


Figure 5: Importance of physical characteristics for each fielding group in ODI cricket.

athleticism for cricket fielding. Speed and aerobic fitness increased in importance as fielders move further out into the field and have greater distances to cover. While upper body strength/power was considered to be the least important physical attribute for all positions, it cannot be considered to be unimportant and does increase in importance as fielders move to the outfield. Throughout the survey, respondents suggested that low skin folds/leanness was beneficial for all fielding categories. This suggests that cricketers should be as lean as possible without compromising their speed or strength. For all positions, the importance of the mental component of performance was commented on. However, there was no mention made of how the mental aspects of performance could be quantified or assessed.

Of the total respondents, 20 identified themselves as some type of coach. In general, coaches agreed that there was distinct variability of the skills required to field at different positions, but highlighted the importance of players possessing as many of the skills and qualities as possible. In the coaches' only section of the survey, coaches were asked about the methods they use to test different aspects of physical fitness. Coaches generally all used a yoyo/beep intermittent recovery test to measure aerobic fitness. There was less agreement between the tests used for measuring anaerobic fitness; several coaches reported that they used repeated sprint tests but there was also mention of the Wingate test, 'strength and flexibility tests' (with no further elaboration). A variety of one Repetition Maximum (1RM) tests were reportedly used to assess the lower body (squats, counter-movement jumps, dead lifts) and upper body strength/power (push ups, bench

press, prone pull ups) respectively. Core strength/ power was generally assessed with planks, lumbar pelvic control testing, one coach also mentioned that he made sure to include some sort of rotational test also. Speed was generally assessed over a variety of distances ranging from 5 to 30 metres. The 505 and T-agility tests were reportedly used to assess agility; however in particular, responses highlighted the lack of a valid cricket specific fielding agility test. Generally the same physical tests were used to assess all players, with little to no differentiation between fielding positions.

Conclusions

The results provided insight into the factors which coaches and players believed were important attributes for each fielding category for each format of the game. Agility emerged as the most important physical characteristics for wicket-keepers, close and inner circle fielders, and the second most important attribute for outer circle fielders behind speed. However, no attributes were given an importance value of less than three on the Likert scale, suggesting that none can be considered unimportant for any fielding category.

Several emergent themes recurred throughout the survey including the importance of specific techniques and movement patterns, anthropometric characteristics and mental factors. The importance of mental factors on performance was emphasized repeatedly, particularly for the wicket-keeper and close fielders. This information provides insight into some of the demands associated with wicket-keeping and fielding. The findings of this survey can provide good indicators for the assessment of players' suitability for different positions, for the development of training programmes, and could be of assistance to coaches in selection of players and in providing guidance to the players. The information also highlights some areas that may require further research.

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