The contribution of certain physical and motor ability parameters to the match performance of provincial academy cricket batsmen

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FOREWORD

I would like to take this opportunity to thank a few exceedingly special people for all their assistance and support during the last few years. To my **parents** thank you for your love, interest and support throughout my time at University. To my big brother **Donovan,** I want to thank you for always being there for me, you really are the greatest brother and friend anyone can wish for. To my supervisor, **Ben Coetzee**, thank you for all your guidance, fatherly advice, time and effort during this study and my years at the institute. Your knowledge and hard work is truly an inspiration to me. It is truly a privilege to have spent these last few years under your guidance and I can only hope to someday have the same influence in someone's life, as you have had in mine. For that, I thank you.

My dearest **Siobhain**, thank you for all your love, care and encouragement throughout my years at University. The Lord truly blessed me when I met you and I look forward to having you by my side as a companion and best friend in the future. I will always love you. **Cindy**, you are such an amazing and special person. There are simply no words to describe how much I value and cherish your friendship. **Veronica**, thank you for always bringing a smile to my face and for the amazing friendship we have shared, may it last forever. To the **Sport science honours students** of 2004 and 2005, thank you all for your hard work and dedication during the collection of my data. A special word of thanks to **Heinrich** "my batting partner", you may not know it but you inspired me to want to achieve more in life and for that I thank you.

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The financial assistance of the National Research Foundation (NRF) towards this research is hereby acknowledged. Opinions expressed and conclusions arrived at are those of the author(s) and are not necessarily to be attributed to the National Research Foundation.

To my **Saviour, Lord Jesus Christ**, thank you for the strength and devotion you instil in me. Without you in my life, I am insignificant.

"Faith in God is the sole answer to the mystery of evil. This year is going to be tough, situations hard to understand and the minds of others somewhat confusing. Be tough, and have Faith."

John 5:24:

"Most *assuredly, I say to you, he who hears my Word and believes in Him who sent Me has everlasting life, and shall not come into judgment, but has passed from death into life."*

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DECLARATION

The co-author of the two articles which form part of this dissertation, Mr. Ben Coetzee (Supervisor), hereby gives permission to the candidate, Mr. Terence Nunes to include the two articles as part of a Masters dissertation. The contribution (advisory and supportive) of the co-author was within reasonable limits, thereby enabling the candidate to submit this dissertation for examination purposes. This dissertation, therefore, serves as partial fulfilment of the requirements for the M.Sc. degree in Sport Science within the School of Biokinetics, Recreation and Sport Science in the Faculty of Health Sciences at the North-West University (Potchefstroom Campus).

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Mr. B. Coetzee

Supervisor en co-author

ABSTRACT

The contribution of certain physical and motor ability parameters to the match performance of provincial academy cricket batsmen

Cricket has evolved from a traditional and conservative sport to a fast-paced, vigorous game. As a result of this the physical conditioning programmes of players have changed drastically with regular fitness tests that are now an integral part of these programmes. In spite of this, no studies have made an attempt to determine the exact relationship between the physical and motor ability parameters of batsmen and their performance. The purpose of this study was, therefore, firstly to determine which physical and motor ability parameters discriminate between successful and less successful provincial academy batsmen and secondly, to determine how much these parameters contribute to the batting performance of provincial academy batsmen.

Twenty-two batsmen from the Gauteng and North-West cricket academies in South Africa were used in this study. Thirteen batsmen (20.15 ± 1.41 years) participated during the 2004 season whilst nine batsmen (21.11 ± 1.83 years) took part during the 2005 season. The players were subjected to 23 physical and motor ability tests, whilst 72 isokinetic measurements were also taken. The data was analysed by means of descriptive statistics, cluster analyses, forward stepwise discriminant analyses and finally forward stepwise multiple regression analyses.

The discriminant analyses showed that right (RKEPT) and left knee extensor peak torque (LKEPT), right knee extensor average power (RKEAP), left knee extensor total work (LKETW) and left knee flexor peak torque (LKFPT) (all at 30°/sec), as well as LKEPT, RKEPT and LKEAP (all at 240°/sec), left (LIRAP) and right shoulder internal rotator average power (RIRAP), right shoulder external/internal rotator peak torque ratio (REIRPTR) and right shoulder internal rotator peak torque (RIRPT) (all at 240°/sec) as well as left shoulder internal rotator total work (LIRTW) (60°/sec) discriminated non-significantly between the successful (top 5 ranked batsmen of both seasons) and less successful academy batsmen. The physical and motor ability parameters which were identified as discriminators were left 505 agility, shuttle run aerobic endurance and 1RM (repetition-maximum) hack squat strength (all significant) ($p \leq 0.05$) whilst left grip strength and *abdominal muscle strength discriminated non-significantly. The forward stepwise multiple regression analyses indicated that RKEPT 30° (16%), LKEPT 30° (7%), RKEAP 30° (7%), LKFPT 30° (7%), LKEAP 240° (6%), RKFPT 240° (5%), LKETW 30° (5%) and LKEPT 240° (4%) were the isokinetic knee strength parameters which contributed non-significantly to batting performance. The isokinetic shoulder strength parameters which also contributed non-significantly to batting performance were: RIRPT 240° (28%), LIRAP 240° (16%), REIRPTR 240° (8%), LIRTW 60° (5%) and RIRAP 240° (4%). Vertical jumping power (13%) ($p \leq 0.05$), left 505 agility (9%) ($p \leq 0.05$), abdominal muscle strength (5%) ($p \leq 0.05$), aerobic capacity (10%), 1RM bench press strength (7%), 1RM hack squat strength as well as left shoulder internal rotation flexibility (4% each) were the physical and motor ability parameters which contributed to batting performance. The conclusion that can, therefore, be drawn is that physical and motor ability parameters contribute to the performance of provincial academy batsmen and that these components should be included in the physical conditioning programmes of batsmen.*

Key Words: *cricket, physical parameters, motor ability, isokinetic, batsmen, batting*

OPSOMMING

Die bydrae van sekere fisieke en motoriese parameters tot die wedstryd-prestasies van provinsiale, akademie krieket-kolwers

Krieket het ontwikkel vanaf 'n tradisionele en konserwatiewe sport na 'n vinnige-tempo en lewenskragtige-tipe spel. As gevolg hiervan het die fisieke kondisioneringsprogramme van spelers drasties verander met gereelde fiksheidstoetse wat nou 'n integrale deel van die programme vorm. Ten spyte hiervan, blyk dit dat geen studie 'n poging aangewend het om die spesifieke verband tussen die fisieke en motoriese parameters van kolwers en hul prestasies te bepaal nie. Die doelwitte van die studie was dus om ten eerste te bepaal watter fisieke en motoriese parameters diskrimineer tussen suksesvolle en minder suksesvolle provinsiale, akademie kolwers en tweedens om te bepaal hoeveel die parameters bydrae tot die prestasies van provinsiale, akademie kolwers.

Twee-en-twintig kolwers van Gauteng en die Noordwes Krieketakademies in Suid-Afrika is in die studies gebruik. Dertien kolwers (20.15 ± 1.41 jaar) het gedurende die 2004-seisoen aan die studie deelgeneem terwyl nege kolwers (21.11 ± 1.83 jaar) gedurende 2005 deelgeneem het. Die spelers is aan 23 fisieke en motoriese toetse onderwerp, terwyl 72 isokinetiese metings geneem is. Die data is geanaliseer deur middel van beskrywende statistiek, trosontleding-analises, voorwaartse stapsgewyse diskriminant- sowel as meervoudige regressie-analises.

Die diskriminantanalises het getoon dat regter (RKEPW) en linker knie-ekstensor piek wringkrag (LKEPW), regter knie-ektensor gemiddelde eksplosiewe krag (RKEGE), linker knie-ekstensor totale werk (LKETW) en linker knie-fleksor piek wringkrag (LKFPW) (alles teen 30°/sek), sowel as LKEPW, RKEPW en LKEGE (alles teen 240°/sek), linker (LIRGE) en regter skouer interne rotator gemiddelde eksplosiewe krag (RIRGE), regter skouer eksterne/interne rotator piek wringkragratio (REIRPWR) en regter skouer interne rotator piek wringkrag (RIRPW) (alles teen 240°/sek) sowel as linker skouer interne rotator totale werk (LIRTW) (60°/sek) nie-betekenisvol gediskrimineer het tussen suksesvolle (5 hooggeplaasde kolwers van beide seisoene) en minder suksesvolle kolwers. Die fisieke en motoriese parameters wat as diskriminators geïdentifiseer is, was linker 505-ratsheid, wisselloop aërobiese uithouvermoë en 1RM (repetisie-maksimum) hack squat krag (alles betekenisvol) ($p \leq 0.05$) terwyl linker greepkrag en abdominale spierkrag nie-betekenisvol gediskrimineer het. Die voorwaartse, stapsgewyse meervoudige regressie-analises het aangedui dat RKEPW 30° (16%), LKEPW 30° (7%), RKEGE 30° (7%), LKFPW 30° (7%), LKEGE 240° (6%), RKFPW 240° (5%), LKETW 30° (5%) en LKEPW 240° (4%) die isokinetiese kniekrag parameters is wat nie-betekenisvol bygedrae het tot kolfprestasies. Die isokinetiese skouerkrag parameters wat ook nie-betekenisvol tot kolfprestasie bygedrae het, was: RIRPW 240° (28%), LIRGE 240° (16%), REIRPWR 240° (8%), LIRTW 60° (5%) en RIRGE 240° (4%). Vertikale sprong-eksplosiewe krag (13%) ($p \leq 0.05$), linker 505-ratsheid (9%) ($p \leq 0.05$), abdominale spierkrag (5%) ($p \leq 0.05$), aërobiese kapasiteit (10%), 1RM bench press krag (7%), 1RM hack squat krag sowel as linker-skouer-interne rotasie soepelheid (4% elk) was die fisieke en motoriese parameters wat bygedrae het tot kolfprestasies. Die gevolgtrekking wat dus gemaak kan word, is dat die fisieke en motoriese komponente in die fisieke kondisioneringsprogramme van kolwers ingesluit behoort te word.

Sleutelwoorde: krieket, fisieke parameters, motoriese vermoëns, isokinetiese, kolwers, kolf.

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LIST OF ABBREVIATIONS

LFPT	Left Flexor Peak Torque
LFTW	Left Flexor Total Work
LFAP	Left Flexor Average Power
LEPT	Left Extensor Peak Torque
LETW	Left Extensor Total Work
LEAP	Left Extensor Average Power
RFPT	Right Flexor Peak Torque
RFTW	Right Flexor Total Work
RFAP	Right Flexor Average Power
REPT	Right Extensor Peak Torque
RETW	Right Extensor Total Work
REAP	Right Extensor Average Power
LFEPTR	Left Flexor/Extensor Peak Torque Ratio
LFETWR	Left Flexor/Extensor Total Work Ratio
LFEAPR	Left Flexor/Extensor Average Power Ratio
RFEPTR	Right Flexor/Extensor Peak Torque Ratio
RFETWR	Right Flexor/Extensor Total Work Ratio
RFEAPR	Right Flexor/Extensor Average Power Ratio
LERPT	Left External Rotator Peak Torque
LERTW	Left External Rotator Total Work
LERAP	Left External Rotator Average Power
LIRPT	Left Internal Rotator Peak Torque
LIRTW	Left Internal Rotator Total Work
LIRAP	Left Internal Rotator Average Power
RERPT	Right External Rotator Peak Torque
RERTW	Right External Rotator Total Work
RERAP	Right External Rotator Average Power
RIRPT	Right Internal Rotator Peak Torque
RIRTW	Right Internal Rotator Total Work
RIRAP	Right Internal Rotator Average Power
LEIRPTR	Left External/Internal Rotator Peak Torque Ratio

LEIRTWR	Left External/Internal Rotator Total Work Ratio
LEIRAPR	Left External/Internal Rotator Average Power Ratio
REIRPTR	Right External/Internal Rotator Peak Torque Ratio
REIRTWR	Right External/Internal Rotator Total Work Ratio
REIRAPR	Right External/Internal Rotator Average Power Ratio
m	Meter
km	Kilometer
km/h	Kilometer Per Hour
1RM	One Repetition Maximum
°	Degrees
sec	Seconds
$\leq$	Smaller than or equal to
n	Number
$\overline{x}$	Average
±	Plus-minus
SD	Standard Deviation
%	Percentage
r	Reliability
cm	Centimeter
kg	Kilogram
min	Minutes
ml	Milliliter

CHAPTER 1

Problem statement and purposes of the study

1. PROBLEM STATEMENT

During the last ten years cricket has diverged into a game of immense proportions and evolved from a traditional and conservative sport to a professional game that requires high fitness and skill levels (Bourden *et al.*, 2000:238). A further feature of the modern game is that one-day games are now an integral part of most programmes, demanding fast scoring rates, quick over rates and field restrictions that force players to field athletically in a variety of positions (Bourden *et al.*, 2000:238). These factors have all given rise to an alteration in the way that cricket players prepare for matches. Regular fitness testings is now an integral part of most cricket squads' preparation (Bourden *et al.*, 2000:238). It is in light of this trend that there has been an increase in the amount of published studies and books that deal with the types of tests and protocols that should be used in the evaluation of cricket players (Bourden *et al.*, 1998:4; 2000:238). The physical and motor ability parameters of batsmen are, however, a research area that has not received much attention during the last few years. The available research findings concerning the different aspects of batsmen will, however, be highlighted in the subsequent section to gain a clearer understanding of the nature, importance and contribution of certain physical and motor ability parameters to the performance of provincial cricket players.

Stretch *et al.* (2000:932) indicated that batsmen cover an average distance of ± 20 m for every run that is taken, and then have an active recovery period of roughly 30 seconds during which time the bowler walks back to his bowling mark for the next delivery. Batsmen will, therefore, primarily depend on the phosphate system for energy delivery during the run-taking activity (Stretch *et al.*, 2000:932). The aerobic energy system will deliver most of the energy during the active recovery phase between deliveries (Hawley & Burke, 1998:58; Stretch *et al.*, 2000:932). The fitness requirements of batsmen are accentuated when the estimated physical activity of a batsman during a one-day cricket match is brought to light. Noakes and Durandt (2000:926) estimated that a batsman who scores 100 runs in a one-day match would hypothetically have to run a total distance (during run-taking) of 3.2 km in an approximate time of 8 minutes. The overall running speed during these run-taking periods will, therefore, have to be 24 km/h (Noakes & Durandt, 2000:926). The demands that are placed on the aerobic and anaerobic energy systems are, therefore, quite substantial.

From the above-mentioned it also seems that speed between the wickets is an essential prerequisite for a batsman who wants to perform in one-day cricket. This contention is confirmed by Stretch *et al.* (2000:932) who are of the opinion that batsmen need speed to run successfully between the wickets whilst padded up. A factor that has, however, been established as a major determinant of sprinting speed among a wide range of athletes, is isokinetic knee extensor/flexor peak torque (Dowson *et al.*, 1998:257: Newman *et al.*, 2004:867) with the highest correlations being reported for the relationships between short sprint distances (0-15 m) and relative peak knee extension torque. Research evidence also suggests that leg muscle strength may assist batsmen to lower the centre of mass and increase the stability of the body so that shots like the front-foot drive can be played while remaining completely balanced (Hay & Reid, 1988:8). The fact that Noakes and Durandt (2000:928) stated that batsman require a substantial amount of muscle strength to cope with repeated continuous eccentric muscle contractions, further supports the notion that strength is indeed an important determinant. On the other hand, Stretch *et al.* (2000:942) argue that higher grip strength is not likely to increase the power of attacking shots, but is required to maintain the centripetal forces generated in the execution of cricket shots.

Isokinetic knee extensor/flexor average power and total work may also play a significant role in the ability of the batsmen to score runs fast and continuously. Batsmen will probably also require a large amount of leg muscle endurance because of the long time period that they stand in one position while batting. Furthermore, a biomechanical analysis of batting has shown that the pendulum movements of the upper limbs, as well as rotating at the shoulder, elbow and wrist joints all give rise to the subsequent peaking of the linear speed of the segment end-points and resulting bat speed (Stretch *et al.*, 1998:718). From an anatomical point of view, biomechanical shot analysis such as the last-mentioned, seem to indicate that the deltoid, shoulder rotator cuff muscles and humerus rotator muscles of batsmen all play a vital role in the execution of certain cricket shots. The importance of muscle strength in the last-mentioned areas can, therefore, not be taken lightly.

The execution of power related activities is also dependant on the level of muscle flexibility in the exercising area. In this regard Wilson *et al.* (1992:116) demonstrated that flexible muscles have a more beneficial effect on the stretch shortening cycle type of activities. Flexible muscles may also help to decrease the risk of musculoskeletal injuries (Cross & Worrell, 1999:13; Hantig & Henderson, 1999:173), lead to an increase in joints' range of movements (Roberts & Wilson, 1996:260) and from the study of Wilson *et al.* (1992:116), play a role in the amount of power that will be generated during the batting action.

The above-mentioned research seems to suggest that cricket batsmen need a certain physiological make-up to achieve high performance levels in cricket batting. In this regard, Noakes and Durandt (2000:921) conclude that physiological factors play an immense role in the long-term success that a cricket player will achieve.

In spite of the evidence that a strong link exists between certain physical (which includes the isokinetic strength variables) and motor ability measures and cricket batting performance, to the researchers' knowledge no studies have made an attempt to establish the exact link between the stated variables and batting performance. It is against this research background and lack of research that the following research questions are posed: Firstly, which of the isokinetic knee and shoulder strength parameters discriminate between successful and less successful provincial academy cricket batsmen? Secondly, how much do the isokinetic knee and shoulder strength parameters contribute to the performance of provincial academy cricket batsmen? Thirdly, which of the physical and motor ability parameters discriminate between successful and less successful provincial academy cricket batsmen? Fourthly, how much do the physical and motor ability parameters contribute to the performance of provincial academy cricket batsmen? Answers to these questions ought to provide coaches, sport scientists and other sport related professionals with direction concerning the parameters that have the biggest influence on cricket performance.

2. OBJECTIVES

The objectives of this study are:

- To determine which of the isokinetic knee and shoulder strength parameters discriminate between successful and less successful provincial academy cricket batsmen.
- To determine how much the isokinetic knee and shoulder strength parameters contribute to the performance of provincial academy cricket batsmen.
- To determine which physical and motor ability parameters discriminate between successful and less successful provincial academy cricket batsmen.
- To determine how much the physical and motor ability parameters contribute to the performance of provincial academy cricket batsmen.

3. HYPOTHESES

The study is based on the following hypotheses:

- The identified isokinetic knee and shoulder strength parameters will discriminate between successful and less successful provincial academy cricket batsmen.
- Certain of the identified isokinetic knee and shoulder strength parameters will contribute significantly ($p \leq 0.05$) to the performance of provincial academy cricket batsmen.
- The identified physical and motor ability parameters will discriminate between successful and less successful provincial academy cricket batsmen.
- Certain of the identified physical and motor ability parameters will contribute significantly ($p \leq 0.05$) to the performance of provincial academy cricket batsmen.

4. STRUCTURE OF THE DISSERTATION

The dissertation is submitted in article format as approved by the Senate of the North-West University and is structured as follows:

Chapter 1: Problem statement, hypotheses and objectives of the study. A source list is provided at the end of the chapter according to the prescriptions of the North-West University.

Chapter 2: Article 1 – The contribution of isokinetic parameters to the performance of provincial academy cricket batsmen. The article will be presented for publication in

The journal of isokinetics and exercise science. A source list is presented at the end of the chapter according to the prescriptions of the journal. Although not according to the prescriptions of the journal, tables and figures will be included within the text so as to make the article easier to read and understand.

Chapter 3: Article 2 – The contribution of physical and motor ability parameters to the performance of provincial academy cricket batsmen. The article will be presented for publication in The journal of human movement studies. A source list is presented at the end of the chapter according to the prescriptions of the journal. Although not according to the prescriptions of the journal, tables and figures will be included within the text so as to make the article easier to read and understand.

Chapter 4: Summary, conclusions and recommendations.

Chapter 5: Appendix – the demographic, general information questionnaires, informed consent forms, physical and motor ability data collection forms as well as the instructions for authors are attached as addendums.

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CHAPTER 2

The contribution of isokinetic strength parameters to the performance of provincial academy cricket batsmen

The contribution of isokinetic strength parameters to the performance of provincial academy cricket batsmen

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ABSTRACT

The purposes of this study were firstly, to determine which of the isokinetic knee and shoulder strength parameters discriminate between successful and less successful provincial academy cricket batsmen and secondly, to determine the contribution of isokinetic knee and shoulder strength parameters to the performance of provincial academy cricket batsmen. Twenty-two contracted batsmen (20.63 ± 1.62 years) from the Gauteng and North-West Cricket Academies in South Africa were tested during the 2004 and 2005 seasons. The forward stepwise discriminant analyses showed that right (RKEPT) and left knee extensor peak torque (LKEPT), right knee extensor average power (RKEAP), left knee extensor total work (LKETW) and left knee flexor peak torque (LKFPT) (all at 30°/sec), as well as LKEPT, RKEPT and LKEAP (all at 240°/sec), left (LIRAP) and right internal rotator average power (RIRAP), right external/internal rotator peak torque ratio (REIRPTR) and right internal rotator peak torque (RIRPT) (all at 240°/sec) as well as left internal rotator total work (60^0/sec) discriminated non-significantly between the successful (top 5 ranked batsmen of both seasons) and less successful academy batsmen. The forward, stepwise multiple regression analyses showed that RKEPT 30° (16%), LKEPT 30° (7%), RKEAP 30° (7%), LKFPT 30° (7%), LKEAP 240° (6%), RKFPT 240° (5%), LKETW 30° (5%) and LKEPT 240° (4%) were the isokinetic knee strength parameters which contributed non-significantly to batting performance. The isokinetic shoulder strength parameters which also contributed non-significantly to batting performance were: RIRPT 240° (28%), LIRAP 240° (16%), REIRPTR 240° (8%), LIRTW 60° (5%) and RIRAP 240° (4%). The conclusion that can, therefore, be drawn is that isokinetic knee and shoulder strength parameters contribute to the performance of provincial academy cricket batsmen and that these components should be included in the talent identification protocols for young promising batsmen.

[**Keywords:** cricket, isokinetic parameters, motor ability parameters, batsmen, batting]

The contribution of isokinetic parameters to the performance of provincial academy cricket batsmen

INTRODUCTION

During the last ten years cricket has diverged into a game of immense proportions and evolved from a traditional and conservative sport to a professional game that requires very high fitness and skill levels [4]. A further feature of the modern game is that one-day games are now an integral part of most competitions, demanding fast scoring rates, quick over rates and field restrictions that force players to field athletically in a variety of positions [4]. These factors have all given rise to an alteration in the way that cricket players prepare for matches, including regular fitness testings which usually consist of various flexibility, speed, agility, strength, anaerobic and aerobic power tests [4].

One of the testing methods by which sport related professionals evaluate athletes' muscle strength is the use of isokinetic dynamometry [5, 30]. Although various studies have been done regarding the effect of isokinetic strength on the performance of various sports such as volleyball [27], soccer [20] and swimming [15], to the researchers' knowledge no such studies have been conducted on cricket players. It is, however, important that isokinetic testing forms part of cricket players' testing protocols due to the fact that it provides valuable information that may be used for performance enhancement [7]. In this regard, Davies et al. [7] stated that isolated isokinetic testing allows sport related professionals to identify pre-existing muscle weaknesses and imbalances that can be addressed in strength and conditioning programmes.

Analysis of cricket clearly shows that muscle strength is a prerequisite for batsmen, bowlers and fielders who want to achieve success in the one-day cricket format [19]. A study in which the muscle strength of all these groups of players are examined, would however, be too comprehensive for the purpose of this study and it is in the light of this problem that it was decided to focus on the muscle strength of batsmen. In order to gain a clearer understanding of the importance and contribution of muscle strength to the performance of batsmen, the next section will be dedicated to literature that has investigated this relationship.

The physical performance parameters of batsmen is a research area that has not received as much attention as that of bowlers during the last few years. The research that does, however, exist shows that batsmen need a high degree of speed to run successfully between the wickets whilst padded up [26]. A factor that has been established as a major determinant of sprinting performance among a wide range of athletes, is isokinetic knee extensor/flexor peak torque [9, 18]. The highest correlations were reported for the relationships between short sprint distances (0–15m) and relative peak knee extension torque [9, 18]. As such, isokinetic knee extensor/flexor strength can be regarded as a crucial component for running between the wickets during a one-day game. Researchers have further provided evidence supporting a link between muscle strength endurance and one-day cricket performance. Noakes and Durandt [19], for example, estimated that a batsman who scores 100 runs in a one-day match would hypothetically have to run a total distance (during run-taking) of 3.2 km in an approximate time of 8 minutes. Therefore, it is apparent that variables such as isokinetic knee extensor/flexor average power and total work can possibly also play a significant role in the ability of batsmen to score runs fast and continuously. Noakes and Durandt [19] further noted that batsman require a substantial amount of muscle strength to cope with repeated continuous eccentric muscle contractions that occur during a cricket match.

According to Hay and Reid [11] the batting action itself also depends on isokinetic leg muscle strength. These authors presented evidence that flexion of the front knee during front-foot shots allows the batsmen to lower the centre of mass and increase the stability of the body which in turn assists the batsmen to remain completely balanced while playing forceful shots. It is, therefore, safe to assume that extension of the front knee, during back-foot shots, will allow the batsmen to do the same.

Unfortunately, no studies could be found that have researched the influence of upper body strength values on the hitting ability and power of batsmen. Its importance, however, cannot be underestimated as the pendulum movements of the front upper limbs, as well as the rotating actions of the shoulder, elbow and wrist joints all give rise to the consequent peaking of the linear speed of the segment end-points and resulting bat speed [25]. In a technical analysis of the hook shot Bob Woolmer, former South African coach, showed that a player must step back on his toes so as to maintain balance and power, turn his shoulders, roll the wrists as the bat swings across the body and extend his arms to their fullest to make full contact with the ball [29]. From an anatomical point of view, cricket shot analyzes such as the last-mentioned indicate that a batsman's deltoid, shoulder rotator cuff muscles (supraspinatus, subscapularis, teres minor and infraspinatus), humerus rotator muscles (pectoralis major, lattisimus dorsi, teres major) all play a vital role in the execution of certain cricket shots. The importance of muscle strength in the last-mentioned areas can, therefore, not be taken lightly.

It is against the background of a lack of research concerning the link between isokinetic strength measures and batting cricket performance that this study was undertaken. Therefore, the purpose of this study was two-fold. Firstly, to determine which of the isokinetic knee and shoulder strength parameters discriminate between successful and less successful provincial academy cricket batsmen. Secondly, to determine the contribution of isokinetic knee and shoulder strength parameters to the performance of provincial academy cricket batsmen. Information that arises from this study may provide important knowledge to sport professionals with regard to the exact link between different isokinetic muscle strength measures and on-field cricket performance. It can also help professionals to develop and refine their training programmes and testing protocols.

METHOD OF RESEARCH

Research Design

The design of the study was a cross-sectional experimental design. Information was obtained by means of a questionnaire and a test battery. The objectives of the study were explained to the players, after which they all completed an informed consent form. The study was approved by the Ethics Committee of the North-West University (05M12).

Test Subjects

The subjects consisted of two groups of batsmen that were tested over a period of the 2004 and 2005 cricket seasons respectively. Thirteen contracted batsmen (20.15 ± 1.41 years) from the Gauteng and North West Cricket Academies in South Africa were tested during the 2004 season and nine contracted batsmen (21.11 ± 1.83 years) during the 2005 season. The subjects were expected to perform as they would in a match situation. The average batting scores of each season were used to rank the players for each season. The top 5 ranked batsmen for both seasons were classified as the successful batsmen.

Research Procedures

a. Demographic and general information questionnaire

The player's demographic and personal information (race and age) were collected by means of a demographic and general information questionnaire. The player's exercising habits, injury incidence and competing level were also determined by means of this questionnaire. The isokinetic performance data was collected through a set protocol.

b. Isokinetic muscle strength components

The Cybex II Dynamometer was used to measure isokinetic concentric knee extension and flexion as well as shoulder internal and external rotation strength. The procedures of Mayer et al. [16] were used to measure shoulder internal and external strength and that of Pääsuke et al. [21] to measure knee extension and flexion torque. Each subject was subjected to a warm-up so that he could be prepared for the main set and familiarize himself with the testing procedures. During the warm-up and familiarization period, each subject was instructed to perform five repetitions at a moderate velocity of 180°/second followed by a 30 second resting period, after which another two repetitions were performed at 30°/second or 60°/second, depending on the body part that was tested. A resting period of 60 seconds followed before the commencement of the main set during which six repetitions were performed at 30°/second for knee extension/flexion and 60°/second for shoulder internal/external rotation followed by 120 seconds rest and finally the completion of 30 repetitions at 240°/second for both the knee and shoulder. The relative peak torque, total work, average power and agonist-antagonist muscle ratios for each of the above-mentioned body movements were recorded.

Statistical procedures

The Statistical Consultation Service of the North-West University determined the statistical methods and procedures for the analyses of the research data. The Statistical Data Processing package [24] was used to process the data. The descriptive statistics (average and standard deviation values) of each test variable of the different research populations were calculated first. This was followed by cluster analyses of the different isokinetic strength variables which were used to detect clusters of measures that appear to tap similar abilities. The linkage distance for the detection of different clusters was set at 60 and 40 by the researchers for the knee and shoulder respectively.

In another step, a forward step-wise discriminant analysis was performed to calculate the variables that discriminate the most between the successful and less successful academy batsmen. Lastly, forward step-wise multiple regression analyses provided the researchers with answers regarding the isokinetic strength variables that have the biggest contribution in predicting batting performance. The level of significance was set at $p \leq 0.05$.

RESULTS AND DISCUSSION

The descriptive statistics of the batsmen's isokinetic concentric knee extension and flexion as well as shoulder internal and external rotation results are presented in Tables 1 and 2 respectively.

Table 1: Descriptive statistics of the academy cricket batsmen's relative isokinetic knee extension and flexion strength results (N = 22)

	Season 1 Batsmen (N = 13)		Season 2 Batsmen (N = 9)	
Testing speed = 30°/sec				
Variables (% of body weight)	$\overline{X}$	**SD**	$\overline{X}$	**SD**
Left Flexor Peak Torque (LFPT)	184.28	34.64	193.50	49.53
Left Flexor Total Work (LFTW)	201.06	57.69	203.33	46.00
Left Flexor Average Power (LFAP)	60.65	12.77	73.74	23.39
Left Extensor Peak Torque (LEPT)	221.53	37.90	268.36	63.06
Left Extensor Total Work (LETW)	249.81	51.50	290.21	57.16
Left Extensor Average Power (LEAP)	72.55	14.15	103.22	34.51
Right Flexor Peak Torque (RFPT)	178.68	40.08	171.04	20.57
Right Flexor Total Work (RFTW)	194.89	47.28	190.96	26.70
Right Flexor Average Power (RFAP)	57.68	14.60	67.03	21.09
Right Extensor Peak Torque (REPT)	240.56	41.36	262.93	36.62
Right Extensor Total Work (RETW)	259.49	44.54	270.26	26.96
Right Extensor Average Power (REAP)	76.45	13.39	97.50	30.08
Left Flexor/Extensor Peak Torque Ratio (LFEPTR)	84.38	12.42	72.16	11.13
Left Flexor/Extensor Total Work Ratio (LFETWR)	80.87	12.48	70.32	12.27
Left Flexor/Extensor Average Power Ratio (LFEAPR)	83.59	12.78	72.33	10.21
Right Flexor/Extensor Peak Torque Ratio (RFEPTR)	73.56	13.77	65.46	6.98
Right Flexor/Extensor Total Work Ratio (RFETWR)	74.39	12.57	71.06	10.06
Right Flexor/Extensor Average Power Ratio (RFEAPR)	74.38	14.72	69.42	8.72
Testing speed = 240°/sec				
Left Flexor Peak Torque (LFPT)	98.43	27.85	95.41	34.43
Left Flexor Total Work (LFTW)	110.92	39.07	98.73	38.72
Left Flexor Average Power (LFAP)	202.55	67.66	193.60	82.68
Left Extensor Peak Torque (LEPT)	126.15	39.68	137.73	44.22
Left Extensor Total Work (LETW)	144.47	52.36	144.72	51.51
Left Extensor Average Power (LEAP)	266.88	96.40	289.68	114.06
Right Flexor Peak Torque (RFPT)	98.13	26.20	99.58	18.02
Right Flexor Total Work (RFTW)	107.15	27.76	108.22	20.07
Right Flexor Average Power (RFAP)	203.36	42.83	204.40	36.12
Right Extensor Peak Torque (REPT)	136.51	37.45	126.28	25.61
Right Extensor Total Work (RETW)	151.00	39.27	128.23	29.23
Right Extensor Average Power (REAP)	284.21	83.20	249.27	63.64

Table 1: Descriptive statistics of the academy cricket batsmen's relative isokinetic knee extension and flexion strength results (N = 22) (cont.)

	Season 1 Batsmen (N = 13)		Season 2 Batsmen (N = 9)	
Testing speed = 240°/sec				
Variables (% of body weight)	$\overline{X}$	**SD**	$\overline{X}$	**SD**
Left Flexor/Extensor Peak Torque Ratio (LFEPTR)	81.09	19.38	72.57	11.80
Left Flexor/Extensor Total Work Ratio (LFETWR)	80.02	20.86	71.49	12.43
Left Flexor/Extensor Average Power Ratio (LFEAPR)	80.80	23.14	69.77	14.09
Right Flexor/Extensor Peak Torque Ratio (RFEPTR)	74.64	11.59	81.10	12.40
Right Flexor/Extensor Total Work Ratio (RFETWR)	72.65	10.04	87.91	16.48
Right Flexor/Extensor Average Power Ratio (RFEAPR)	71.98	10.02	84.98	15.68

$\overline{X}$ = Average SD = Standard Deviation

Table 2: Descriptive statistics of the academy cricket batsmen's relative isokinetic shoulder internal and external rotation strength results (N = 22)

	Season 1 Batsmen (N = 13)		Season 2 Batsmen (N = 9)	
Testing speed = 60°/sec				
Variables (% of body weight)	$\overline{X}$	**SD**	$\overline{X}$	**SD**
Left External Rotator Peak Torque (LERPT)	42.46	11.87	41.76	12.13
Left External Rotator Total Work (LERTW)	53.17	17.23	48.17	14.18
Left External Rotator Average Power (LERAP)	25.48	9.00	24.96	8.40
Left Internal Rotator Peak Torque (LIRPT)	75.59	14.23	68.82	12.78
Left Internal Rotator Total Work (LIRTW)	114.87	19.98	102.80	17.45
Left Internal Rotator Average Power (LIRAP)	54.13	11.66	51.50	10.79
Right External Rotator Peak Torque (RERPT)	38.72	14.69	40.89	12.76
Right External Rotator Total Work (RERTW)	49.80	17.97	44.78	14.72
Right External Rotator Average Power (RERAP)	23.87	9.74	22.94	7.38
Right Internal Rotator Peak Torque (RIRPT)	76.82	16.87	79.01	8.89
Right Internal Rotator Total Work (RIRTW)	118.18	26.40	119.19	17.67
Right Internal Rotator Average Power (RIRAP)	54.45	12.41	59.78	7.63
Left External/Internal Rotator Peak Torque Ratio (LEIRPTR)	59.27	12.46	59.08	13.94
Left External/Internal Rotator Total Work Ratio (LEIRTWR)	46.42	12.92	46.68	8.95
Left External/Internal Rotator Average Power Ratio (LEIRAPR)	46.78	15.28	47.26	11.28
Right External/Internal Rotator Peak Torque Ratio (REIRPTR)	50.05	12.16	49.94	14.35
Right External/Internal Rotator Total Work Ratio (REIRTWR)	44.51	11.93	38.31	10.28
Right External/Internal Rotator Average Power Ratio (REIRAPR)	44.64	11.86	37.93	10.42
Testing speed = 240°/sec				
Left External Rotator Peak Torque (LERPT)	33.32	6.45	29.70	6.50
Left External Rotator Total Work (LERTW)	31.81	7.66	27.33	7.15
Left External Rotator Average Power (LERAP)	43.22	18.32	34.01	16.35
Left Internal Rotator Peak Torque (LIRPT)	50.53	11.13	46.20	7.81
Left Internal Rotator Total Work (LIRTW)	71.19	18.41	59.67	17.78
Left Internal Rotator Average Power (LIRAP)	101.05	27.25	84.38	34.11
Right External Rotator Peak Torque (RERPT)	30.05	7.97	29.26	3.53
Right External Rotator Total Work (RERTW)	29.78	10.78	25.52	4.03
Right External Rotator Average Power (RERAP)	37.89	19.99	32.00	8.61
Right Internal Rotator Peak Torque (RIRPT)	54.85	16.76	52.16	9.04
Right Internal Rotator Total Work (RIRTW)	79.45	27.71	70.41	17.73
Right Internal Rotator Average Power (RIRAP)	116.55	40.99	108.91	22.93
Left External/Internal Rotator Peak Torque Ratio (LEIRPTR)	65.45	12.14	64.41	12.67
Left External/Internal Rotator Total Work Ratio (LEIRTWR)	47.62	15.28	49.30	18.55
Left External/Internal Rotator Average Power Ratio (LEIRAPR)	44.76	21.82	42.73	23.28
Right External/Internal Rotator Peak Torque Ratio (REIRPTR)	55.82	10.80	57.28	7.52

Table 2: Descriptive statistics of the academy cricket batsmen's relative isokinetic shoulder internal and external rotation strength results (N = 22) (cont.)

	Season 1 Batsmen (N = 13)		Season 2 Batsmen (N = 9)	
Testing speed = 240°/sec				
Variables (% of body weight)	$\overline{X}$	SD	$\overline{X}$	SD
Right External/Internal Rotator Total Work Ratio (REIRTWR)	39.04	9.54	37.51	5.89
Right External/Internal Rotator Average Power Ratio (REIRAPR)	34.29	13.16	30.76	7.85

$\overline{X}$ = Average SD = Standard Deviation

In an attempt to first identify variables that relate to each other and to retain only the relevant variables for the discriminant analysis, a cluster analysis was performed. The isokinetic strength variables for the knee extension and flexion were reduced from 36 to 16 strength variables by means of the cluster analysis. The isokinetic knee flexion and extension strength variables that remained were: REPT, LEPT, REAP, LETW, LFPT, LFTW, RFPT and RETW (all at 30°/sec), as well as LEPT, RFPT, LEAP, LFAP, RFAP, REPT, REAP and RFEPTR (all at 240°/sec). In a subsequent step, a forward stepwise discriminant analysis was performed to determine which of the cluster analysis' reduced relative isokinetic knee extension/flexion strength variables discriminate between the successful (top 5 ranked batsmen of both seasons) and less successful academy batsmen respectively. The discriminant analysis' results of the isokinetic knee extension and flexion strength variables are firstly presented together with the discussion of these results. Table 3 contains the last-mentioned analysis' results.

Table 3: Results of the forward step-wise discriminant analysis performed on the relative isokinetic knee extension/flexion strength variables of the batsmen (N = 22)

Variables (% of body weight)	F value	P level
REPT 30°	3.84	0.0643
LEPT 240°	1.06	0.3170
LEPT 30°	1.72	0.2065
RFPT 240°	1.16	0.2965
LEAP 240°	1.52	0.2354
REAP 30°	2.00	0.1773
LETW 30°	1.55	0.2335
LFPT 30°	2.22	0.1601

Eight variables were identified as the primary isokinetic knee flexion/extension strength variables that are responsible for the difference between the two groups of batsmen, which included the following: REPT, LEPT, REAP, LETW and LFPT (all at 30°/sec), as well as LEPT, RFPT and LEAP (all at 240°/sec). None of the results were, however, significant. The results show that six of the discriminant analysis' identified variables are isokinetic quadriceps strength related variables and two variables, isokinetic hamstring strength related variables. According to current knowledge, no researchers have made an attempt to determine the relationship between isokinetic strength and batting performance, which makes it difficult to compare these results to that of other researchers. The results of the lower body isokinetic results do, however, indicate that the relative peak torque of both the left and right quadriceps of batsmen seem to be an important discriminator between successful and less successful batsmen. Several authors have concluded that a significant inverse relationship exists between peak isokinetic concentric torque generated by the knee extensor muscles and sprinting performance over short (0–15m, 30–35m) [9] and long distances (100m) [1]. For a sporting activity, such as one-day cricket, it is essential that a batsman must be able to increase running velocity rapidly (acceleration) over short distances such as the pitch length (17.68m). According to Cronin and Hansen [6], athletes who achieve maximum speed earlier or possess greater acceleration will have an obvious advantage. The study of Dowson et al. [9] also suggests that the strongest relationship exists between peak torque during concentric knee extension at a high velocity (240°/sec) and sprint performance. Research has furthermore shown that an increase in the hip flexor (quadriceps) strength may increase leg speed during the hip flexion phase due to a greater use of the stretch-shortening cycle in the hip extensor muscles during the hip extension phase [3]. Some researchers also posit that batsmen require substantial muscle strength to reduce the extent of muscle damage that is induced in the repeated decelerations that occur when turning during batting [19].

The results in Table 3 show further that right flexor peak torque at 240°/sec is also an important discriminator of better batting performance. Again, authors have found a direct relationship between 40-yard dash times for male college athletes and peak concentric hamstring force measured at slower speeds (60°/sec) [2]. In addition, Dowson et al. [9] also observed significant but weak correlations for most knee-flexion measures and short sprint distances (0–15m, 30–35m). However, in male sprinters, it seems that the hip flexor strength (quadriceps) rather than the hip extensor strength (hamstrings) is what limits sprinting performance [3]. It is, therefore, possible that the same applies for the batsmen who want to have the ability to sprint at high speeds when taking runs during a cricket match.

A muscle endurance related isokinetic strength variable which was also identified as a discriminator of successful and less successful batsmen is total work of the left quadriceps. The testing speed at which the last-mentioned variable was measured was 30°/sec. Relative average power of the left quadriceps was the only discriminant analysis' identified measurement that was obtained at a higher speed of 240°/sec. The data, therefore, shows that muscle endurance of the quadriceps is an important variable for discriminating between batsmen of different performance levels. Batsmen must have the ability to perform activities repeatedly such as run taking near a maximal level with limited rest between bouts of activities, which might explain the need for good muscle endurance. According to Noakes and Durandt [19] a batsmen must be able to score runs at a speed of approximately 24 km/h when scoring 100 runs in a one-day cricket game. Based on this contention, it is clear that a player who has more muscle endurance will be able to maintain a high speed when running between the wickets.

It can also be postulated that batsmen require a large amount of quadriceps muscle endurance because of the fact that they have to spend much time standing in one position. During the batting stance, for example, the knees have to be flexed slightly in order to maintain the correct position. In this regard the findings of Hsu et al. [12] suggest that electromyographical activity of the quadriceps correlates directly with the knee angle of flexion ($r = 0.88$). This would imply that the quadricep muscles must be able to generate force continuously to enable the batsman to maintain the correct batting position.

As part of the purpose of the study a further analysis was performed during which prediction functions that would be able to discriminate between batsmen of different performance levels were compiled. The following functions emerged:

Successful batsmen = 0.2007 (REPT30°) - 0.5980 (LEPT240°) + 0.0481 (LEPT30°) + 0.2908 (RFPT240°) + 0.1452 (LEAP240°) - 0.2142 (REAP30°) + 0.1542 (LETW30°) - 0.0322 (LFPT30°) - 43.1126

Less successful batsmen = 0.1353 (REPT30°) - 0.2246 (LEPT240°) + 0.0408 (LEPT30°) + 0.1712 (RFPT240°) + 0.0353 (LEAP240°) - 0.0284 (REAP30°) + 0.0415 (LETW30°) + 0.0348 (LFPT30°) - 27.0050

The results of the classification matrix show that the prediction functions are 90.91% accurate in classifying the groups of batsmen into their respective groups. Hence, the finding that the isokinetic strength variables which are included in the prediction functions are indeed accurate discriminators of academy batsmen of different performance levels. The results of the classification matrix are presented in Table 4.

Table 4: The classification matrix of the successful and less successful batsmen with regards to the relative isokinetic knee extension/flexion strength variables to indicate what percentage of the batsmen can be classified into their respective groups through the use of the two prediction functions (N = 22)

Group	Correct Percentage	Group 1	Group 2
Group 1: Successful Batsmen	80.00	4	1
Group 2: Less Successful Batsmen	94.12	1	16
Total	90.91	5	17

In the next step a forward stepwise multiple regression analysis was performed to determine the contribution of each of the cluster analysis' reduced isokinetic knee extension and flexion strength variables to the ranking of the batsmen. The results of the last-mentioned analysis are presented in Table 5.

Table 5: Results of the forward step-wise multiple regression analysis to determine the relative knee extension/flexion strength variables which contribute the most to the ranking of the batsmen (N = 22)

Variables (% of body weight)	Beta In	Multiple R	Multiple R-square	R-square change	P-level
REPT 30°	-0.50	0.40	0.16	0.16	0.0643
LEPT 240°	2.90	0.45	0.21	0.04	0.3170
LEPT 30°	-0.07	0.52	0.27	0.07	0.2065
RFPT 240°	-0.52	0.57	0.32	0.05	0.2965
LEAP 240°	-2.12	0.62	0.38	0.06	0.2354
REAP 30°	0.83	0.67	0.45	0.07	0.1773
LETW 30°	-1.20	0.71	0.51	0.05	0.2335
LFPT 30°	0.52	0.76	0.58	0.07	0.1601

The percentage contribution of the isokinetic knee extension and flexion strength variables to the ranking of the batsmen as was calculated by means of the r-square change is graphically presented in Figure 1.

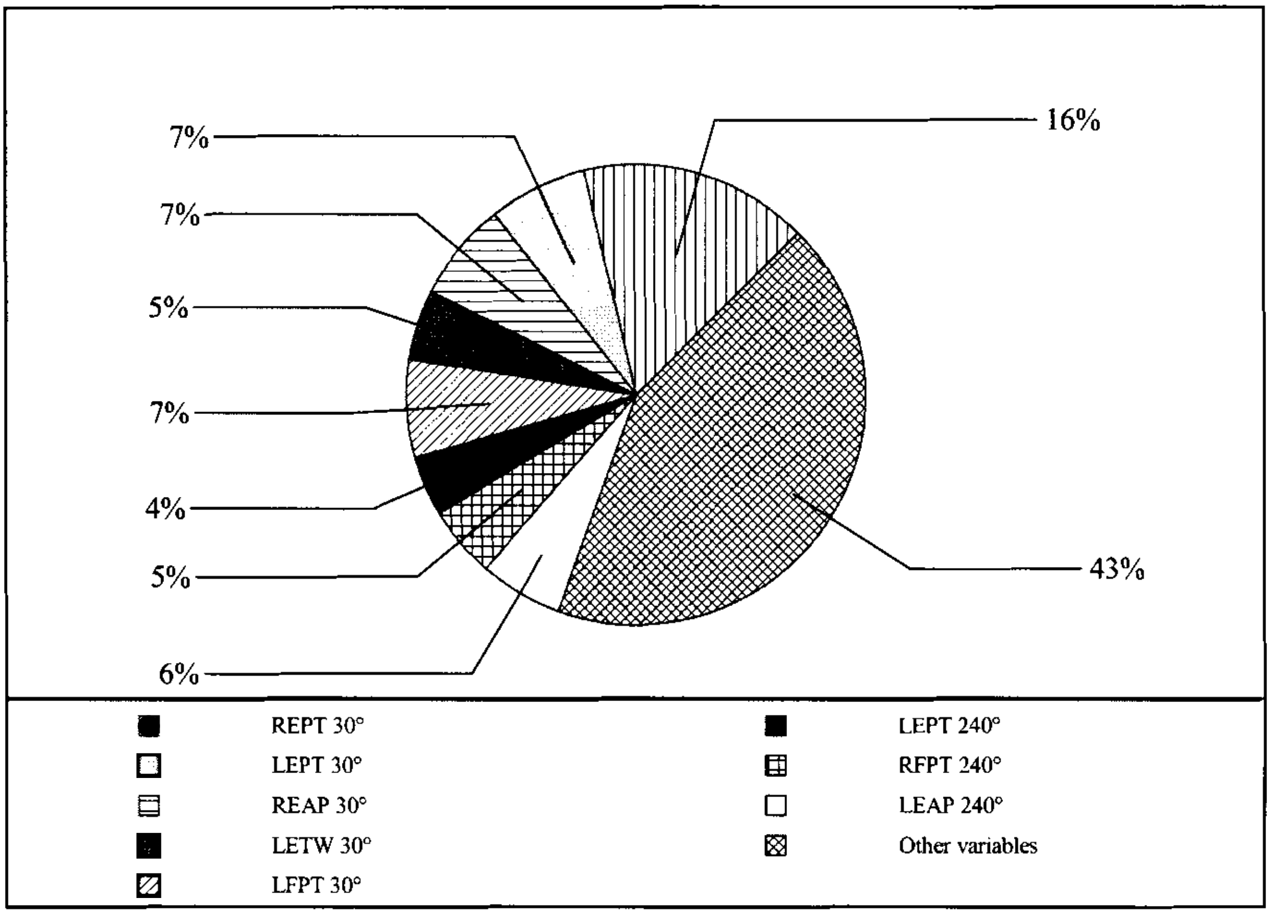

Figure 1: Percentage contribution of the most important relative isokinetic knee extension/flexion strength variables to the ranking of the batsmen (N = 22)

According to these results the ranking that was achieved by the batsmen was mostly influenced by REPT at 30°/sec (16%). The second, third, fourth, fifth, sixth, seventh and eighth most contributing isokinetic strength variables were LEPT, LFPT as well as REAP at 30°/sec (7% each), LEAP at 240°/sec (6%), LETW at 30°/sec and RFPT at 240°/sec (5% each) and lastly LEPT (4%). Overall the results show that knee extensor peak torque, average power and total work, which are all indicators of quadriceps strength and strength endurance, are the isokinetic variables which have a prediction power of 45% in predicting the batting performance (ranking) of the batsmen. The knee flexor related variables, which are associated with hamstring strength, have a prediction power of 12%. Possible reasons for the inverse relationships between REPT at 30°/sec, LEPT at 30°/sec, RFPT at 240°/sec, LEAP at 240°/sec and LETW at 240°/sec and batting performance ranking have already been provided in the earlier discussion. Positive correlations were found with the relative peak torque values of the left hamstring and the right quadriceps at speeds of 30°/sec and 240°/sec respectively, which means that the batsmen with lower peak torque values in these scores will have a higher ranking order. It is difficult to explain these findings, although similar results were found in Farrar and Thorland's study [10] who reported some non-significant, positive correlations between isokinetic knee extension and flexion peak torque measures (60°/sec and 300°/sec) and sprint performance. High variability in the different values between the batsmen might have influenced the multiple regression results negatively. For instance; the individual relative peak torque values of the left hamstring at a speed of 30°/sec varied between 114.10% (minimum) and 276.30% (maximum) with a standard deviation of 40.52%.

The relative average power of the right quadriceps at 30°/sec was the only muscle endurance related isokinetic variable which obtained a positive correlation with ranking. Once again, this implies that batsmen with a lower average power in the right quadriceps will have a higher ranking order. This finding is difficult to explain although it can possibly again be attributed to the large variations between the values of the different batsmen. The multiple regression analysis showed further that the ranking of the batsmen was more influenced by the isokinetic knee extension/flexion strength variables (57%) compared to other variables (43%). From the literature it is clear that there are many other variables which play a role in determining batting performance. In this regard, Stretch et al. [26] proved that speed and grip strength are characteristics of better batsmen. In other studies, investigators found that co-ordination as well as anthropometric composition are also important performance determinants of batsmen [23, 8]. These findings seem to suggest that factors other than the isokinetic knee extension/flexion strength variables in this study contribute to the variance in the academy batsmen's rankings.

From this point, the focus was turned to the results of the isokinetic shoulder internal and external rotation strength variables. Again, a cluster analysis was used to identify and eliminate the isokinetic strength variables which correlate with each other. Of the 36 shoulder related isokinetic variables, only 16 variables remained after the cluster analysis was conducted. These included the following: LIRTW, LERPT, LERAP, RIRPT and RIRTW (all at 60°/sec), as well as LIRAP, REIRPTR, RIRAP, RIRPT, LERAP, LIRPT, LIRTW, RERPT, RIRTW, LEIRPTR and LEIRAPR (all at 240°/sec). In the following step, the cluster analysis' reduced isokinetic shoulder related strength variables which discriminate between the successful (top 5 ranked batsmen of both seasons) and less successful academy batsmen respectively were identified. The forward stepwise discriminant analysis' results of the isokinetic shoulder internal and external rotation strength variables are presented together with the discussion of these results. The results of the forward stepwise discriminant analysis are presented in Table 6.

Table 6: Results of the forward step-wise discriminant analysis performed on the relative isokinetic shoulder internal/external rotation strength variables of the batsmen (N = 22)

Variables (% of body weight)	F value	P level
LIRAP 240°	3.70	0.8440
REIRPTR 240°	1.88	0.7680
RIRAP 240°	1.06	0.7253
RIRPT 240°	10.40	0.4500
LIRTW 60°	1.88	0.4027

The results of the discriminant analysis seem to indicate that only five isokinetic shoulder internal/external rotation strength variables served as statistically insignificant discriminators between the successful and less successful batsmen. They are: LIRAP, REIRPTR, RIRAP and RIRPT (all at 240°/sec) as well as LIRTW at 60°/sec. All of the identified variables were, however, related to the isokinetic shoulder internal rotator muscles. The speeds at which the identified variables were measured would also suggest that most of the discriminators (4 out of a possible 5) were obtained at faster limb speeds. The relationship between the isokinetic shoulder strength and the performance of batsmen has until now not received any attention from researchers. It is, therefore, not possible to compare the findings of this study to that of other studies.

Nonetheless, from a biomechanical and anatomical viewpoint, it is clear that the internal shoulder rotators are responsible for the movements of the shoulder during the execution of a wide range of cricket shots. Batting shots such as the hook, pull, cut and sweep shots will depend on the internal shoulder rotators of the right arm (in the case of right handed players) to generate peak bat velocity during ball impact. Based on the findings of Table 6 it is, however, apparent that the success of the batsmen is more related to their ability to generate high isokinetic internal shoulder rotator peak torque and average power scores of the dominant shoulder (RIRPT and RIRAP) at high movement speeds (240°/sec) than their ability to generate high peak torque scores at lower speeds. A possible explanation for this is that improvements in internal shoulder isokinetic strength will allow batsmen to generate higher bat velocities during the execution of the different cricket shots [14]. Due to the nature of a one-day cricket match, it can also be expected that shoulder muscle endurance will have a significant effect on the outcome of batsmen's batting scores as batsmen must be able to perform an array of different cricket shots continuously at a fast rate for the whole duration of a one-day match.

Mulligan et al. [17] recommended that the ratio of external to internal shoulder rotation should favour external rotation much more than internal rotation which would also lead to added stability in the glenohumeral joint. Furthermore, by increasing the external to internal shoulder ratio (ER/IR ratio), the risk of injury to the shoulder joint may possibly be prevented [17]. It is, therefore, reasonable to think that the batsmen with higher ER/IR ratios will have a lower risk for sustaining shoulder injuries and will probably be able to play more regularly and for longer periods. Moreover, it is also possible that batsmen who show higher ER/IR ratios will have more control over their cricket shots due to the greater glenohumeral joint stability. Additionally research showed that weak stabilizing around a joint will lead to inefficient length/tension relationships between the muscles that act as primary movers and that this could lead to interference with optimal firing patterns during rapid concentric and eccentric contractions that occur during different movements [13, 28]. This effect might inevitably hinder the batsmen's performance.

It is difficult to explain why LIRAP at 240° was identified as one of the biggest discriminators between the successful and less successful batsmen. The same applies to the result that LIRTW at 60° was also identified as a discriminator. These results could possibly be attributed to the backlift that is primarily performed by the front arm (which is the left arm in the case of right handed batsmen) just before the start of the downswing. Based on a kinematic analysis of the batting action by Stretch et al. [25], they concluded that the backlift for the attacking shots such as the drive was higher than for the defensive shots such as the forward defensive. They also found that the bat was not kept stationary at the top of the backlift during any stage of this action [25]. These findings have two implications. The first one is that the batsmen will probably use a higher backlift during attacking shots to generate more power by making use of the stretch-shortening-cycle (SSC). Concentric contractions of the internal shoulder rotators of the left arm are thus used to perform the high backlift and to keep the bat in position. The higher batlift just before the onset of the downswing leads to an eccentric contraction (stretching) of the shoulder external rotators, which in turn leads to the generation of force in the prestretched elements. The prestretched force is then added to the force of the concentric shoulder external rotator muscles so that the force of ball impact is increased. It can be expected that batsmen will probably make more use of attacking shots during one-day matches due to the required run rate that must be maintained. This will repeatedly put strain on the internal rotators of the left shoulder which may explain the need for higher left shoulder internal rotator muscle endurance.

The second implication is that batsmen must be able to hold the backswing for a short time to allow him to make final adjustments to the stroke-selection decision [26]. Batsmen who, therefore, do not have high levels of left shoulder rotator muscle endurance will probably make mistakes with regard to the selection of the right cricket shots due to an inability to hold the backswing for a short time.

As part of the purpose of the study a further analysis was performed during which prediction functions that would be able to discriminate between batsmen of different performance levels were compiled. The following functions emerged:

Successful batsmen = 0.2342 (LIRAP240°) + 1.6326 (RERIRPT240°) + 0.5266 (RIRAP240°) - 0.5104 (RIRPT240°) - 0.0025 (LIRTW60°) - 81.9642

Less successful batsmen = 0.2142 (LIRAP240°) + 1.4942 (RERIRPT240°) + 0.1750 (RIRAP240°) + 0.3486 (RIRPT240°) - 0.0914 (LIRTW60°) - 65.4640

The results of the classification matrix show that the prediction functions are 90.91% accurate in classifying the groups of batsmen into their respective groups. Hence, the finding that the isokinetic strength variables which are included in the prediction functions are indeed accurate discriminators of academy batsmen of different performance levels. The results of the classification matrix are presented in Table 7.

Table 7: The classification matrix of the successful and less successful batsmen with regards to the relative isokinetic shoulder internal/external rotation strength variables to indicate what percentage of the batsmen can be classified into their respective groups through the use of the two prediction functions (N = 22)

Group	Correct Percentage	Group 1	Group 2
Group 1: Successful Batsmen	80.00	4	1
Group 2: Less Successful Batsmen	94.12	1	16
Total	90.91	5	17

In the next step, a forward stepwise multiple regression analysis was performed to determine the contribution of each of the cluster analysis' reduced isokinetic shoulder internal and external rotation strength variables to the ranking of the batsmen. The results of the last-mentioned analysis are presented in Table 8.

Table 8: Results of the forward step-wise multiple regression analysis to determine the relative shoulder internal/external rotation strength variables which contribute the most to the ranking of the batsmen (N = 22)

Variables (% of body weight)	Beta In	Multiple R	Multiple R-square	R-square change	P-level
LIRAP 240°	-0.11	0.39	0.16	0.16	0.8440
REIRPTR 240°	-0.24	0.48	0.23	0.08	0.7680
RIRAP 240°	-2.19	0.52	0.27	0.04	0.7253
RIRPT 240°	2.17	0.74	0.55	0.28	0.4500
LIRTW 60°	-0.31	0.77	0.60	0.05	0.4027

The percentage contribution of the isokinetic shoulder internal and external rotation strength variables to the ranking of the batsmen, as was calculated by means of the r-square change, is graphically presented in Figure 2.

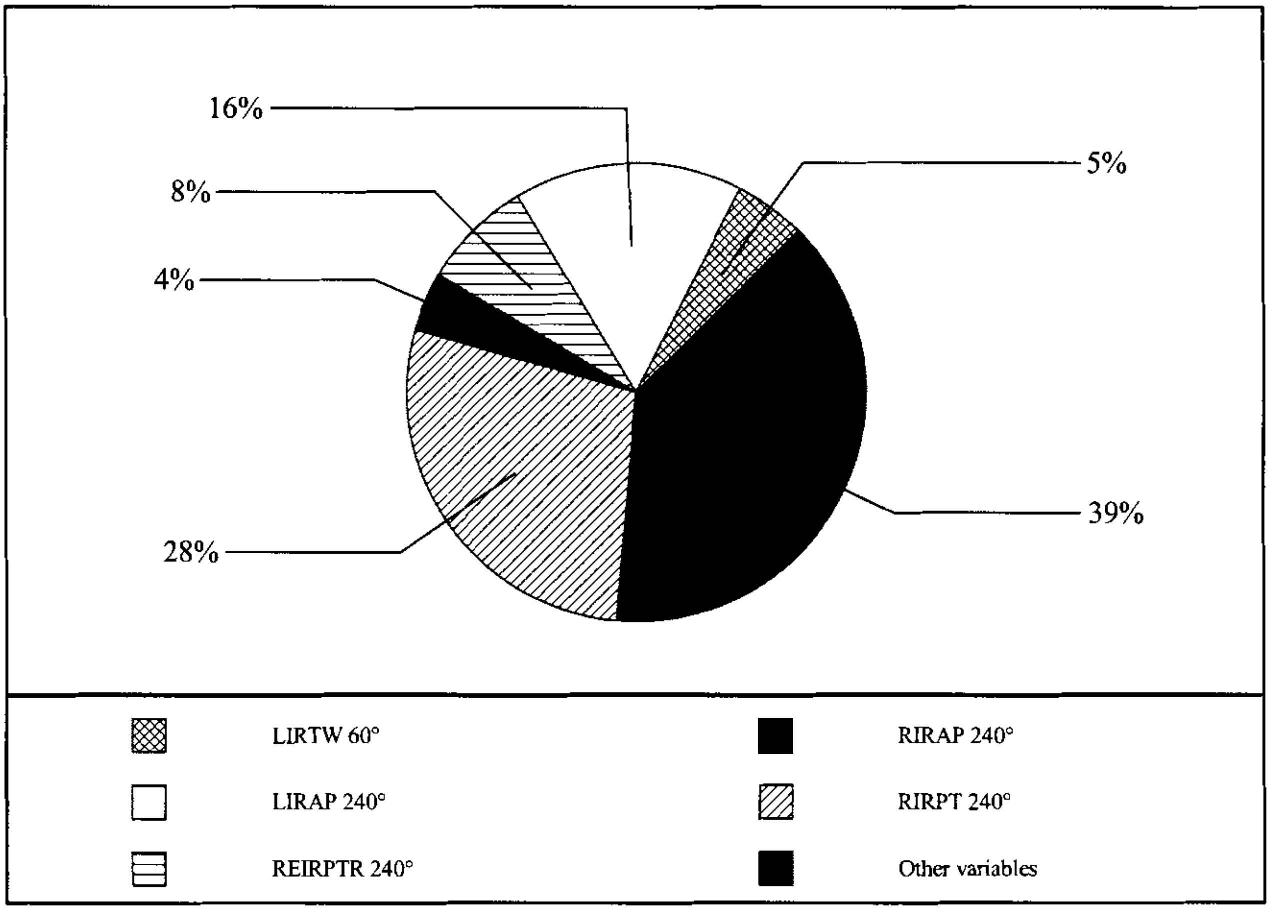

Figure 2: Percentage contribution of the most important relative isokinetic shoulder internal/external rotation strength variables to the ranking of the batsmen (N = 22)

According to these results the ranking that was achieved by the batsmen was mostly influenced by RIRPT at 240°/sec (28%). The second, third, fourth and fifth most contributing isokinetic variables were LIRAP at 240°/sec (16%), REIRPTR at 240°/sec (8%), LIRTW at 60°/sec (5%)

and lastly RIRAP at 240°/sec (4%). Four out of the possible five variables (LIRAP at 240°/sec, REIRPTR at 240°/sec, RIRAP at 240°/sec and LIRTW at 60°/sec) displayed inverse relationships with ranking. Explanations for these relationships were already provided in the discussion of the discriminant analysis. A somewhat unexpected outcome of the forward stepwise multiple regression analysis was the result that a positive relationship existed between ranking and the batsmen's RIRPT at 240°/sec. This would imply that batsmen who displayed lower RIRPT values at 240°/sec would be ranked higher according to their batting performances. The fact that the successful batsmen seem to be more fatigue resistant (higher RIRAP at 240°/sec and LIRTW at 60°/sec), which may be the direct consequence of the generation of lower maximal (peak) muscle force (torque) during a prolonged period of time [22], could possibly explain the unexpected result. The results of the multiple regression analysis revealed that the ranking of the batsmen, in comparison to other variables (39%), was influenced more by the isokinetic shoulder internal/external rotation strength variables (61%). As previously mentioned, the literature has presented evidence that there are many other variables which play a role in batting performance.

CONCLUSIONS

In conclusion, the study first revealed that REPT, LEPT, REAP, LETW and LEPT (all at 30°/sec), LEPT, RFPT, LEAP, LIRAP, REIRPTR, RIRAP, RIRPT (all at 240°/sec) as well as LIRTW (60°/sec) were the isokinetic knee and shoulder strength parameters that discriminated accurately (90.91%) between successful and less successful academy cricket batsmen. However, it should be noted that none of the isokinetic parameters contributed significantly ($p \leq 0.05$) to the separation between the successful and less successful groups of batsmen.

Secondly, the isokinetic knee extension/flexion strength variables which emerged as the biggest contributors (57%) to the performances of provincial academy cricket batsmen were in order of contribution: REPT 30° (16%), LEPT 30°, LFPT 30°, and REAP 30° (7% each), LEAP 240° (6%), LETW 30° and RFPT 240° (5% each) as well as LEPT (4%). The results also showed that RIRPT 240° (28%), LIRAP 240° (16%), REIRPTR 240° (8%), LIRTW 60° (5%) and RIRAP 240° (4%) were the isokinetic shoulder internal/external rotation strength variables which contributed to the performances (61%) of the provincial academy cricket batsmen. These results do, however, suggest that factors other than the isokinetic strength variables in this study also contribute substantially to the variance (43% and 39%) in the cricket batsmen's performances. None of the isokinetic variables did, however, contribute significantly to the variance in batting performances.

Overall, the results of the present study emphasize the importance of isokinetic strength parameters to the performances of cricket batsmen. It can, therefore, be recommended that isokinetic knee and shoulder strength tests should be included in the sport scientific testing protocols of cricket batsmen due to its influence on batting performance.

Several shortcomings of this study should, however, be considered. Small group sizes in this study could have caused outliers to have influenced the mean values of the respective isokinetic strength scores more than would have been the case with larger group sizes. A much bigger sample size would, therefore, be advisable. Apart from this, only data of players distributed over a small geographical area in South Africa were utilized. Generalization of the results to the whole of South Africa would, therefore, not be accurate. The current study does, however, provide a basis for further research where these types of analyses are done.

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CHAPTER 3

The contribution of physical and motor ability parameters to the performance of provincial academy cricket batsmen

THE CONTRIBUTION OF PHYSICAL AND MOTOR ABILITY PARAMETERS TO THE PERFORMANCE OF PROVINCIAL ACADEMY CRICKET BATSMEN

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THE CONTRIBUTION OF PHYSICAL AND MOTOR ABILITY PARAMETERS TO THE PERFORMANCE OF PROVINCIAL ACADEMY CRICKET BATSMEN

SUMMARY

The purpose of this study was firstly, to determine which of the physical and motor ability parameters discriminate between successful and less successful provincial academy cricket batsmen and secondly, to determine the contribution of physical and motor ability parameters to the performance of provincial academy cricket batsmen. Twenty-two contracted batsmen (20.63 ± 1.62 years) from the Gauteng and North-West Cricket Academies in South Africa were tested during the 2004 and 2005 seasons. A comprehensive battery of 13 physical and motor performance tests was performed by each subject. The cluster analyses reduced the amount of test variables (23) to only 10. The proceeding forward discriminant analysis showed that left 505 agility, shuttle run aerobic endurance and 1RM hack squat strength discriminated significantly ($p \leq 0.05$) between the successful (top 5 ranked batsmen of both seasons) and less successful academy batsmen, whilst left grip strength and abdominal muscle strength discriminated non-significantly. The forward stepwise multiple regression analyses showed that vertical jumping power (13%), left 505 agility (9%) and abdominal muscle strength (5%) were the physical and motor ability parameters which contributed significantly to batting performance. The physical and motor ability parameters which contributed non-significantly to batting performance were aerobic capacity (10%), 1RM bench press strength (7%), 1RM hack squat strength as well as left shoulder internal rotation flexibility (4% each). The conclusion that can, therefore, be drawn is that physical and motor ability parameters contribute to the performance of provincial academy cricket batsmen and that these components should be included in the physical conditioning programmes of batsmen.

Keywords: cricket, physical parameters, motor ability parameters, batsmen, batting]

INTRODUCTION

For the last century, cricket has been regarded as a traditional and conservative sport, but during the past decade it has transformed into a professional game which competes to attract a more global audience (Noakes and Durandt, 2000). As a result of this and the appearance of the one-day cricket match format which demands high scoring rates, rapid over rates and more athletic fielding, batting and bowling due to field restrictions (Bourden et al, 2000), cricketers are now exposed to much greater physical demands than a few years ago. The format of players' physical preparation programmes has also changed with regular fitness testing which normally consists of various flexibility, speed, agility, strength, anaerobic and aerobic power tests that have now become an integral part of these programmes (Bourden et al, 2000).

In spite of an increase in the physical demands that are placed on modern-day cricket players and the changes in the physical preparation programmes, very few studies (Gibson and Adams, 1989; Regan, 1997) have focused on the physical and motor ability parameters of cricket batsmen. The research that does, however, exist with regards to the physical and motor ability parameters of batsmen will be highlighted in the next section to gain a clearer understanding of the nature, importance and contribution of these parameters to the performance of cricket batsmen.

A good cricket innings during a one-day cricket match can last several hours and will involve that a batsman must run the length of the pitch (17.68 m) for each run that is scored (except for boundaries) while wearing protective equipment such as pads and a helmet (Stretch et al, 2000). Batsmen are, therefore, required to repeat short sprints which do not normally last more than 10 sec by depending primarily on the anaerobic, phosphate energy system (Noakes and Durandt, 2000; Janssen et al, 2001). This is normally followed by a recovery period of roughly 30 sec during which time the bowler walks back to his bowling mark for the next delivery. During this recovery period the body will primarily rely on the aerobic energy system to recuperate and replenish the phosphate stores in preparation for the next bout of intensive activities (Hawley and Burke, 1998; Stretch et al, 2000). Occasionally energy supplies are needed for periods of between 10 and 20 sec when batsmen decide to take more than one run at a time (Payne et al, 1986). In these cases the muscles will be fuelled mainly by the anaerobic glycolysis energy system. The fitness requirements of batsmen are further accentuated when the estimated peak physical activity of a batsman during a one-day cricket match is calculated.

Noakes and Durandt (2000) estimated that a batsman who scores 100 runs in a one-day match would hypothetically have to run a total distance (during run-taking) of 3.2 km in an approximate time of 8 min. The overall running speed during the run-taking periods will, therefore, have to be 24 km/h (Noakes and Durandt, 2000). The demands that are placed on the aerobic and anaerobic energy systems are, therefore, substantial especially in view of the fact that the player must also participate in a vigorous fielding session after conclusion of the batting innings.

Moreover, from the literature (Jamison, 1994) and the above-mentioned it is also clear that speed between the wickets is an essential prerequisite for batsmen who want to perform in one-day cricket. Jamison (1994) also suggested that batsmen must have the ability to change body position and direction quickly when turning during run-taking. Agility is, therefore, also a speed related variable that is crucial for batsmen. Speed and agility can, however, be influenced to a large extent by a player's strength and power (Duthie et al, 2003). Noakes and Durandt (2000) also posit that batsman require a substantial amount of muscle strength to reduce the extent of muscle damage that is induced in the repeated decelerations and continuous eccentric muscle contractions that occur when turning during batting. According to Stretch et al (2000), a particularly strong grip is not likely to add power to the cricket shot, but a strong grip will be essential to sustain the centripetal forces generated in the execution of attacking shots in cricket.

Furthermore, as has been stated before, batsmen must have the ability to repeatedly perform activities such as run-taking near a maximal level with limited rest between bouts of activities, which explains the need for good muscle endurance. It is clear that a player who has more muscle endurance will be able to maintain a high speed when running between the wickets. It can also be postulated that batsmen require a large amount of leg muscle endurance because of the long time period that they stand in one position. The knees are flexed slightly in order to maintain the correct batting position, which increases the load on the leg muscles such as the quadriceps (Hsu et al, 1993). This would imply that the upper leg muscles must be able to generate force continuously to enable the batsmen to maintain the correct batting stance.

The execution of power related activities such as run-taking and batting are also dependant on the level of muscle flexibility in the exercising area. In this regard Shrier (2004) demonstrated that the majority of research articles that have focused on the effects of regular stretching and flexibility movements (7 out of a possible 9) showed that flexibility improvements are beneficial (2-5%) to force, explosive power and speed development. In one of the research articles (Wilson et al, 1992) it is specifically shown that the maximal series elastic component stiffness of the muscle is reduced with an increase in muscle flexibility and the potential to store and release elastic strain to facilitate concentric muscle contractions increased.

It is against the background and the lack of research concerning the link between physical and motor ability measures and cricket performance that the study was undertaken. Therefore, the purpose of this study is two-fold. Firstly, to determine which physical and motor ability parameters discriminate between successful and less successful provincial academy cricket batsmen and secondly, to determine the contribution of certain physical and motor ability parameters to the performance of provincial academy cricket batsmen. Information that arises from this study may provide important knowledge to sport professionals with regard to the exact link between different physical and motor ability measures and on-field cricket performance. It may also help professionals to develop and refine their training programmes and testing protocols.

METHOD

Research design:

The design of the study was a cross-sectional experimental design. Information was obtained by means of a questionnaire and a test battery. The objectives of the study were explained to the players, after which they all completed an informed consent form. The study was approved by the Ethics Committee of the North-West University (05M12).

Test subjects:

The subjects consisted of two groups of batsmen that were tested over a period of the 2004 and 2005 cricket seasons respectively. Thirteen contracted batsmen (20.15 ± 1.41 years) from the Gauteng and North-West Cricket Academies in South Africa were tested during the 2004 season and nine contracted batsmen (21.11 ± 1.83 years) during the 2005 season. The subjects were expected to perform as they would in a match situation during the execution of different shots. The average batting scores of each season were used to rank the players for each season. The top 5 ranked batsmen for both seasons were classified as the successful batsmen.

Research procedures:

The players' demographic and personal information (race and age) were collected by means of a demographic and general information questionnaire. The exercising habits, injury incidence and competing levels were also determined by means of this questionnaire. The physical and motor ability data were collected through a set protocol.

Physical and motor ability components

The following components were evaluated by making use of the stated tests:

Hamstring and shoulder flexibility: As determined by the active knee extension test and the shoulder internal/external rotation test of Harvey and Mansfield (2000).

Leg explosive power: As determined by the vertical jump test as explained by Safrit (1990).

Abdominal muscle strength: As determined by the seven level abdominal muscle strength test of Ellis et al (2000).

Muscle strength: As determined by the One Repetition Maximum (1RM) Bench Press test of Ball (1991), the 1RM Incline Hack squat test (adapted from Gale, 1991) and the dynamometer-handgrip strength test of Wadsworth et al (1992).

Speed over 5 m, 10 m, 20 m and 40 m: As determined by the method of Tumilty (2000).

Agility: As determined by the 505 agility test of Ellis et al (2000) as well as a pitch run. In the last-mentioned test the players completed two trials of two runs on a standard pitch length in the fastest possible time, whilst wearing the normal match gear. Players had a two minute rest period between the two trials.

Speed endurance: As determined by the 5 m Multiple shuttle run test of Boddington et al (2001).

Aerobic endurance: As determined by the 20 m shuttle run test of the Australian Sports Commission (1998).

Statistical procedures:

The Statistical Consultation Service of the North-West University determined the statistical methods and procedures for the analyses of the research data. The Statistical Data Processing package (StatSoft Inc, 2005) was used to process the data. The descriptive statistics (average and standard deviation values) of each test variable of the different research populations were calculated first. This was followed by a cluster analysis of the different variables which was used to detect clusters of measures that appear to tap similar abilities. The linkage distance for the detection of different clusters was set at 60 by the researchers.

In another step a forward step-wise discriminant analysis was performed to determine the variables that discriminate the most between the successful (top 5 ranked) and less successful academy batsmen. The dependant variable was set as batsmen ranking during the execution of the discriminant analysis. Lastly, a forward step-wise multiple regression analysis provided the researchers with answers regarding the variables that have the biggest contribution in predicting average batting score. The level of significance was set at $p \leq 0.05$.

RESULTS AND DISCUSSION

The descriptive statistics of the batsmen's physical and motor ability results are presented in Table 1.

In an attempt to first identify variables that relate to each other and to retain only the relevant variables for the discriminant analysis, a cluster analysis was performed. The physical and motor ability variables were reduced from 23 to 10 variables by means of the cluster analysis. The physical and motor ability variables that remained were: left shoulder internal rotation flexibility, left shoulder external rotation flexibility, vertical jumping power, left grip strength, abdominal muscle strength, 1RM bench press strength, 1RM hack squat strength, left 505 agility, shuttle run aerobic endurance and lastly, aerobic capacity (bleep level-shuttle). In a subsequent step, a forward stepwise discriminant analysis was performed to determine which of the cluster analysis' reduced physical and motor ability variables discriminate between the successful (top 5 ranked batsmen of both seasons) and less successful academy batsmen, respectively. The discriminant analysis results of the physical and motor ability variables are presented in Table 2 followed by the discussion of these results.

TABLE 1: Descriptive statistics of the academy cricket batsmen's physical and motor ability results (n=22)

	Batsmen (season 1) (n=13)		Batsmen (season 2) (n=9)	
Variables	$\overline{X}$	SD	$\overline{X}$	SD
Left active knee extension flexibility (°)	93.62	8.48	92.61	12.59
Right active knee extension flexibility (°)	94.08	6.44	90.00	8.32
Left shoulder internal rotation flexibility (°)	68.42	17.25	72.28	13.61
Right shoulder internal rotation flexibility (°)	64.19	14.17	64.33	12.35
Left shoulder external rotation flexibility (°)	92.96	9.91	89.89	8.26
Right shoulder external rotation flexibility (°)	97.38	10.43	97.11	5.94
Vertical jumping power (cm)	50.12	8.93	53.13	6.86
Left grip strength (kg)	47.56	6.68	47.77	8.40
Right grip strength (kg)	49.07	6.88	48.04	8.62
Abdominal muscle strength (level)	4.54	2.11	4.89	1.62
1RM bench press strength (kg)	73.46	10.08	69.44	10.74
1RM hack squat strength (kg)	146.38	32.51	134.44	23.51
Speed over 5 m (sec)	1.18	0.22	1.31	0.08
Speed over 10 m (sec)	2.60	0.57	2.08	0.10
Speed over 20 m (sec)	3.31	0.31	3.34	0.09
Speed over 40 m (sec)	5.82	0.48	5.69	0.15
Left 505 agility (sec)	2.42	0.20	2.51	0.19
Right 505 agility (sec)	2.41	0.17	2.46	0.09
Left 505 agility with equipment (sec)	2.49	0.18	2.53	0.13
Right 505 agility with equipment (sec)	2.44	0.21	2.56	0.12
Agility pitch run (sec)	7.19	0.40	7.37	0.21
Shuttle run aerobic endurance (m)	753.46	33.06	734.72	31.63
Aerobic capacity (bleep level-shuttle)	12.26	1.07	10.90	1.14

$\overline{X}$ = Average; SD = Standard Deviation

TABLE 2: Results of the forward step-wise discriminant analysis performed on the physical and motor ability variables of the batsmen (n=22)

Variables	F value	P-level
Left 505 agility (sec)	3.35	0.0168*
Shuttle run aerobic endurance (m)	3.03	0.0460*
1RM hack squat strength (kg)	2.56	0.0341*
Left grip strength strength (kg)	2.96	0.0906
Abdominal muscle strength (level)	1.46	0.2437

*$p \leq 0.05$

Five variables were identified as the primary physical and motor ability variables that are responsible for the difference between the two groups of batsmen and included the following: left 505 agility, shuttle run aerobic endurance, 1RM hack squat strength, left grip strength and abdominal muscle strength. Only the first three stated variables did, however, achieve significant results ($p \leq 0.05$). The result that left 505 agility was identified as the biggest discriminator between the two groups of batsmen, is consistent with the statement of Jamison (1994) which suggests that running speed and agility are important components for batting success. Some literature sources hypothesize that a high level of agility would facilitate effective foot movements during batting and allow batsmen to start and stop as well as change direction quickly during run-taking (Fitness 4 cricket, 2006). It is difficult to explain the finding that left 505 agility was identified as a major discriminator as opposed to right 505 agility. The result could possibly be attributed to the way right-handed batsmen turn when they take more than one run. It can probably be expected that most batsmen will score the majority of their runs on the off-side, which will force right-handed batsmen to run with their bats in the left hand and turn with their left foot that leads. This will allow a batsman to view the activities of the fielders on the off-side area of the field.

Shuttle run aerobic endurance was the only endurance related variable which was identified as a significant discriminator between the two groups of batsmen. As stated before, the body primarily relies on the aerobic energy system to recover after the completion of high-intensity activities such as running between the wickets. The aerobic capacity of a player is, therefore, of crucial importance for any sport participant who wants to achieve success (Hawley and Burke, 1998). This contention was confirmed by the research of Hawley and Burke (1998) who found that the average indirect VO_2max value of the South African cricket team was 60.5 ml/kg/min.

The results in Table 2 further show that 1RM hack squat strength was also a significant discriminator of better batting performance. According to Delavier (2006), the movement of the hack squat puts primary emphasis on quadriceps' strength. It can be postulated that batsmen require a large amount of quadriceps muscle strength because of the fact that they have to spend a lot of time standing in the batting position. During the batting stance the knees have to be flexed slightly in order to maintain the correct position. In this regard the findings of Hsu et al (1993) suggest that electromyographical activity of the quadriceps correlates directly with the knee angle of flexion ($r = 0.88$). This would imply that the quadriceps muscles must be able to generate a high amount of force to enable the batsmen to maintain the correct batting position. Research has furthermore shown that an increase in the hip flexor (quadriceps) strength may increase leg speed during the hip flexion phase of, for instance, running due to a greater use of the stretch-shortening cycle in the hip extensor muscles during the hip extension phase (Blazevich and Jenkins, 1998). As mentioned before, some researchers also posit that batsmen require substantial muscle strength to reduce the extent of muscle damage that is induced in the repeated decelerations that occur when turning during batting (Noakes and Durandt, 2000).

The second strength related variable which was also identified as an important discriminator is grip strength. A plausible explanation may be that batsmen need a strong grip to sustain the rather large centripetal forces that are built up during the downswing and follow-through phases of attacking shots (Stretch et al, 2000). A strong grip will allow a batsman to extend greater control over his bat during different cricket shots which may result in greater consistency of stroke production (Stretch et al, 2000). The left hand in the case of right-handed batsmen is regarded as the dominant hand during shot execution which affirms the result that the left rather than the right hand grip strength is of importance.

The last strength related variable which also served as an important discriminator of batting performance was abdominal muscle strength. The abdominal muscles together with the adductors and abductors, the hip rotators and the gluteus muscle groups, as well as the lower back, hip flexors and extensors are all muscle groups that initiate, support and stabilize the various movements of the human body (Goldenberg and Twist, 2002). The importance of the strength of the abdominal muscles was emphasized by Bompa and Carrera (2005) who stated that various movements of the body which include trunk flexion, twisting, rotation, lateral bending and abdominal compression are all performed by the abdominal muscles and that they also help to fixate and stabilize the trunk so that the arms and legs can be used to perform an athletic task precisely and effectively. From a biomechanical and anatomical viewpoint, it is clear that batsmen will not be able to perform a vast array of cricket shots such as the hook, pull, cut, front foot drive or sweep shots if they are not able to move and fixate the trunk successfully.

As part of the purpose of the study a further analysis was performed during which prediction functions, that would be able to discriminate between batsmen of different performance levels, were compiled. The following functions emerged:

Successful batsmen = 413.24 (Left 505 agility) + 2.51 (Shuttle run aerobic endurance) - 0.60 (1RM Hack squat strength) + 3.23 (Left grip strength) + 9.96 (Abdominal muscle strength) - 1539.68

Less successful batsmen = 398.18 (Left 505 agility) + 2.44 (Shuttle run aerobic endurance) - 0.53 (1RM Hack squat strength) + 2.99 (Left grip strength) + 9.45 (Abdominal muscle strength) - 1443.24

The results of the classification matrix showed that the prediction functions are 90.91% accurate in classifying the groups of batsmen into their respective groups. Hence, the finding that the physical and motor ability variables which are included in the prediction functions are indeed accurate discriminators of academy batsmen of different performance levels. The results of the classification matrix are presented in Table 3.

TABLE 3: The classification matrix of the successful and less successful batsmen with regards to the physical and motor ability variables (n=22)

Group	Correct Percentage	Group 1	Group 2
Group 1: Successful Batsmen	80.00	4	1
Group 2: Less Successful Batsmen	94.12	1	16
Total	90.91	5	17

In the next step, a forward stepwise multiple regression analysis was performed to determine the contribution of each of the cluster analysis' reduced physical and motor ability variables to the average runs that each batsman scored during the course of both seasons. The results of the last-mentioned analysis are presented in Table 4.

TABLE 4: Results of the forward step-wise multiple regression analysis to determine the physical and motor ability variables which contribute the most to the average runs that were scored by the batsmen during the two seasons (n=22)

Variables	Beta In	Multiple R	Multiple R-square	R-square change	P-level
Left 505 agility (sec)	0.59	0.30	0.09	0.09	0.03*
Vertical jumping power (cm)	0.56	0.47	0.22	0.13	0.03*
Abdominal muscle strength (level)	0.47	0.52	0.27	0.05	0.04*
Aerobic capacity (bleep level-shuttle)	0.43	0.61	0.37	0.10	0.11
1RM bench press strength (kg)	0.44	0.67	0.44	0.07	0.09
1RM hack squat strength (kg)	-0.28	0.70	0.48	0.04	0.23
Left shoulder internal rotation flexibility (°)	-0.24	0.72	0.53	0.04	0.29

*p ≤0.05

The percentage contribution of the physical and motor ability variables to the average runs scored by the batsmen during the two seasons, as was calculated by means of the r-square change, is graphically presented in Figure 1.

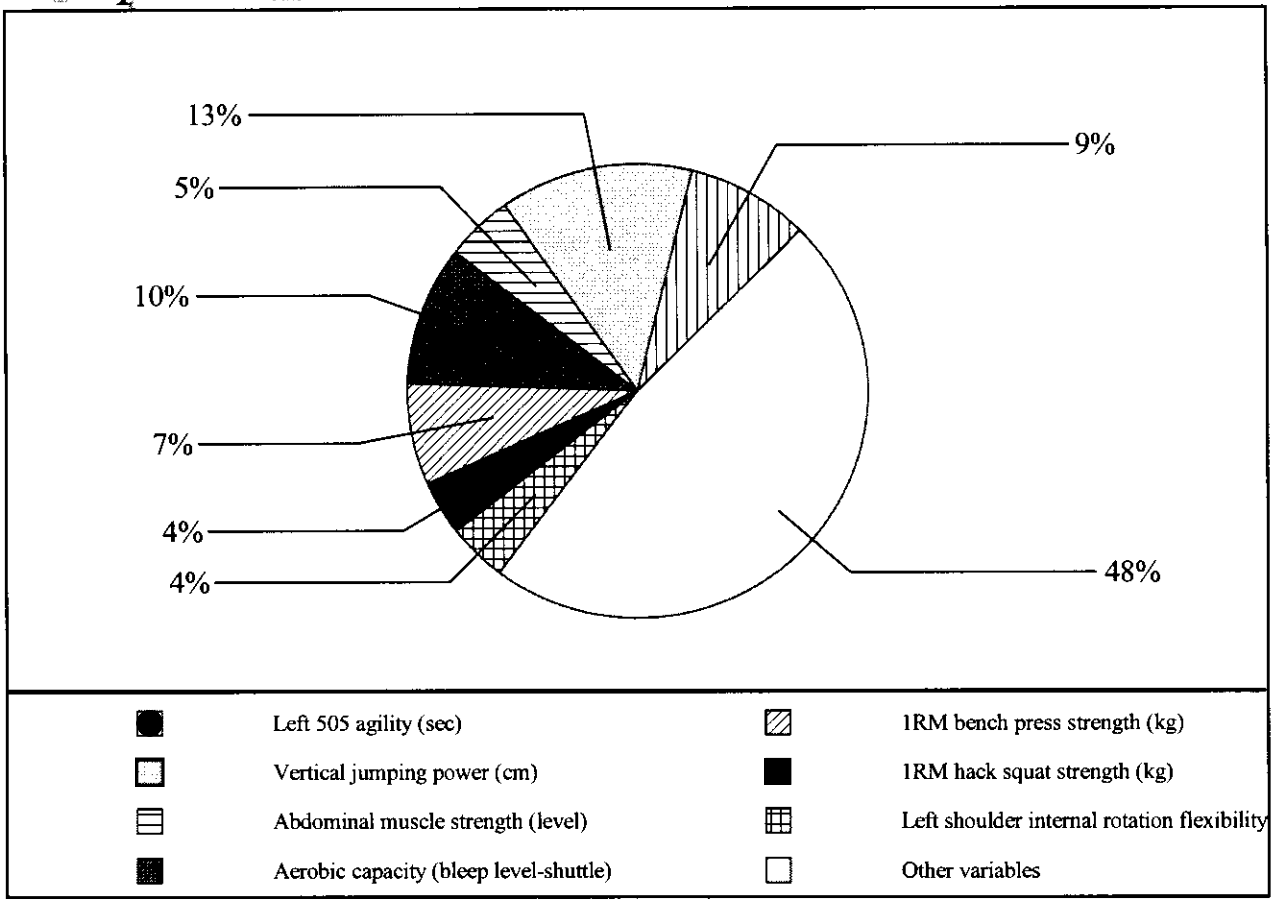

FIGURE 1: Percentage contribution of the most important physical and motor ability variables to the average runs scored by the batsmen during the two seasons (n=22)

According to these results the average runs scored by the batsmen was mostly influenced by vertical jumping power (13%), aerobic capacity (10%) and left 505 agility (9%). The contribution of the first and third stated variables to the variance in batting scores was significant ($p \leq 0.05$). The fourth, fifth, sixth and seventh most contributing physical and motor ability variables were 1RM bench press strength (7%), abdominal muscle strength (also significant) (5%), 1RM hack squat strength as well as left shoulder internal rotation flexibility (4% each). Overall the results show that the last-mentioned variables have a prediction power of 52% in predicting the batting performance of the batsmen. The finding that vertical jumping power was positively related to batting performance could be explained by the link that exists between leg power and speed as well as agility (Bourden et al, 2000). Leg power will, therefore, assist batsmen to increase their agility and speed while running between the wickets. According to Bloomfield et al (1994), explosive leg power will be a prerequisite for any athlete who participates in sport that requires short bursts of speed as well as sudden changes in direction, while moving at high speeds.

The data also suggests that 1RM bench press strength contributes positively to cricket batting performance. The last-mentioned test primarily focused on the strength of the pectorals, triceps, anterior deltoids, serratus anterior and corachobrachialis muscles (Delavier, 2006). These are all muscles that are involved in the execution of back foot shots such as the hook and pull due to the internal rotation of the right arm (anterior deltoid and pectoralis major in the case of right-handed players) that takes place as well as the front foot shots such as the front foot drive due to the flexion of the left arm (anterior deltoid, pectoralis major and coracobrachialis) and the extension of the left forearm (triceps brachii). The serratus anterior is involved in most shots due to the upward rotation and lateral tilt of the shoulder girdle that takes place. Improvements in the strength of these muscles will, therefore, possibly allow batsmen to generate higher bat velocities especially during the execution of the attacking shots. In the present one-day format, it is vital that batsmen must be capable of scoring boundaries to achieve success in the international arena.

It is, however, clear that the rest of the variables (left 505 agility, 1RM hack squat strength and left shoulder internal rotation flexibility) all showed negative relationships with batting performance. This implies that batsmen who display lower values in these last-mentioned variables would achieve higher batting averages during the course of the season. This result is completely unexpected and difficult to explain. Nevertheless, several possible explanations can be provided.

High variability in the different values between the batsmen might have influenced the multiple regression results negatively. For instance; the individual values of the left 505 agility test varied between 2.13 sec (minimum) and 2.84 sec (maximum) with a standard deviation of 0.20 sec; the values of the 1RM hack squat strength test varied between 85 kg (minimum) and 210 kg (maximum) with a standard deviation of 29.16 kg, whilst the values of the left shoulder internal rotation flexibility test varied between 34° (minimum) and 90.5° (maximum) with a standard deviation of 15.63°. The variability of all these values could have influenced the relationships between these values and batting performance negatively.

Further investigation reveals that outliers among the batsmen who scored the highest runs also could have "pulled" the multiple regression results skew due to the small sample size in this study. For example, the batsmen who achieved the highest average runs during both seasons, obtained the second lowest left 505 agility test result of 2.70 sec and an under average shoulder internal flexibility score of 63°. Additionally, the players who scored the third and fourth most runs, were the players who respectively obtained the lowest left 505 agility test time of 2.84 sec and the lowest 1RM hack squat strength weight of 85 kg. In view of this the exclusion of these results could have a marked effect on the outcome of the multiple regression analysis.

Lastly, it is possible that variables other than the physical and motor ability variables in this study could also have contributed to the variance in the batting scores. In this regard, the results of the multiple regression analysis also suggests that factors (variables) other than the variables in this study contributed (48%) to the variance in the batting scores among the batsmen. The Australian Cricket Board (2000) noted that batting performance is especially dependant on a player's concentration level, his batting technique and balance, all factors that did not receive any attention in this study. Other authors (Wilson and Falkel, 2004) also stated that cricket is one of the most demanding sports visually and that binocular vision must be optimally developed. The literature evidence, therefore, suggests that batsmen do not only primarily depend on agility, leg strength or shoulder flexibility to score runs during a one-day match, but on other factors as well.

CONCLUSIONS

In conclusion, the study first revealed that left 505 agility, shuttle run aerobic endurance, 1RM hack squat, left grip and abdominal muscle strength were the physical and motor ability parameters that discriminated accurately (90.91%) between successful and less successful academy cricket batsmen. However, it should be noted that left 505 agility, shuttle run aerobic endurance and 1RM hack squat strength were the only physical and motor ability parameters that contributed significantly ($p \leq 0.05$) to the separation between the successful and less successful groups of batsmen.

Secondly, the physical and motor ability variables which emerged as the biggest contributors (52%) to the performances of provincial academy cricket batsmen were in order of contribution: vertical jumping power (13%) ($p \leq 0.05$), aerobic capacity (10%), left 505 agility (9%) ($p \leq 0.05$), 1RM bench press strength (7%), abdominal muscle strength (5%) ($p \leq 0.05$), 1RM hack squat strength as well as left shoulder internal rotation flexibility (4% each). However, left 505 agility, 1RM hack squat strength and left shoulder internal rotation flexibility all had a negative influence on the batting performance (scores). A high variability between the individual values of these parameters may account for these conflicting results. Moreover, these results also suggest that factors other than the physical and motor ability variables in this study also contribute substantially to the variance (48%) in the cricket batsmen's performances.

Nevertheless, these findings highlight the important relationship between a vast array of physical and motor ability parameters and cricket batting performance. The results of this study suggest that batting performance can be enhanced by improving the last-mentioned variables. It must, however, be underscored that batting performance is also dependant on factors such as a player's concentration levels, batting technique and balance, all factors that did not receive attention in this study. As such, it can be recommended that further studies should focus on more elaborate testing protocols which also include other factors that may have an influence on batting performance. In addition, small group sizes in this study caused outliers to influence the multiple regression results. A larger sample size would, therefore, be advisable. It can also be recommended that the data of players who are distributed over a bigger geographical area must be used so that the generalization of these results to a wider range of batsmen is possible.

In spite of the shortcomings of the study, the study provides the basis for further research in this area due to the fact that no other studies could be found that have researched the link between physical and motor ability parameters and cricket batting performance.

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CHAPTER 4

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

4.1 SUMMARY

The purpose of this study was firstly to determine which of the isokinetic knee and shoulder strength as well as physical and motor ability parameters discriminate between successful and less successful provincial academy cricket batsmen. Secondly, to determine the contribution of isokinetic knee and shoulder strength as well as other physical and motor ability parameters to the performance of provincial academy batsmen. Chapter 1 provided a brief summary of the problem statement that underlies the research questions of the study and the research questions itself, the purposes as well as the hypotheses that outline the basis of this study.

Chapter 2 consisted of the first article entitled "The contribution of isokinetic strength parameters to the performance of provincial academy cricket batsmen". The purposes of this article were firstly, to determine which of the isokinetic knee and shoulder strength parameters discriminate between successful and less successful provincial academy cricket batsmen and secondly, to determine the contribution of isokinetic knee and shoulder strength parameters to the performance of provincial academy cricket batsmen. The first part of the results showed that right (RKEPT) and left knee extensor peak torque (LKEPT), right knee extensor average power (RKEAP), left knee extensor total work (LKETW) and left knee flexor peak torque (LKFPT) (all at 30°/sec), as well as LKEPT, RKEPT and LKEAP (all at 240°/sec), left (LIRAP) and right internal rotator average power (RIRAP), right external/internal rotator peak torque ratio (REIRPTR) and right internal rotator peak torque (RIRPT) (all at 240°/sec) as well as left internal rotator total work (60°/sec) discriminated non-significantly between the successful and less successful academy batsmen. The second part of the results showed that RKEPT 30° (16%), LKEPT 30° (7%), RKEAP 30° (7%), LKFPT 30° (7%), LKEAP 240° (6%), RKFPT 240° (5%), LKETW 30° (5%) and LKEPT 240° (4%) were the isokinetic knee strength parameters which contributed non-significantly to batting performance (ranking). The isokinetic shoulder strength parameters which contributed non-significantly to batting performance (ranking) were RIRPT 240° (28%), LIRAP 240° (16%), REIRPTR 240° (8%), LIRTW 60° (5%) and RIRAP 240° (4%). In conclusion, the results of this research suggest that isokinetic knee and shoulder strength parameters contribute to the performance of provincial academy cricket batsmen.

The second article, entitled "The contribution of physical and motor ability parameters to the performance of provincial academy cricket batsmen" was presented in Chapter 3. The purpose of this article was firstly to determine which physical and motor ability parameters discriminate between successful and less successful provincial academy cricket batsmen, and secondly, to determine the contribution of physical and motor ability parameters to the performance of provincial academy cricket batsmen. Firstly, the results revealed that left 505 agility, shuttle run aerobic endurance and 1RM hack squat strength discriminated significantly ($p \leq 0.05$) between the successful (top 5 ranked batsmen of both seasons) and less successful academy batsmen whilst left grip strength and abdominal muscle strength discriminated non-significantly. Secondly, it could be observed that vertical jumping power (13%) and left 505 agility (9%) were the physical and motor ability parameters which contributed significantly to batting performance. The parameters that contributed non-significantly to batting performance were aerobic capacity (10%), 1RM bench press strength (7%), abdominal muscle strength (5%), 1RM hack squat strength as well as left shoulder internal rotation flexibility (4% each). To conclude it was, therefore, found that physical and motor ability parameters contribute to the performance of academy cricket batsmen.

Both articles are included and compiled according to the guidelines of the specific journals (Journal of isokinetics and exercise science and Journal of human movement studies). Each consists of an introduction and the research purposes of the specific study. The research methods (subjects, measurement procedures and data analysis) are also described together with the results and discussions of each of the studies followed by the research conclusions and recommendations.

4.2 CONCLUSIONS

The conclusions that are drawn from this research are presented in accordance with the set hypotheses (chapter 1).

4.2.1 Hypothesis 1: *The identified isokinetic knee and shoulder strength parameters will discriminate between successful and less successful provincial academy cricket batsmen.*

Hypothesis 1 is accepted based on the research findings that REPT, LEPT, REAP, LETW and LEPT (all at 30°/sec), LEPT, RFPT, LEAP, LIRAP, REIRPTR, RIRAP, RIRPT (all at 240°/sec) as well as LIRTW (60°/sec) discriminated accurately (90.91%) between successful and less successful academy cricket batsmen. However, it was established that none of the isokinetic parameters contributed significantly (p ≤ 0.05) to the separation between the successful and less successful groups of batsmen.

4.2.2 Hypothesis 2: *Certain of the identified isokinetic knee and shoulder strength parameters will contribute significantly to the performance of provincial academy cricket batsmen.*

Hypothesis 2 is not accepted based on the research findings that none of the identified isokinetic knee and shoulder strength parameters contributed significantly to the performance of provincial academy cricket batsmen. However, it was demonstrated that certain isokinetic knee and shoulder strength parameters do indeed contribute non-significantly to the performance of provincial academy cricket batsmen.

4.2.3 Hypothesis 3: *The identified physical and motor ability parameters will discriminate between successful and less successful provincial academy cricket batsmen.*

Hypothesis 3 is accepted due to the conclusion that left 505 agility, shuttle run aerobic endurance, 1RM hack squat, left grip and abdominal muscle strength were the physical and motor ability parameters that discriminated accurately (90.91%) between successful and less successful academy cricket batsmen. Three of the identified physical and motor ability parameters namely, left 505 agility, shuttle run aerobic endurance and 1RM hack squat strength, were significant discriminators between the successful and less successful provincial academy cricket batsmen. The remaining two physical and motor ability parameters, namely left grip strength and abdominal muscle strength did, however, contribute non-significantly to the separation between the successful and less successful provincial academy cricket batsmen.

4.2.4 Hypothesis 4: *Certain of the identified physical and motor ability parameters will contribute significantly to the performance of provincial academy cricket batsmen.*

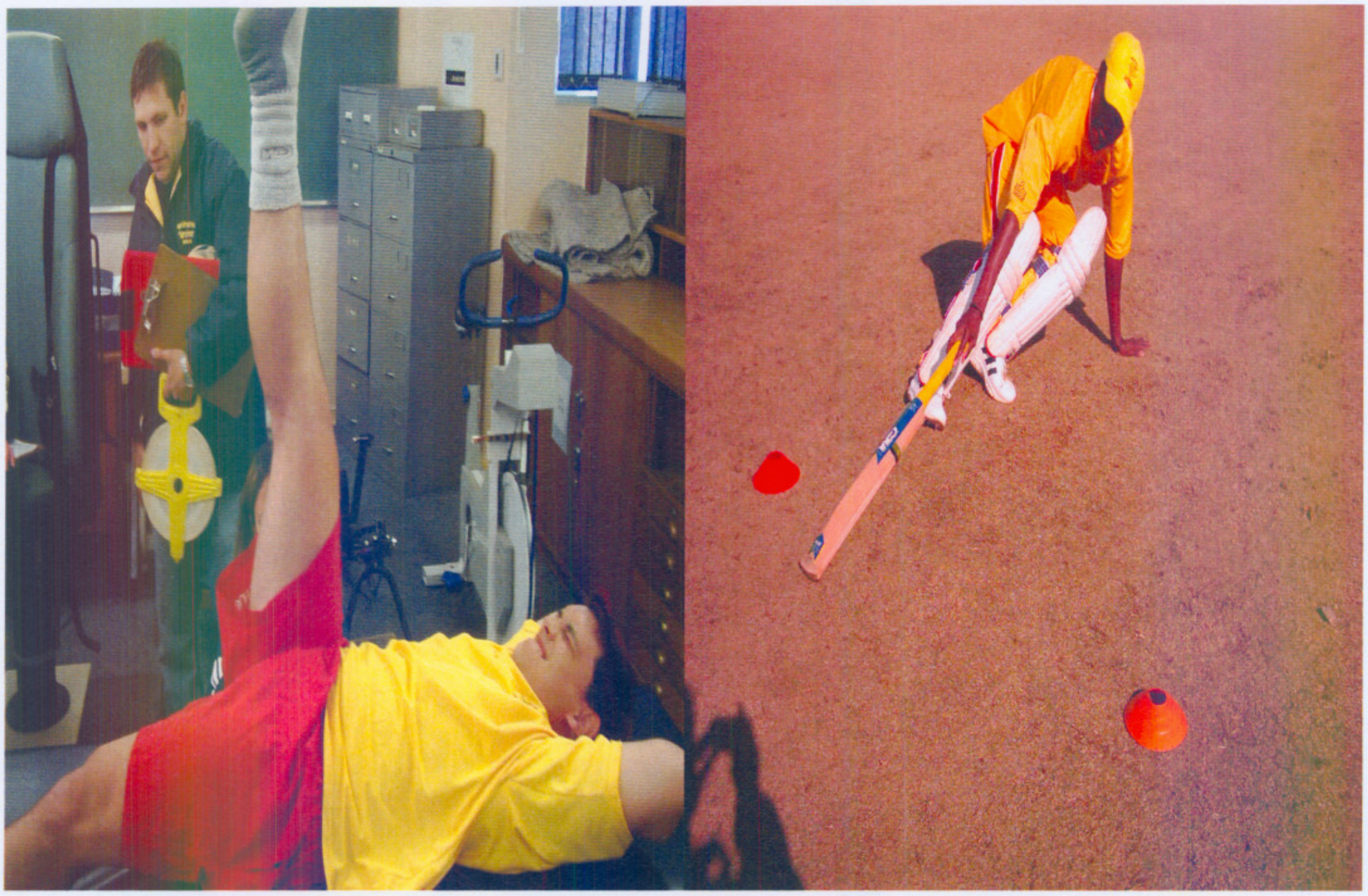
Hypothesis 4 is accepted due to the conclusion that vertical jumping power, left 505 agility and abdominal muscle strength were the identified physical and motor ability parameters which contributed significantly to the batting performance of the provincial academy cricket batsmen. The rest of the physical and motor ability parameters, namely aerobic capacity, 1RM bench press strength, 1RM hack squat strength and left shoulder internal rotation flexibility did, however, contribute non-significantly to the batting performance of the academy cricket batsmen.

4.3 RECOMMENDATIONS

The study provides support for including different physical and motor ability parameters in the testing protocols of cricket batsmen. Furthermore, it also emphasizes the importance of improving the different physical and motor ability components of batsmen through well structured and scientific conditioning programmes. The lack of statistical significant results in this study, however, suggests that certain shortcomings must be addressed:

- A multi-factorial method of analysis that focuses on all the relevant, potential performance parameters of cricket batsmen who participate in one-day matches.
- A small number of subjects were selected for the study. Outliers had a much greater influence on the study results than would have been the case with a larger sample size. Further research of this nature must, therefore, focus on larger group sizes.
- The high variability which existed between the results of the different individuals, accentuates the importance of rather including players who are more similar in terms of their batting performance in a study of this nature.
- Only data of players who are distributed over a small geographical area in South Africa were utilized. For generalization purposes it would, therefore, be advisable to include players who are situated over a larger geographical area.
- More research of the same nature should be conducted to supply a bigger base of literature and knowledge to sport professionals in the cricket arena. The results of the studies might also assist researchers and sport professionals to compile more relevant testing protocols and scientific conditioning protocols for cricket batsmen.

CHAPTER 5



APPENDIX

APPENDIX A: GENERAL INFORMATION QUESTIONNAIRE, INFORMED CONSENT FORMS AND PHYSICAL AND MOTOR ABILITY DATA COLLECTION FORMS FOR PROVINCIAL ACADEMY CRICKET BATSMEN

APPENDIX B: GUIDELINES FOR AUTHORS

APPENDIX A

General information, informed consent and physical and motor performance data protocol for provincial academy cricket batsmen

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ISSD·ISWO

Institute for Sport Science and Development
Instituut vir Sportwetenskap en -ontwikkeling

GENERAL INFORMATION

Please write clearly!

1. GEOGRAPHICAL INFORMATION

1.1 Surname:	Initials	First Name

1.2 Gender (cross out the one that is applicable):

Male	Female

1.3 Age:

Years:	Months:

1.4 Birth date:

Year:	Month:	Day:

1.5 Job description (cross out the one that is applicable):

Student	Part-time employment	*Full-time employment	*Major sponsorship

* *Please specify if you marked any of these two options:*

____

1.6 Permanent residential address in South Africa:

____
____
____
____
____

1.7 Permanent postal address in South Africa:

____
____
____
____
____

1.8 Phone numbers:

Home:	Work:
Fax:	Cell:
E-mail:	

1.9 Ethnic group

White	Coloured	Black	Indian

In the next few question cross out the answers that are applicable to you!!

2. INFORMATION REGARDING TRAINING HABITS

2.1 Years you've been playing cricket - since you started to specialise in cricket.

1-2 years	3-4 years	5-6 years	7-8 years	8-9 years	10-11 years	12 or more

2.2 Frequency of training - how many days per week do you normally train?

1 day	2 days	3 days	4 days	5 days	6 days	7 days

2.3 Frequency of training - how many days per week do you normally do weight training?

1 day	2 days	3 days	4 days	5 days	6 days	7 days

2.4 Frequency of training - how many days per week do you normally have net sessions?

1 day	2 days	3 days	4 days	5 days	6 days	7 days

2.5 Frequency of training - how many days per week do you normally have fielding sessions?

1 day	2 days	3 days	4 days	5 days	6 days	7 days

2.6 How many hours per day do you normally train?

1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 or more

2.7 How many hours per day do you normally spend on weight training?

1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 or more

2.8 How many hours per day do you normally spend on training in the nets?

1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 or more

2.9 How many hours per day do you normally spend on batting in the nets?

Not Applicable	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours

2.10 How many hours per day do you normally spend on fielding?

Not Applicable	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours

2.11 How do you think does your coaching compare with those of international cricketers?

Does not compare well at all	Does not compare well	In some aspects the same	Very well

2.12 Do you spend any time on psychological preparation for cricket and competitions?

Never	*Sometimes	*Often	*Always

*** Please specify the type of psychological preparation you do if you marked any of these three options:**

3. MEDICAL INFORMATION

3.1 Please describe any past or current musculoskeletal conditions you have incurred (i.e., muscle pulls, sprains, fractures, surgery, back pain, or any general discomfort):

Head/Neck:

Shoulder/Clavicle:

Arm/Elbow/Wrist/Hand:

Back:

Hip/Pelvis:

Thigh/Knee:

____

____

____

____

____

Lower leg/Ankle/Foot:

____

____

____

____

____

3.2 Please list any medication being taken currently and/or taken during the last year:

____

____

____

____

____

3.3 List any other illness or disorder that a physician has told you of:

____

____

____

____

____

4. COMPETITION DATA

4.1 Arrange from your best to your weakest category (bowling = 1, fielding = 2 etc.)

Batting =	Bowling =	Fielding =

4.2 In which category do you regard yourself?

Bowler	Batsmen	All-rounder	Wicketkeeper	Wicketkeeper batsmen

4.3 At what level are you competing this year?

____

4.4 What is the highest level that you competed at last year?

Provincial	National	International

4.5 What are your current national rankings? (IF AVAILABLE)

Category	Test Ranking	ODI Ranking
Bowling		
Batting		

4.6 What is your highest score in a Provincial and/or National ODI?

4.7 What are your best bowling figures in a Provincial and/or National ODI?

4.8 What is your current batting average in the ODI format?

4.9 What is your current bowling average in the ODI format?

4.10 How many matches, approximately, have you played in the ODI format?

Provincial =	National =

4.11 What is your preferred position of fielding?

First Slip	Second Slip	Third Slip	Gully	Point
Fine Leg	Third Man	Cover	Square Leg	Mid-wicket
Mid-off	Mid-on	Silly mid-off	Silly mid-on	Sweeper

4.12 What were the highest achievements you attained the past two years?

Achievement	**Competition**	**Date**

4.13 What are your most important competitions this year and when will it take place?

No. of importance	**Competition**	**Date**
1		
2		
3		
4		

YUNIBESITI YA BOKONE-BOPHIRIMA
NORTH WEST UNIVERSITY
NOORDWES UNIVERSITEIT

ISSD·ISWO

Institute for Sport Science and Development
Instituut vir Sportwetenskap en -ontwikkeling

CONFIDENTIAL

Informed consent form

PART 1

1. School/Institute:

   School for Biokinetics, Recreation and Sport Science and The Institute for Sport Science and Development.

2. Title of project/trial:

   The contribution of certain physical and motor ability parameters to the match performance of provincial academy cricket batsmen

3. Full names, surname and qualifications of project leader:

   Ben Coetzee, B.Sc., B.Sc. (Hons) and M.Sc.

4. Rank/position of supervisor:

   (Professor, Lecturer, research scientist etc.)

   Head lecturer

5. Full names, surname and qualifications of supervisor of the project:

   (Complete only if not the same person named in 4.)

   Same as above.

6. Name and address of supervising medical officer *(if applicable)*:

   Not applicable

7. Aim of this project

   The aim of this study is:

   i. To determine what the contribution of different physical and motor ability parameters are to the performance of provincial cricket players

8. Explanation of the nature of all procedures, including identification of new procedures:

i) Collection procedures and selection of cricket players.

Twenty-two players from the Gauteng and North-West provincial academies will participate in the study.

ii) Measure methods

Demographic and general information questionnaire

The players' demographic and personal information (gender, race and age) will be collected by means of a demographic general information questionnaire. The players' exercising habits, injury incidence and competing level will also be determined by means of this questionnaire. Data will be collected through a test battery.

Physical and motor performance determinants.

The following determinants will be evaluated by making use of the named tests:

i) Hamstring and shoulder flexibility:
As determined by the active knee extension test and the shoulder internal/external rotation test of Harvey and Mansfield (2000).

ii) Leg explosive power:
As determined by the vertical jump test as explained by Safrit (1990).

iii) Abdominal muscle strength:
As determined by the seven level abdominal muscle strength test of Ellis *et al.* (2000).

iv) Muscle strength:
As determined by the One Repetition Maximum (1RM) Bench Press test of Ball (1991), the 1RM Incline Hack squat test (adapted from Gale, 1991) and the dynamometer-handgrip strength test of Wadsworth *et al.* (1992).

v) Speed over 5 m, 10 m, 20 m and 40 m:
As determined by the method of Tumilty (2000).

vi) Agility:
As determined by the 505 agility test of Ellis *et al.* (2000) as well as a pitch run. In the last-mentioned test the players completed two trials of two runs on a standard pitch length in the fastest possible time, whilst wearing the normal match gear. Players had a two minute rest period between the two trials.

vii) Speed endurance:
As determined by the 5 m Multiple shuttle run test of Boddington *et al.* (2001).

viii) Aerobic endurance:

As determined by the 20 m shuttle run test of the Australian Sports Commission (1998).

ix) Batting test:

As determined by the Strikers-Zone test, adapted from the method of Woolmer (2004).

x) Isokinetic muscle torque:

As determined by external and internal shoulder rotation (Mayer *et al.*, 2001) and knee extension and flexion tests (Pääsuke *et al.*, 2001).

Test protocol

The players will undergo four days of testing and evaluations. On day one, the players will complete the general information questionnaire. After completion of the questionnaire, the players will undergo flexibility, grip strength, explosive power, abdominal strength and muscular strength testing. On the second day of testing each player will be subjected to speed, agility and speed endurance tests. On the third day of testing each player will complete aerobic endurance tests. On the fourth day, each player will carry out isokinetic strength tests.

9. Description of the nature of discomfort or hazards of probable permanent consequences for the subjects which may be associated with the project:

(Including possible side-effects of and interactions between drugs or radio-active isotopes which may be used.)

The subjects may sustain slight muscle injuries, experience a bit of muscle discomfort and nausea.

10. Precautions taken to protect the subjects:

The players will perform a proper warm-up before physical and motor ability tests commence and the testing procedures and –methods will be thoroughly explained to each of the players.

11. Description of the benefits which may be expected from this project:

The results might point to possible contributions of physical and motor ability parameters to the performance of provincial cricket players. This will also help coaches to plan their season correctly in order to optimize performance for their players.

12. Alternative procedures which may be beneficial to the subjects:

(Complete only if applicable.)

The physiological measurements will give the players and researcher an indication of the importance of different variables contributing to as well as an indication of the comparison between their values and existing norms.

Signature:.. **Date:** 04/05/2004

Project leader

PART 2

To the subject signing the consent as in part 3 of this document:

You are invited to participate in a research project as described in paragraph 2 of Part 1 of this document. It is important that you read/listen to and understand the following general principles, which apply to all participants in our research project:

1. Participation in this project is voluntary.
2. It is possible that you personally will not derive any benefit from participation in this project, although the knowledge obtained from the results may be beneficial to other people.
3. You will be free to withdraw from the project at any stage without having to explain the reasons for your withdrawal. However, we would like to request that you would rather not withdraw without a thorough consideration of your decision, since it may have an effect on the statistical reliability of the results of the project.
4. The nature of the project, possible risk factors, factors which may cause discomfort, the expected benefits to the subjects and the known and the most probable, permanent consequences which may follow from your participation in this project, are discussed in Part 1 of this document.
5. We encourage you to ask questions at any stage about the project and procedures to the project leader or the personnel, who will readily give more information. They will discuss all procedures with you.
6. If you are a minor, we need the written approval of your parent or guardian before you may participate.
7. We require that you indemnify the University from any liability due to detrimental effects of treatment by University staff or students or other subjects to yourself or anybody else. We also require indemnity from liability of the University regarding any treatment to yourself or another person due to participation in this project, as explained in Part 1. Lastly it is required to abandon any claim against the University regarding treatment of yourself or another person due to participation in this project as described in Part 1.

PART 3

Consent

Title of the project: The contribution of certain physical and motor ability parameters to the match performance of provincial academy cricket batsmen

I, the undersigned .... (Full names) read/listened to the information on the project in PART 1 and PART 2 of this document and I declare that I understand the information. I had the opportunity to discuss aspects of the project with the project leader and I declare that I participate in the project as a volunteer. I hereby give my consent to be a subject in this project

.

I indemnify the University, also any employee or student of the University, of any liability against myself, which may arise during the course of the project.

I will not submit any claims against the University regarding personal detrimental effects due to the project, due to negligence by the University, its employees or students, or any other subjects.

(Signature of the subject)

Signed at .... on ....

Witnesses

1. ....

2. ....

Signed at .... on ....

For non-therapeutic experimenting with subjects under the age of 21 years the written approval of a parent or guardian is required.

I, ... (Full names)

Parent or guardian of the subject named above, hereby give my permission that he/she may participate in this project and I also indemnify the University and any employee or student of the University, against any liability which may arise during the course of the project.

Signature: .... Date: ....

Relationship: ....

Appendix A

YUNIBESITI YA BOKONE-BOPHIRIMA
NORTH WEST UNIVERSITY
NOORDWES UNIVERSITEIT

ISSD·ISWO

Institute for Sport Science and Development
Instituut vir Sportwetenskap en -ontwikkeling

Cricket Protocol

Name & Surname			
Position	**Batsmen**	**Bowler**	**All-rounder**

Anthropometry

Measurement	**Right**		
Skinfolds	**Trial 1**	**Trial 2**	**Average**
Stature (cm)			
Body mass (kg)			
Biceps (mm)			
Triceps (mm)			
Subscapular (mm)			
Supra-spinal (mm)			
Abdominal (mm)			
Thigh (mm)			
Medial calf (mm)			
Girths	**Trial 1**	**Trial 2**	**Average**
Contracted upper arm (cm)			
Forearm (cm)			
Thigh (cm)			
Calf girth (cm)			
Diameter	**Trial 1**	**Trial 2**	**Average**
Humerus (cm)			
Wrist (cm)			
Femur (cm)			
Ankle (cm)			

Flexibility

	Right			**Left**		
Measurement	**Trial 1**	**Trial 2**	**Average**	**Trial 1**	**Trial 2**	**Average**
Internal shoulder rotation						
External shoulder rotation						

	Right			Left		
Measurement	**Trial 1**	**Trial 2**	**Average**	**Trial 1**	**Trial 2**	**Average**
Active knee extension						

Explosive power

Measurement	**Reach Height**	**Trial 1**	**Trial 2**
Vertical jump			

Strength

	Right			Left			
Measurement	**Trial 1**	**Trial 2**	**Average**	**Trial 1**	**Trial 2**	**Average**	
Grip strength							
Abdominal strength	1	2	3	4	5	6	7

Muscle strength

Measurement	**1RM**
Bench Press	
Incline Hack squat	

Speed

Measurement	**Trial 1**	**Trial 2**
0 - 5m		
0 - 10m		
0 - 20m		
0 - 40m		

Agility

Measurement	**Trial 1**		**Trial 2**	
505 Test	L	R	L	R
505 Test (with equipment)	L	R	L	R

Measurement	**Trial 1**	**Trial 2**
Pitch Run with pads		

Speed Endurance

Measurement	1	2	3
Multiple shuttle run	4	5	6
Total Distance			

Aerobic Endurance

Measurement	Shuttle	Level
Beep Test		

Batting Test

Coach will evaluate each shot played according to technique, movement and correct execution

Fielding Test

Measurement	1	2	3
Dead-Eye	4	5	6

3 points = Direct hit on first throw

2 points = Direct hit on second throw

1 points = Direct hit on third throw

Isokinetic strength

See computer

Knee extension/flexion

Shoulder internal/external rotation

APPENDIX B

Guidelines for Authors

Isokinetics and Exercise Science
Official Journal of the European Interdisciplinary Society for Clinical and Sports Application

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The following electronic files are required:
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- separate files of all figures (if any); see "Preparation of manuscripts" for the required file formats.

Colour figures
It is possible to have figures printed in colour, provided the cost of their reproduction is paid for by the author. See Preparation of Manuscripts for the required file formats.

PREPARATION OF MANUSCRIPTS

Organization of the paper and style of presentation
Manuscripts must be written in English. Authors whose native language is not English are recommended to seek the advice of a native English speaker, if possible, before submitting their manuscripts.
Manuscripts should be prepared with wide margins and double spacing throughout, including the abstract, footnotes and references. Every page of the manuscript, including the title page, references, tables, etc., should be numbered. However, in the text no reference should be made to page numbers; if necessary, one may refer to sections. Try to avoid the excessive use of italics and bold face.
Manuscripts should be organized in the following order:
- Title page
- Body of text (divided by subheadings)
- Acknowledgements
- References

- Tables
- Figure captions
- Figures

Headings and subheadings should be numbered and typed on a separate line, without indentation.
Numbers should appear with decimal point, not comma: 12.3 and not 12.3
The units for isokinetic measurement is Nm. If the system's output is otherwise, authors are urged to convert e.g. from ft•lb into Nm.
On the other hand, there is **no** need to number the headings.
SI units should be used, i.e., the units based on the metre, kilogramme, second, etc.

Title page
The title page should provide the following information:
- Title (should be clear, descriptive and not too long)
- Name(s) of author(s); please indicate who is the corresponding author
- Full affiliation(s)
- Present address of author(s), if different from affiliation
- Complete address of corresponding author, including tel. no., fax no. and e-mail address
- Abstract: should be structured, clear, descriptive, self-explanatory and not longer than 200 words. it should also be suitable for publication in abstracting services
- Keywords.

Tables
Number as Table 1, Table 2 etc, and refer to all of them in the text.
Each table should be provided on a separate page of the manuscript. Tables should not be included in the text.
- Each table should have a brief and self-explanatory title.

Column headings should be brief, but sufficiently explanatory. Standard abbreviations of units of measurement should be added between parentheses.
Vertical lines should not be used to separate columns. Leave some extra space between the columns instead.
Any explanations essential to the understanding of the table should be given in footnotes at the bottom of the table.

Figures
- Number figures as Fig. 1, Fig 2, etc and refer to all of them in the text.

Each figure should be provided on a separate sheet. Figures should not be included in the text.
Colour figures can be included, provided the cost of their reproduction is paid for by the author.
For the file formats of the figures please take the following into account:
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- grayscales (incl photos) should have a minimum resolution of 300 dpi (no lettering), or 500 dpi (when there is lettering); save as tiff
- do not save figures as JPEG, this format may lose information in the process
- do not use figures taken from the Internet, the resolution will be too low for printing
- do not use colour in your figures if they are to be printed in black & white, as this will reduce the print quality (note that in software often the default is colour, you should change the settings)

- for figures that should be printed in colour, please send a CMYK encoded EPS or TIFF

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On maps and other figures where a scale is needed, use bar scales rather than numerical ones, i.e., do not use scales of the type 1:10,000. This avoids problems if the figures need to be reduced.

Each figure should have a self-explanatory caption. The captions to all figures should be typed on a separate sheet of the manuscript.

Photographs are only acceptable if they have good contrast and intensity.

Reference

For citations in the text numbers between square brackets should be used. All publications cited in the text should be presented in a list of references following the text of the manuscript.

References should be listed alphabetically in the following style:

[1] T.D. Cahalan, M.E. Johnson and E.Y. Chao, Shoulder strength analysis using the Cybex II isokinetic dynamo, *Clinical Orthopaedics and Related Research* **271** (1991), 249-257.

[2] H.D. Hartsell, The effects of body position and stabilization on isokinetic torque ratios for the shoulder rotators, *I E S* **7** (1998/1999), 161-170.

[3] S. Lippitt, Mechanism of glenohumeral joint stability, *Clinical Orthopaedics and Related Research* **291** (1993), 20-27.

Footnotes

Footnotes should only be used if absolutely essential. In most cases it is possible to incorporate the information in the text.

- If used, they should be numbered in the text, indicated by superscript numbers and kept as short as possible.

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summary.

The title page should be laid out as follows: title of page, names of authors (without qualifications or title), institutions and full address for correspondence. Authors should provide a fax number or e-mail where available.

If possible figures should be submitted on 3,5" discs in the original graphics program (with a note to the editor stating the program used) and also as glossy prints on good quality paper. Figures should be numbered consecutively throughout the paper. The name of the first author and figure number should appear on the reverse of the figure and they should be at least twice the size they are to appear in print. Half-tones must be of first-class quality and on glossy paper. Tables should appear on a separate sheet and must be numbered consecutively. They should be set using a table editor function (using cells rather than tabs or bar spacing). Figures and tables should have self-explanatory legends presented on a separate sheet.

Footnotes numbered consecutively in the text using subscripts should be presented on a separate sheet at the end of the paper. They should be kept to a minimum.

References should appear in the format of the examples given below.

KENNEDY, M.D.J. AND BELL, G.J. (1996).
Measurement of heart rate response during a 55km cross country ski race.
Journal of Human Movement Studies, 31:161-177

KELSO, J.A.S. AND DING, M. (1993).
Fluctuations, intermittency and controllable chaos in biological coordination.
In Variability and motor control.
Human Kinetics, (Edited by K.M. Newell and D.M. Corcos), Champaign, IL., pp. 291-316.

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