IMPACT OF BATTING SKILL ON PACING DURING REPEATED SPRINTS BETWEEN THE WICKETS

BY

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THESIS

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ABSTRACT

Introduction: With batting in cricket, there is no known end point, making the allocation of resources and the development of a suitable pacing strategy more difficult. How batsmen allocate resources and pace themselves when repeatedly sprinting between the wickets is therefore not known. According to the 'anticipatory feedback' model, the level of expertise/experience has a substantial influence on the development of a suitable pacing strategy. Skilled or experienced batsmen may therefore have a greater ability to develop and implement a pacing strategy compared to that of novice or less-skilled batsmen.

Purpose: To assess whether the absence of a known end point at the beginning of repeated sprint bouts between the wickets effects how batsmen pace themselves comparing skilled and less-skilled batsmen.

Methods: Twenty-four male cricketers from a university league were selected. Twelve skilled batsmen (players in the top five batting order), and 12 less-skilled batsmen (players in the bottom five batting order) completed three experimental. All trials required batsmen to complete the same number of shuttle sprints (14 shuttles and therefore 28 runs), while only the information provided before each trial differed. *Control Trial:* This trial is also referred to as the 'informed' trial as the batsmen are aware of the exercise requirements (end point). *Unknown Trial:* The batsmen were not informed of the exercise end point and were required to run on command for an indefinite period (28 runs). *Deceptive Trial:* Batsmen' were incorrectly informed with regards to the number of sprints (told they were only doing 14 runs when in fact they were doing 28 runs). Muscle activity, sprint times and RPE measures were obtained during all three trials and compared.

Results:

Significant ($p<0.05$) group effects were apparent for sprint times and, 'central' and 'local' RPE. Specifically, skilled batsmen obtained the faster mean sprint times, and less-skilled batsmen reported the higher mean 'central' and 'local' RPE values in all three experimental trials. There were no significant group effects for muscle activation. Skilled batsmen did however have lower muscle activation compared to less-skilled batsmen in all three trials. Furthermore, general trends revealed that sprint times and muscle activation decreased over time (from shuttle 1 to shuttle 14), and RPE ('central' and 'local') ratings increased, regardless of the experimental trials. Skilled batsmen performed the best in all three trials. This was determined by the attainment of faster sprint times, lower muscle activation and low RPE ratings in each of the three trials. The assessment of the relationship of the dependent variables measured in each trial, did however suggest that skilled batsmen performed best in the deceptive trial while less-skilled batsmen performed best in the control trial. Skilled batsmen thus showed superior performance when trial requirements were unclear. Less-skilled batsmen however, were seen to experience decrements in performance when information regarding the end point was unknown or misleading.

Conclusion:

It can thus be concluded that previous experience facilitates in the obtainment of improved sprint times between the wickets, especially when the exact end point is unknown.

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TABLE OF CONTENTS

PAGE

CHAPTER III: METHODOLOGY

CHAPTER IV: RESULTS

APPENDICES

LIST OF TABLES

TABLE **PAGE**

LIST OF FIGURES

FIGURE **PAGE**

CHAPTER I
INTRODUCTION

1.1 BACKGROUND OF STUDY

Pacing can be defined as the interaction of an athlete's assessment of the external environment and the afferent feedback of the internal environment (Foster, De Koning, Hettinga, Lampen, La Clair, Dodge, Bobbert and Porcari, 2003; Abbiss and Laursen, 2008). This interaction works in such a way as to regulate exercise intensity to avoid premature fatigue (St Clair Gibson, Lambert, Rauch, Tucker, Baden, Foster and Noakes, 2006). Pacing strategies therefore facilitate in the optimization of performance, by regulating work output and ensuring the correct allocation of energy resources over a specific duration of time (Foster *et al*., 2003; Foster, Hoyos, Earnest and Lucia, 2005).

Past research has shown the importance of an exercise end point in the formation of a pacing strategy (Ansley, Robson and St Clair Gibson, 2004; Spencer, Bishop, Dawson and Goodman, 2005). Knowledge of an exercise end point improves performance by allowing for prior planning. Factors such as resource allocation, muscle recruitment patterns, exercise intensity and ratings of perceived exertion (RPE); can all be pre-determined by the brain prior to the commencement of the exercise bout (Noakes, St Clair Gibson and Lambert, 2005; Tucker, 2009). The interplay between the subconscious and conscious brain then further ensures that a down regulation of skeletal muscle recruitment, energy substrates and heart rate, occurs at a specific time such as to ensure catastrophic failure is avoided before the end of an exercise bout (Tucker, 2009).

A model termed the 'anticipatory feedback' model has been proposed in an attempt to explain the mechanisms behind the development and adoption of various pacing strategies during exercise (Tucker, Marle and Lambert, 2006; Tucker, 2009). The 'anticipatory feedback' model describes how athletes' regulate performance through the integration of RPE, physiological functions and various performance measures. Additionally, the model utilizes previous experience, the anticipation of exercise distance or exercise duration, and physiological feedback to explain how performance is regulated (Tucker, 2009).

Applying this model to the game of cricket, and specifically batting, is challenging as the majority of the components of batting are complex, intermittent and dynamic in nature (Noakes and Durandt, 2000).

Batting requires intense sprinting efforts between wickets (Abbiss and Laursen. 2008). These sprints involve numerous concentric but, particularly, eccentric muscle activations. Eccentric muscle actions are characterized as muscle actions which have higher forces with lower motor unit activation. This combination of large force and low muscle recruitment patterns, results in greater mechanical stress placed on muscle fibres during this type of exercise (Enoka, 1996). Consequently, the force producing capacity of the muscle will lessen substantially causing a decrement in performance. In addition to the decrease in force production, Nicol, Komi and Marconnet (1991), propose that repeated eccentric muscle actions alter the skeletal muscle functioning, which results in a loss in elastic energy production. Moreover, eccentric muscle actions elicit a different form of fatigue (Enoka, 1996; Kellis and Baltzopoulos, 1998). This form of fatigue can be described as fatigue which is longer lasting and if sufficient recovery is not attained, batsmen may become predisposed to premature fatigue as well as risk injury.

In addition to the intense cardiovascular and muscular demands placed on batsmen, batsmen are required to perform optimally with no information pertaining to the exercise requirements. The time spent at the crease and the number of runs to be made during the batting innings is unknown. The absence of this end point prevents the brain from pre-determining the necessary allocation of resources, suitable muscle recruitment patterns and the initial work rate, which all contribute to the development of a suitable pacing strategy.

Furthermore, according to the ‘anticipatory feedback’ model, the level of experience has a substantial influence on the development of a suitable pacing strategy (Tucker, 2009). Skilled or experienced batsmen may therefore have a greater ability to develop and implement a pacing strategy compared to that of less-skilled or less-experienced batsmen. Defining the characteristics, or attributes, of skilled performance poses many challenges. A skilled performer is an individual who has learnt how to achieve a particular performance goal at almost every attempt, while concurrently minimizing both physical and mental energy, as well as time (Matschiner, Shea and Wulf, 1998). There are numerous confounding variables that influence the stages of skill acquisition. These variables can be categorized into both intrinsic and extrinsic variables. The complex relationship between the intrinsic and extrinsic factors, as well as the accumulation of training hours, plays a crucial role in enabling an athlete to reach their performance potential (Tucker and Collins, 2012).

Looking specficially at batting, some players may possess certain instrinsic factors which predispose them to achieving skilled status. Instrinsic factors such as age, neuromusclar characteristics, and the psychology of an individual all contribute to the process of becoming a skilled batsmen (Woolmer, Noakes and Moffet, 2008). It is however the addition of the external enviroment that ultimatimalty provides the opportunity for these players to achieve sporting success. External inputs during the stages of skills acquistion is crucial in both the internalisation and mastery of a specific skill, in this case batting. Factors such as feedback during coaching, the accumulation of time spent in the nets as well as exposure to competition, all influence the ‘level of performance’ reached by athletes (Tucker and Collins, 2012). Skilled batsmen therefore have certain intrinsic attributes or traits which enable them to perform both physically and mentally, however the time spent manipulating these factors, is essentially what contributes to sporting success. While the cognitive aspect of batting is arguably the most important factor influencing performance, the physical side cannot be ignored and, as such, this aspect was the focus of the current study. Based on the physical effort of repeated sprint ability of batsmen, it is contended that based on the theory of the ‘anticipatory feedback’ model, the level of experience of a batsmen will in all probability, influence their ability to successfully select and implement a pacing strategy when required to sprint repeatedly between the wickets.

1.2 STATEMENT OF THE PROBLEM

The purpose of this investigation was to assess whether the absence of a known end point at the beginning of a batting innings prevents batsmen from adopting a suitable pacing strategy when repeatedly sprinting between the wickets. This research will also aim to assess whether skilled batsmen have a greater ability to develop and implement a pacing strategy compared to less-skilled batsmen.

1.3 RESEARCH HYPOTHESES

It was expected that pacing would occur during short repeated-sprint efforts when different information regarding the total number of shuttle sprints to be completed was provided to batsmen prior to sprinting. Furthermore, it was expected that the level of experience of the batsmen would influenced their ability to pace themselves.

1.4 STRUCTURE OF THESIS

Chapter I outlines the background to the study, the research question and hypotheses pertaining thereto.

Chapter II provides a review of the various theories of exercise-induced fatigue, the mechanisms of pacing in an intermittent environment, the theories behind the proposed anticipatory feedback model, the application of this model to the game of cricket, and specifically to the act of batting. Additional literature available explores the influence of experience on pacing, as well as what attributes differentiate a skilled performance.

Chapter III provides details of the methodology of the study. This chapter will address the research aim, experimental design, the testing procedures, the participant recruitment and characteristics, the testing environment, the measurements and equipment used in the study, and lastly the statistical hypotheses, with the key considerations for the statistical interpretation of the study.

Chapter IV presents the findings of the study. Overall effects, as well as individual analyses of the dependent variables will be considered.

Chapter V will discuss the findings of chapter IV. Once again, the overall effects will be discussed followed by the interpretation of each variable separately in order to reduce the complexity of the results.

Chapter VI will summarise the procedures and results of the study, declare the concluding remarks and recommendations of the study.

Accompanying documentations and information which bear relevance to the findings and the interpretation thereof is catalogued in the Appendices. To reduce the content, specifically in chapter III, the Rhodes University, Department of Human Kinetics and Ergonomics ethical standards for this research protocol has been attached and provides additional justification for the selected methodological details of the study (Appendix C, pg 126).

CHAPTER II
LITERATURE REVIEW

2.1 THEORIES OF EXERCISE-INDUCED FATIGUE

There has been much controversy regarding the trigger of fatigue which ultimately limits athletic performance (Bassett and Howley, 1997). Fatigue is best understood as being either central or peripheral in nature (Bassett and Howley, 1997). Simplistically, the peripheral model of fatigue suggests that fatigue occurs as a result of the limitations of the cardiovascular system. It is believed that the cardiovascular system reaches a point beyond which it is unable to supply the skeletal muscle with the increasing oxygen requirements associated with continuous exercise (Bassett and Howley, 1997). Lack of oxygen in the skeletal muscles causes anaerobic metabolism resulting in a build up of lactic acid and hydrogen ions in the active muscle. The accumulation of these by-products ultimately disrupts homeostasis and causes fatigue (Bassett and Howley, 1997). A model termed the Central Governor is however in opposition with the peripheral model of fatigue. The Central Governor theory proposes that the brain regulates exercise intensity by detecting changes in the peripheral physiological systems and making the necessary adjustments to ensure that these changes remain within physiological limits (Bassett and Howley, 1997). Changes in the peripheral physiological systems include discrepancies in lactic acid accumulation and decreases in ATP, pH and glycogen in the muscles (Albertus, Tucker, St Clair Gibson, Lambert, Hamspson and Noakes, 2005). These metabolic depletions and accumulation of substrates act as triggers to the brain which then reduce nerve impulses to skeletal muscle. As a result, less skeletal muscle is recruited which decreases force output (St Clair Gibson, Lambert and Noakes, 2001; St Clair Gibson, Hampson and Lambert, 2001). The brain thereby acts as a protective mechanism, preventing hypoxia of the vital organs through the decrease in muscle activation (St Clair Gibson, Schabort and Noakes, 2001; St Clair Gibson *et al.,* 2001; Kayser, 2003).

The Central Governor theory is supported by the shortcomings of the peripheral theory, as well as the changes in pacing and the anticipatory effect evident during endurance exercise (St Clair Gibson *et al.,* 2001; Noakes *et al.,* 2005). In order to strengthen the evidence pertaining to the theories of central fatigue, studies focusing on components such as, the influence of speed and distance in the development of fatigue, have all been done. These studies have however been conducted in a controlled environment thus preventing the assessment of self-pacing and its association with central control, which has proven to be one of the most important features of exercise (St Clair Gibson *et al.,* 2001; Noakes *et al.,* 2005; Tucker, 2009).

2.2 THE SELF-PACING OF EXERCISE

Pacing can be defined as the interaction of an athlete's assessment of the external environment and the afferent feedback of the internal environment (Foster *et al.,* 2005; Abbiss and Laursen, 2008). This interaction regulates exercise intensity in order to avoid premature fatigue (St Clair Gibson *et al.,* 2006). Pacing can further be described as the distribution of energy throughout an exercise bout to ensure superior performance and task completion. Pacing strategies therefore facilitate in the optimization of performance by regulating work output over a specific duration of time (Foster *et al.,* 2003; Foster *et al.,* 2005; Tucker, 2009).

Pacing strongly suggests involvement of the brain in determining performance during endurance exercise (St Clair Gibson *et al.,* 2006; Tucker, 2009). Tucker, Rauch and Harley (2004), looked at the effects of elevated temperature on the pacing of 10 male subjects during a 20km cycling time trial. Results showed that muscle activity and power output both reduced significantly at the high temperature (35ºC) when compared to the cool temperature (15ºC) (Tucker *et al.,* 2004). The reductions that transpired in the hot condition, due to the mechanisms of self-pacing, occurred before physiological effects such as increased heart rate or increased core temperature occurred (Tucker *et al.,* 2004). The anticipatory response of the brain therefore alters the muscle recruitment in the heat before the disruption of homeostasis occurred and core temperatures became dangerously high (Tucker *et al.,* 2004). The anticipatory effect is also demonstrated by Chambers, Bridge and Jones (2009), during which eight male subjects were required to rinse their mouths with different solutions during a cycling time trial. Results found that performance increased significantly when subjects rinsed (without ingesting) with a 6.4% glucose solution compared to rinsing the mouth with a placebo mouthwash, disguised with artificial sweetener. These findings imply that the subconscious sense of the carbohydrate resulted in an improvement in performance even though the carbohydrate was never ingested by the cyclists. Certain regions of the brain thought to be involved in motor control were activated by the presence of glucose therefore the behaviour of the cyclists was subconsciously influenced as a result (Chambers *et al.,* 2009). These findings thus demonstrate the power elicited by both the conscious and the subconscious brain, so much so that the brain was able to revoke physiological control (Chambers *et al.,* 2009).

The majority of pacing-related research has however focused primarily on continuous sports such as running, cycling and swimming. The reason being that these sports all have predetermined end points, either in the forms of the knowledge of the exercise distance or the exercise duration (Foster *et al*., 2003; Spencer *et al.,* 2005). Knowledge of the end point in any exercise is crucial in the development of a fully functional pacing strategy (St Clair Gibson *et al.,* 2006; Tucker, 2009; Billaut, Bishop, Schaerz and Noakes, 2011). The exercise end point allows for the calculation and sufficient allocation of physiological and psychological resources needed in order to optimally complete the exercise bout without reaching a state of exhaustion or acquiring an injury (Spencer *et al.,* 2005; St Clair Gibson *et al.,* 2006; Billaut *et al.,* 2011). Knowledge of the exercise end point, anticipation of the exercise distance, and a known duration, all influence aspects such as muscle activation, ratings of perceived exertion (RPE) and fatigue. With these variables in mind, athletes can adopt a specific, individual or unique pacing strategy to suit the exercising requirements or demands (St Clair Gibson *et al.,* 2006; Tucker, 2009: Billaut *et al.,* 2011).

Research looking at the adoption of various pacing strategies in intermittent sports is limited due to the dynamic nature of these sports (Bishop, Edge, Davis and Goodman, 2004; St Clair Gibson *et al.,* 2006; Billaut *et al.,* 2011). The uncertainty associated with certain intermittent sports may affect an athlete's ability to adopt a suitable pacing strategy and thus negatively affect performance. Furthermore, very little research looking at repeated-sprint ability has been done due to the unpredictable nature of the players' movements during repeated-sprint bouts. Recently more research into repeated-sprint ability has been done as improvements in technology, such as the use of time-motion analysis, has allowed for more detailed analysis of movement patterns during repeated-sprints (Spencer *et al.,* 2005). Additionally, limited pacing research, specifically in intermittent sports, may be attributed to the lack of understanding of the complex nature of the brain, and the body's neural functioning in the absence of an exercise end point (Foster *et al.,* 2003; Abbiss and Laursen, 2008). Bishop *et al.* (2004) looked at fatigue during intermittent exercise and observed a reversible decline in the force production of muscles when the activated muscles are used at their maximum capacity. Lannergren and Westerblad, (1991) and Allen, Lamb and Westerblad (2008) found similar results when looking at repeated short-duration sprints (<10s), interspersed with brief recovery periods of (<30s). These findings are therefore in line with the Central Governor theory as they too found decreasing electromyography (EMG) activity and power output throughout the exercise bout. It can therefore be assumed that if findings in EMG activity between intermittent and endurance sports are similar, then pacing must too be present during the performance of intermittent sports (Bishop *et al.,* 2004).

2.3 UNCERTAINTY OF CRICKET

Cricket, and more specifically batting, is considered intermittent in nature (Woolmer *et al.,* 2008). This is defined as brief periods of intense cardiovascular and muscular activity, followed by brief periods of lower intensity activities (McArdle**,** Katch and Katch, 2001). The changes in intensities of energy transfer are therefore caused by the variation in activity, duration of exercise and rest periods.

2.3.1 BATTING

Batting requires intense sprinting efforts between wickets. The fast rate of acceleration and deceleration between the wickets during sprints elicits large amounts of eccentric muscle actions. These specific muscle actions cause longer lasting fatigue, loss in elastic energy production (Nicol *et al.,* 1991; Noakes and Durandt, 2000), microscopic muscle damage, weakness, soreness, decreased force production, optimal muscle length changes and a shift in the length-tension relationship of the damaged muscles (Nicol *et al.,* 1991; Stretch, 2001: Fridén, Lieber and Thornell, 1991; Thompson, Nicholas and Williams, 1999).

Noakes and Durandt (2000) proposed models for better understanding of fatigue; these are known as the physiological models of fatigue. The model which is most relevant in cricket and more specifically fatigue faced by batsmen is the biomechanical model. The biomechanical model proposes that an alteration in skeletal muscle function and loss of elastic energy production following repetitive eccentric muscle actions, influences performance. Eccentric muscle actions are explained by Noakes and Durandt (2000), to influence the elastic energy return function abilities of muscles. These decrements, due to eccentric muscle actions, are heightened by the presence of higher repetitions of accelerating and decelerating sprinting bouts (Noakes and Durandt, 2000; Faulkner, 2003; Greig and Siegler, 2009). Sufficient recovery time is required in order to fully recover from muscle damage induced by this form of activity, specifically, repeated sprint bouts.

While the physiological aspect of batting is arguably the most important factor influencing repeated sprint between the wickets, the cognitive and psychological side cannot be ignored. The intermittent nature of cricket can be extended to the cognitive and psychological uncertainty of batting in that there are certain variables which are not known at the beginning of a batting innings (Noakes and Durandt, 2000; Woolmer *et al.,* 2008). These variables include the lack of knowledge pertaining to the time spent at the crease, the intensity at which the batsmen is required to bat and the total number of runs to be made during the batting innings (Noakes and Durandt, 2000; Woolmer *et al.,* 2008). The absence of these variables prevents the batsmen from adopting specific pacing strategies which are aimed at preventing premature fatigue, as well as ensuring that optimal performance is maintained throughout the batting innings (Noakes and Durandt, 2000; Woolmer *et al.,* 2008). Batsmen therefore rely on their ability to pre-anticipate the requirements of each innings. The extent to which a batsman can accurately predict the physiological requirements needed during an innings is dependent on their level of batting experience. The level of experience of a batsman may be determined by to a combination of both intrinsic (innate) and extrinsic (environmental) factors. These contributing factors will be discussed in greater detail once the mechanisms of pacing have been addressed.

2.4 THE ANTICIPATORY FEEDBACK MODEL

The exact mechanism by which pacing strategies regulate exercise performance is not yet known. Based on the integration of the RPE, physiological functions and performance measures researched in various studies, a model termed the ‘anticipatory feedback’ model has however been proposed (Nielsen, Hyldig and Bidstrup, 2001; Nybo and Nielsen, 2001; Marino, Lambert and Noakes, 2004; Rasmussen, Stie and Nybo, 2004; Tucker *et al.,* 2006; Tucker, 2009). The ‘anticipatory feedback’ model depicts how the conscious perception of effort regulates exercise performance under all conditions to protect athletes from harm. In addition to this, the model facilitates in the selection of a maintaining work rate, ensuring optimal performance throughout the exercise bout without early termination due to lack of resource availability (Tucker, 2009). This model is said to utilize previous experience, anticipation of exercise distance or exercise duration, and physiological feedback to regulate performance and develop a suitable pacing strategy (Noakes and St Clair Gibson, 2004; Tucker *et al.,* 2006; Tucker 2009). Knowledge of these components therefore contributes to the development of task-specific pacing strategies. With specific reference to batting, the majority of these components are unknown at the beginning of a batting innings and thus conflict with the automatic regulation of a batsmen’s performance during an innings.

2.4.1 APPLICATIONS OF THE ANTICIPATORY RPE FEEDBACK MODEL

Simplistically, the anticipatory feedback model makes use of two constructs, the ‘template’ RPE and the ‘conscious’ RPE (Tucker, 2009). ‘Template’ RPE is the RPE that is set by the brain prior to the commencement of exercise. The brain makes use of previous experience to determine the exercise requirements needed during the work bout. These exercise requirements may include the correct allocation of energy resources, timing of muscle recruitment patterns, initial work rate and changes in power output (Noakes and St Clair Gibson, 2004; Tucker *et al*., 2006; Tucker, 2009). ‘Conscious’ RPE is however developed through afferent feedback signals received during the actual exercise bout (Tucker, 2009). Afferent signals are inclusive of both internal and external cues such as, information regarding temperature, humidity, wind resistance, heart rate, sweat rate, breathing frequency and perceived muscle fatigue (Noakes and St Clair Gibson, 2004; Tucker *et al*., 2006; Tucker 2009). As exercise commences, the brain then strives to ensure that the ‘conscious’ RPE matches the ‘template’ RPE throughout the exercising bout.

Noteworthy, both the 'template' RPE and 'conscious' RPE are not absolute values, but rather change throughout the exercise duration operating on a continuum (Tucker, 2009). The various components contributing to these two RPE values therefore work together ensuring that both values are as similar or as closely matched as possible throughout the entire exercising duration. The more accurate the coalition of these two values, the better the performance, as resources will be equally and accurately distributed throughout the exercising duration (Tucker, 2009). If the exercise duration is known prior to the start of the exercise bout, the initial match up of the 'template' and 'conscious' RPE, the rate of RPE increase, as well as the proceeding interplay between these two values during exercise, will be easier as a more realistic interpretation of the exercise requirements can then be made by the brain prior to the commencement of the work bout (Tucker, 2009). If, however, the athlete is unaware of the exercise requirements, either with regards to the exercising duration or total exercising distance, the brain may not be able to accurately anticipate all the exercise requirements. The absence of sufficient information regarding the exercise demands or requirements will result in the selection of a less realistic or unsuitable 'template' RPE (Tucker, 2009). This misalignment or mismatch will hinder optimal performance as incorrect allocation of resources will result in either underperformance or premature fatigue (Tucker, 2009). This therefore highlights the importance of the information, or lack of information, received before the commencement of exercise. The type or quality of performance is thus dependent on the details of information received before the start of an exercise bout (St Clair Gibson, Baden and Lambert, 2003; Noakes and St Clair Gibson, 2004; Tucker *et al*., 2006; Tucker, 2009; Eston, Stansfield, Westoby and Parfitt, 2012).

2.4.1.1 Underperformance

An athlete will unintentionally underperform if the actual length of exercise is shorter than the athlete was expecting (Figure 1, pg 13) (Tucker, 2009). The comparison between the athlete's 'template' RPE and the 'conscious' RPE will be incorrect as the duration of the exercise has been interpreted incorrectly. The anticipatory setting of the contributing factors such as the total work rate, initial work rate, rate of RPE increase and the interpretation of afferent feedback will all be based on the expectation of a longer exercise duration therefore resulting in an inaccurate distribution of resources during the exercise bout (Tucker, Kayser and Rae, 2007;

Tucker, 2009). Incorrect or misinformed exercise duration thus essentially causes an underutilization of physiological resources therefore resulting in an excessively large substrate reserve towards the end of the exercise bout (Tucker *et al*., 2007; Tucker, 2009).

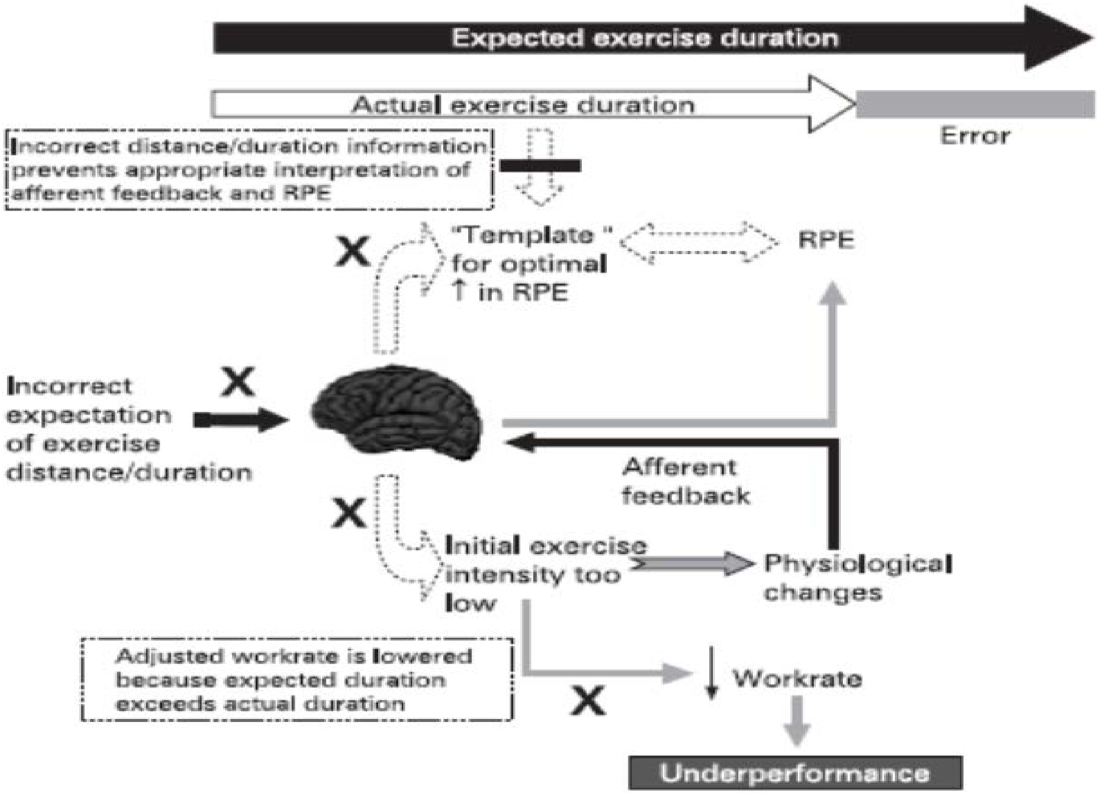

Figure 1: Schematic diagram showing underperformance during exercise due to no information regarding the exercise duration. Grey shadings denotes output from the brain, black shading denotes input to the brain and dashed white lines depict processes that are absent due to the lack of information. RPE, rating of perceived exertion (Tucker, 2009).

In cricket, opening batsmen are faced with the challenge of predicting the upcoming requirements based on little or no external information. Batsmen are therefore unaware of the duration they will be required to spend at the crease, as well as the total number of runs to be made during their batting innings (Noakes and Durandt, 2000; Woolmer *et al.,* 2008). According to the anticipatory model, in the absence of a definite end point, the brain selects a rough ‘template’ RPE (Tucker *et al*., 2007; Tucker, 2009). To complement this template, a slow initial work rate along with a slow rate of RPE increase is employed such as to ensure a constant substrate reserve which will allow batsmen to bat for an extended period of time. Variables such as power output, energy substrate allocations and heart rate will therefore remain fairly constant and within the batsmen's physiological limits (Tucker *et al*., 2007; Tucker, 2009). Batsmen will thus essentially be underperforming as the brain will warrant that resources are available for an indefinite amount of time (Figure 1, pg 13).

2.4.1.2 Premature Fatigue

Athletes are subjected to premature fatigue when the actual length of exercise exceeds the expected or anticipated duration of exercise (Figure 2, pg 15) (Tucker, 2009; Faulkner, Arnold and Eston, 2011). The anticipatory setting of the initial work rate, total work rate, the generation of 'template' RPE and the rate of RPE increase will therefore be selected under the pretences of a shorter exercise bout (Tucker, 2009). Additionally, the interpretation of the afferent feedback will also be based on the notion that the duration is shorter. This incorrect exercise duration results in the selection of a relatively greater work rate for the initial stages of the exercise bout (Tucker, 2009). This greater work rate will be maintained until the actual duration exceeds the expected duration. At this point, the brain then realizes the discrepancy between the 'template' RPE and 'conscious' RPE. A significant decrease in power output will result and an overall underperformance will be observed in the second stage of the work bout, in relation to the performance that could have been achieved if the correct duration was known prior to the commencement of exercise (Tucker, 2009).

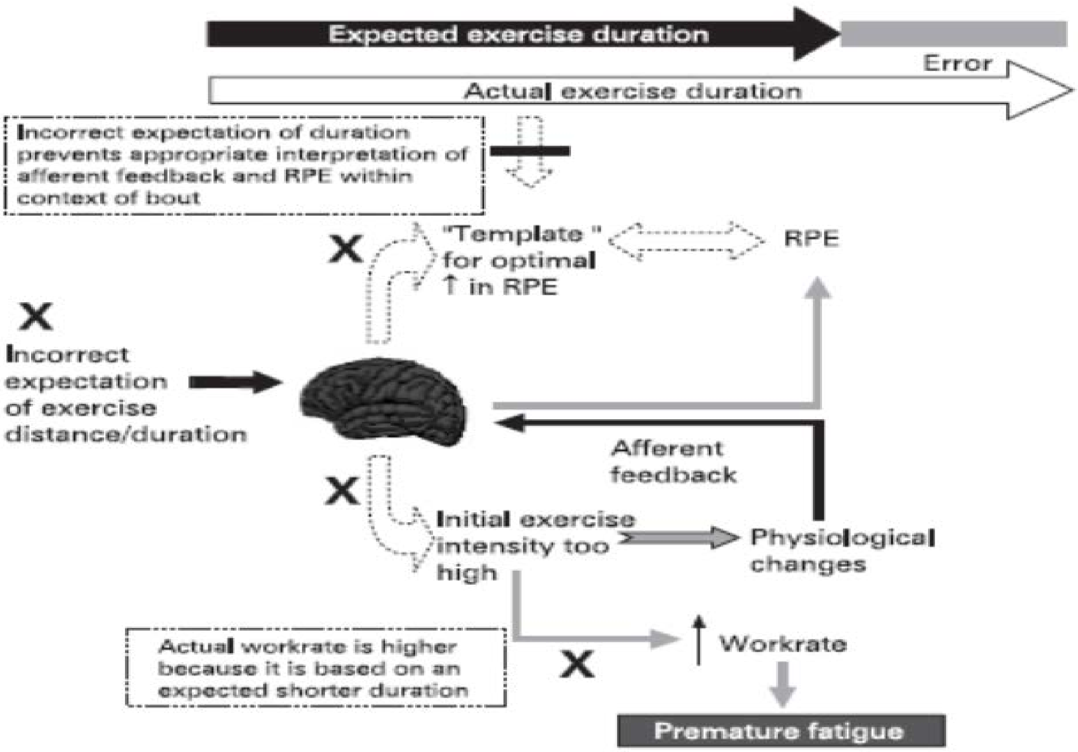

Figure 2: The anticipatory component of the model when incorrect information about the exercise duration is given prior to the commencement of exercise. Grey shadings denotes output from the brain, black shading denotes input to the brain and dashed white lines depict processes that are absent due to the lack of information. RPE, rating of perceived exertion (Tucker, 2009).

With regards to batting, batsmen are also subjected to premature fatigue if they anticipate a shorter duration spent at the crease. The initial and total work rate of the batsmen will be high, and the rate of RPE increase rapid, resulting in the allocation of the majority of the resources early on in the batting innings. In the likelihood of a change in the game situation, requiring batsmen to continue batting for an extended period of time, resources may be sparse due to the overutilization of these resources in the initial stages of the innings, and therefore limiting the extended performance.

2.5 THE INFLUENCE OF EXPERIENCE ON PACING

According to the ‘anticipatory feedback’ model, the level of experience of an athlete may have a great influence on an individual’s ability to develop and successfully implement a suitable pacing strategy during exercise (Tucker, 2009). This theory presumes that experienced athletes have the ability to generate more accurately matched ‘conscious’ and ‘template’ RPE, as well as a more suitable rate of RPE increase compared to that of less-experienced athletes (Tucker, 2009). Batting, being dynamic and self-paced in nature, requires constant recalculations with regards to the time spent at the crease, availability of resources and required duration of concentration (Noakes and Durandt, 2000; Woolmer *et al.,* 2008). The level of experience of the batsmen could therefore be a crucial factor in determining whether batsmen are able to rapidly adapt or alter their existing pacing strategies to suit or meet the new demands of the current game.

2.5.1 COMPARING PACING IN SKILLED AND LESS-SKILLED ATHLETES

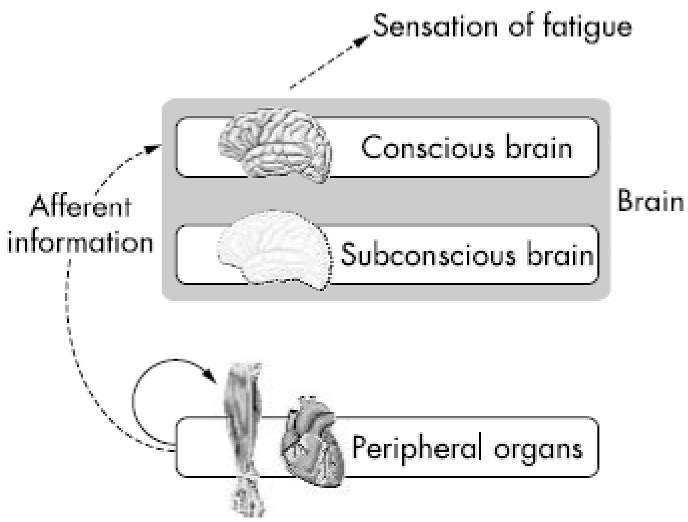

Figure 3: The peripheral model of fatigue illustrating the lack of input from the subconscious brain during the interpretation of fatigue (St Clair Gibson and Noakes, 2004).

The figure above illustrates the process of possible information transfer during exercise. Although this figure is specific to peripheral fatigue, is can further illustrate the lack of communication or interplay between the conscious and subconscious brain which may be apparent in less-experienced individuals (Figure 3, pg 16) (St Clair Gibson *et al.,* 2003; St Clair Gibson and Noakes, 2004; St Clair Gibson *et al.,* 2006). The absence of feedback from the subconscious brain is a consequence of lack of experience or exposure with regards to the task at hand. Afferent signals are sent directly to the conscious brain and interpreted immediately, therefore with no reference measures to draw from which would give the athlete a more realistic interpretation of the actual exercise demands (St Clair Gibson and Noakes, 2004; St Clair Gibson *et al.,* 2006). With specific reference to the anticipatory feedback model, during this circumstance, there is very little interaction between the 'template' RPE the 'conscious' RPE (Tucker, 2009). Contributing variables such as the rate of RPE increase, and the initial work rate will therefore not be able to interact and work together to ensure the selection of factors such as the correct allocation of resources, level of muscle recruitment, and the reserve of sufficient energy substrates, necessary to avoid premature fatigue and maintain optimal performance throughout the exercising bout (Tucker, 2009).

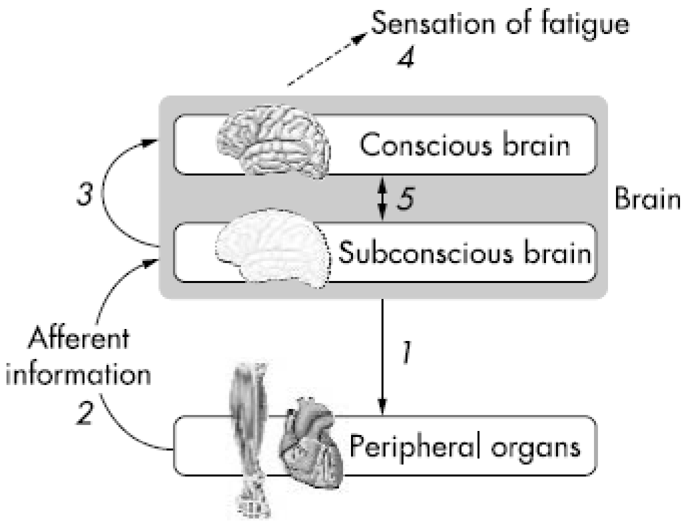

Figure 4: The central integrative model of exercise regulation illustrating the input from the subconscious brain (St Clair Gibson and Noakes, 2004).

The transfer of information in an experienced individual during exercise does however differ from less-experienced individuals, in that there is evidence of an active subconscious brain (St Clair Gibson *et al.,* 2003; St Clair Gibson and Noakes, 2004; St Clair Gibson *et al.,* 2006; Tucker, 2009). The subconscious brain therefore receives afferent information from the peripheral organs as well as communicates with the conscious brain during exercise (Figure 4, pg 17). The constant interplay between the conscious and subconscious brain ensures that the 'template' and 'conscious' RPE are closely and more accurately matched (Tucker, 2009). The selected initial and current work rate, rate of RPE increase, the allocation of energy substrates and level of muscle recruitment patterns will all complement each other throughout the exercising bout. The combination of these contributing variables will ensure optimal performance and prevent premature fatigue. Essentially, in order to be able to understand and assess the extent to which ‘experience’ has an influence on the processes which take place during anticipatory feedback in the brain; a clear concise definition of experience and its association with skill acquisition is needed.

2.6 DEFINING SKILLED VERSES LESS-SKILLED BATSMEN

Defining the characteristics or attributes of ‘skilled’ athlete is challenging due to the large number of contributing factors. These factors consist of both intrinsic and extrinsic factors (Tucker and Collins, 2012). Intrinsic factors are factors that people are born with, their innate characteristics. Extrinsic factors are however factors which are not inherent and therefore act from the external environment. The ‘Athletic Performance Model’ put forward by Tucker and Collins (2012), facilitates in identifying a number of intrinsic and extrinsic factors which may predispose certain individuals to achieving sporting success or skills mastery (Figure 5, pg 19).

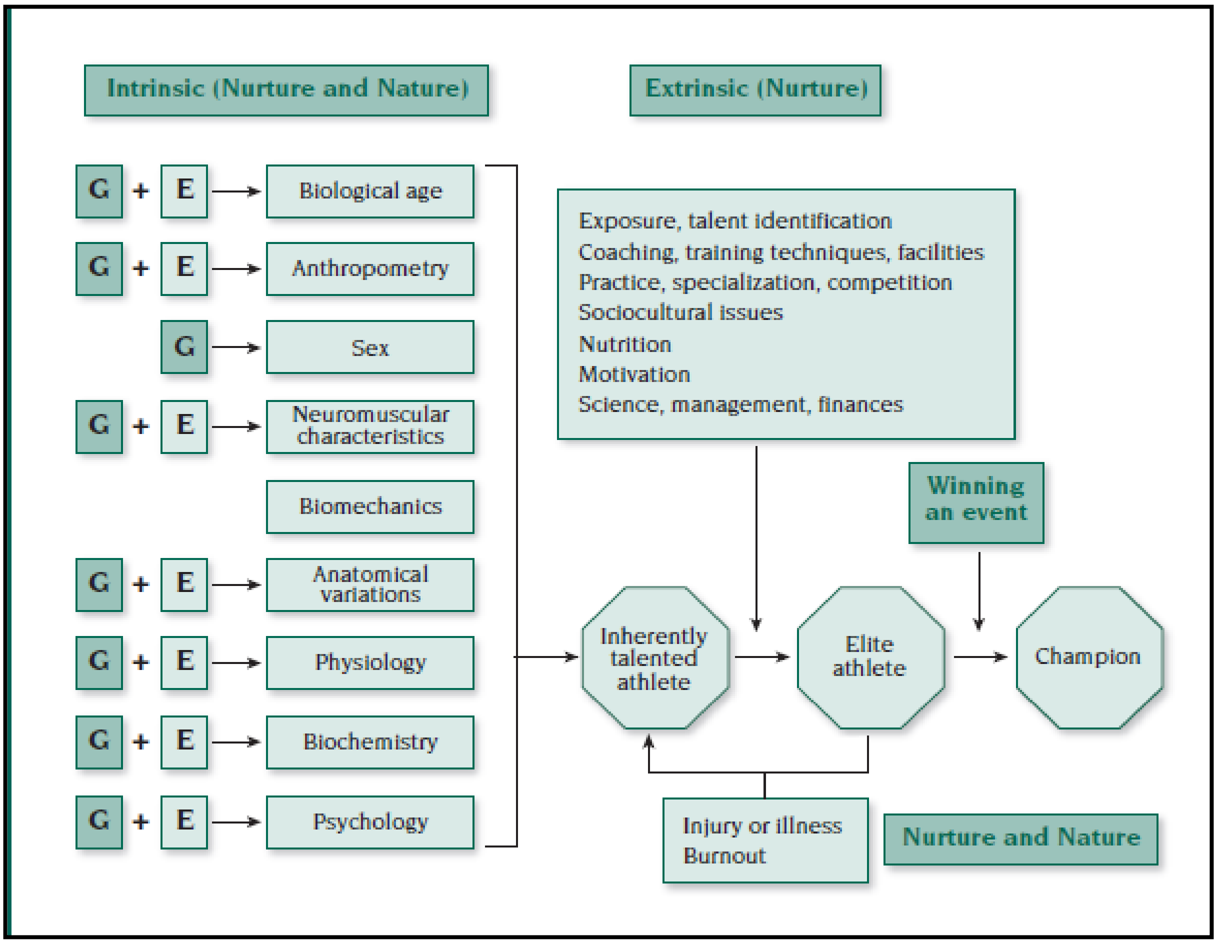

Figure 5: The complex relationship between intrinsic and extrinsic factors which determine superior athleticism. G denotes genetic (nature) and E denotes environmental (nature) factors (Tucker and Collins, 2012).

With specific reference to batting, instrinsic variables such as age, neuromuscular characteristics, physiology and the psychology of individuals all contribute to the process of becoming a skilled batsmen (Woolmer *et al.,* 2008). It is however the addition of extrinsic factors such as exposure, coaching, training techniques, practise, competition, specialization, motivation and optimal nutritition, which coagulate and allow an idivididual to obtain elite status (Higgins, 1991; Bennett, Button, Davids and Handford, 1997; Tucker and Collins, 2012). In summary, the 'Athletic Performance Model' states that players possess certain instrinsic factors which may predispose them to achieving skilled status, however its the addition of the external influences that essentially determine whether an individual will achieve sporting success. External input during the stages of skills acquistion is crucial in both the internalisation and mastery of a specific skill, in this case batting. Factors such as feedback during coaching, the accumulation of time spent in the nets as well as exposure to competition, all influence the 'level of performance' reached by players. It is therefore essential that we gain a more indepth understanding into how various skills are learnt, and what variables contribute to skills acquisition in the journey to becoming a skilled performer (Woolmer *et al.,* 2008).

2.7 KEYS TO SUCCESSFUL SKILL PRACTICE

Generally the learning of a skill involves practice over time (Higgins, 1991; Bennett *et al.,* 1997). Practice over an extended period of time will allow a beginner to progress through the various stages of learning to eventually become a skilled performer (Higgins, 1991; Bennett *et al.,* 1997). Quality practice time is essential for the successful development of skills. In order to be successful in the performance of a particular skill or sport, an individual must be prepared to maximize the number, type and length of practice sessions (Bennett *et al.*, 1997). Practice sessions must be specifically related to the task or activity played thus ensuring that training sessions incorporate situations similar to those experienced during an actual game. The level of skill of the athlete can therefore be determined by assessing and comparing the time spent in the total practice period, time spent on particular skills and the time spent at rest (Higgins, 1991; Bennett *et al.,* 1997). Skilled batsmen spend the majority of their practice time batting in the nets (Woolmer *et al.,* 2008). During this time, batsmen practice specific batting strokes, develop the ability to predict and judge ball projections, and learn to read and internalize decisions made by facing bowlers (Woolmer *et al*., 2008). This form of learning is known as trial and error learning and is a crucial component in the acquiring and mastering of a skill (Higgins, 1991; Bennett *et al.,* 1997). Time spent 'resting' is also a vital component in the conceptualizing and learning of a skill. With specific reference to batting, time spent watching a batting innings; either in person or with the use of technology, are said to develop a greater ability to read the game which contributes to the process of becoming a skilled batsmen (Woolmer *et al.,* 2008). This type of learning is characterized as cognitive learning and when combined with physical learning or learning through trial and error, batsmen increase their ability to accurately predetermine or pre-anticipate the batting requirements during actual match situations.

2.7.1 FEEDBACK

Feedback can be defined as the process in which athletes receive any sensory information regarding an action (Matschiner *et al*., 1998; Hodges and Williams, 2005). Feedback is crucial in the development of a skilled player as it allows for the improvement of performance through the receiving of information regarding any corrections that need to be made (Hodges and Williams, 2005). There are two types of feedback, namely internal and external feedback. Internal feedback, also known as intrinsic feedback, is feedback which comes from within the athlete. Alternatively, external feedback, also known as extrinsic feedback, is feedback that comes from external sources such as information received from coaches, team members and video footage (Hodges and Williams, 2005). With specific reference to batting, internal feedback would be cues received from the body's physiological subsystems. These physiological cues include information regarding body temperature, heart rate, breathing frequency and the availability and rate of uptake of energy substrates (Tucker, 2009; St Clair Gibson *et al.,* 2001; St Clair Gibson *et al.,* 2006). These factors all influence how batsmen perceive their 'conscious' RPE and according to the 'anticipatory feedback' model, this will affect how they chose to pace themselves as the match-up between the 'conscious' RPE and 'template' RPE is vital in optimizing the benefits of pacing. The ability to develop skills to interpret these internal signals sent by the physiological sub-systems can be obtained through time spent practicing either in the nets or during an actual game situation (Woolmer *et al.,* 2008). According to the 'anticipatory feedback' model, skilled batsmen have a greater ability to interpret these internal afferent signals as they have had more experience through greater exposure compared to less-skilled batsmen. Skilled batsmen can thus develop a more suitable pacing strategy prior to the commencement of a batting innings. The dynamic nature of the game further requires constant adjustments to the pre-determined or pre-established pacing strategy. Skilled batsmen are therefore able to make alterations to their existing pacing strategy more automatically than less-skilled batsmen who may take longer resulting in a temporary decrease in performance (Woolmer *et al*., 2008). This decrease in performance can be seen through the selection of the incorrect batting stroke or slower reaction time, either in the stroke played or the time taken to sprint between the wickets (Woolmer *et al*., 2008).

There are two forms of external feedback, namely knowledge of results and knowledge of performance. Knowledge of performance is based on the outcome of the performance and is therefore information provided externally after the completion of an action (Matschiner *et al*., 1998; Hodges and Williams, 2005). This information can either be internally or externally received. Knowledge of results allows the athlete to correct an action and thus informs the athlete about the success of the movement or action performed (Matschiner *et al*., 1998; Hodges and Williams, 2005). With regards to batting, external feedback would be provided by the coaches as well as the statistical analysis of a batsmen's performance. Coaches generally provide feedback in the forms of batting averages so batsmen can assess their performance or progress and aim to make the necessary changes to achieve their performance goals (Woolmer *et al*., 2008).

2.7.2 TIMING OF FEEDBACK

The timing of feedback is crucial in the learning of a skill (Matschiner *et al.,* 1998). Athletes can receive feedback before, during and after a performance. In terms of timing, there are two types of feedback, concurrent and delayed feedback. Concurrent feedback is feedback received during the performance of the skill (Matschiner *et al.,* 1998). Constant changes from the external environment as well as internal physiological changes are received as concurrent information and response to this type of information is immediate (Matschiner *et al.,* 1998). In the game of cricket, this feedback will be the information received during play and with specific reference to batsmen, during the batting innings itself. According to the 'anticipatory feedback' model, it is presumed that skilled batsmen are able to make the necessary alterations to their existing pacing strategy to control these changes to avoid a great shift in the 'conscious' RPE. Prior experience helps batsmen pre-anticipate most of the changes experienced during the innings therefore allowing them to maintain their performance. Less-skilled batsmen however may not anticipate certain external or internal physiological changes which will essentially create uncertainty. The 'conscious' RPE of less-skilled batsmen will suddenly change and this alteration may be dramatic. The brain will then realize the discrepancy in values of the 'conscious' and 'template' RPE, however due to lack of experience and learning, less-skilled batsmen may take longer to rectify the changes, resulting in a decrease in performance (Tucker, 2009).

The second type of timing feedback is delayed or terminal feedback (Matschiner *et al*., 1998). This feedback is provided after the performance of the action or skill. Athletes' are therefore unable to produce a response during the actual performance of the skill or action (Matschiner *et al*., 1998). In cricket, this feedback is the feedback received after the shot has been played. The batsmen has therefore made a decision and acted on it resulting in either a positive or a negative result. Although this type of feedback is delayed and changes cannot be made after a shot has been played, or likewise following the decision to run between the wickets, it is however still useful as it helps the batsmen interpret or internalize factors such as the current game situation, type of pitch, the positioning of the fielders and the type of balls being faced (Woolmer *et al.,* 2008). Through experience and time spent at the crease, skilled batsmen generally use delayed feedback to make minor alterations to their existing pacing strategy. Less-skilled batsmen may however struggle to internalize this feedback and make the necessary alteration as rapidly as skilled batsmen. This could be attributed to their lack of time spent at the crease or their inability to learn through trial and error. Ultimately, the inability to make use of both concurrent and delayed feedback in a dynamic environment will essentially cause a decrease in performance (Matschiner *et al*., 1998; Noakes and Durandt, 2000; Hodges and Williams, 2005; Woolmer *et al.,* 2008).

2.8 SUMMARY OF REVIEWED LITERATURE

To summarize, it can therefore be concluded that a pacing strategy is a measure of how this regulatory control process allocates the required physiological resources, based on information received both prior and during an exercise bout, to optimize performance and prevent the sensation of fatigue from rising excessively during exercise (Noakes and St Clair Gibson, 2004; Tucker, 2009). According to the 'anticipatory feedback' model, the level of experience of athletes will influence how an athlete develops and adopts a suitable pacing strategy to optimize their performance (Noakes and St Clair Gibson, 2004; Tucker, 2009). Experienced athletes are said to have a more automatic interplay between their 'conscious' and 'template' RPE allowing a faster regulation of exercise performance during a work bout. Less-experienced athletes lack the essential input of the subconscious brain during exercise which results in numerous performance decrements (Tucker, 2009). With specific reference to batting, the slightest lack of concentration, misjudgment of the game situation, or additional unforeseen energy costs may result in the termination of the batsmen’s batting innings. It is therefore crucial that batsmen develop the necessary skills to accurately interpret both internal and external inputs, especially in the tentative nature of the act of batting (Woolmer *et al.,* 2008).

CHAPTER III
METHODOLOGY

3.1 RESEARCH AIM

The aim of the study was to assess whether the absence of a known end point at the beginning of repeated sprint bouts between the wickets effects how batsmen pace themselves comparing skilled and less-skilled batsmen.

3.2 RESEARCH DESIGN

Three trials were completed by two groups of batsmen, those classified as ‘skilled’ and those as ‘less-skilled’ (Table I, pg 28).

3.2.1 DEVELOPMENT OF WORK BOUT

Previous research within the Human Kinetics and Ergonomics, Rhodes University, Grahamstown, South Africa, adopted a batting-specific protocol developed by King (2002). This protocol was developed through time-motion analysis conducted on high-scoring one-day Internationals (ODI’s) between 1991 and 2001. It was however suggested that a more recent time motion analysis be developed which would accurately represent more recent day matches.

Sheppard (2012) therefore conducted time-motion analysis on high-scoring one-day Internationals (ODI’s) from the 2010/2011 seasons which including South Africa, West Indies, Pakistan, India, New Zealand, Australia and England. This analysis differed from the analysis observed in the time-motion analysis developed by King (2002). Variations included an increase in both the durations between deliveries to the batsmen, as well as between each over. More specifically, Sheppard (2012) revealed that the mean duration between each ball delivered was found to be 32.67 seconds as opposed to the 30 seconds found in the 2002 analyses. Likewise, a further increase in the duration between each over was observed to be 79.80 seconds, as opposed to the 60 seconds previously found by King (2002). The protocol used in this specific study was therefore from Sheppard (2012) which was adapted from King (2002).

The batting-specific protocol required batsmen to face seven overs of six balls (42 deliveries). Batsmen were required to sprint a double shuttle run every third ball resulting in a total of 4 runs per over, a total of 28 runs overall (14 shuttle sprints). Each delivery was separated by a 32.67 second break and the duration between each over was 79.80 seconds. In order to ensure consistency, each ball (Slazenger practice ball) was delivered by the same research assistant as throw downs.

3.3 PILOT TESTING

Extensive pilot tests were completed prior to testing in order to ensure that the laboratory-specific protocol selected for the study was valid and accurate. The pilot tests involved specific analyses of the physiological, musculoskeletal and perceptual demands placed on the batsmen during the simulated batting work-bout. These tests were conducted to assess whether the selected protocol was in fact testing the presence of pacing during the experimental trials. The pilot tests further facilitated in analyzing the use of deception during the testing protocol and ensured that the researcher was familiar with the testing procedures to avoid the capturing of inaccurate data.

3.4 EXPERIMENTAL TRIALS

The three experimental trials were the Control trial (CT), Deceptive trial (DT), and Unknown trial (UT).

Control Trial (CT)

In this trial batsmen were required to perform a total of 14 shuttle sprints (28 runs). This trial was also referred to as the 'informed' trial as the batsmen were correctly informed of the total number of shuttle sprints to be performed. Batsmen therefore sprinted on command throughout the duration of this trial.

Deceptive Trial (DT)

This trial required batsmen to complete a total of 14 shuttle sprints (28 runs). Batsmen were however incorrectly informed of the total number of sprints to be completed at the beginning of the batting innings. Batsmen were told that they would be completing 7 shuttle sprints (14 runs). However, once these 7 shuttle sprints had been completed, players were required to complete an additional 7 shuttle sprints. Batsmen were therefore unaware of the last 7 shuttle sprints. Deception was used to assess whether the incorrect knowledge of the end point, affected the performance of the batsmen during the trial. This deceptive element further indicated how pacing strategies may have altered when the end point was shifted during the trial. Once the trial was completed, batsmen were then asked to sign a confidentially declaration which prevented batsmen from sharing information with the other batsmen regarding the deception experienced in this trial (See Appendix A, pg 105 and Appendix C, pg 126).

Unknown Trial (UT)

This trial required batsmen to complete a total of 14 shuttle sprints (28 runs). Batsmen were however not aware of the total number of sprints to be completed at the beginning of the batting innings. Batsmen were therefore required to run on command for an indefinite period. The uncertainty experienced by the batsmen during this trial was used to assess whether the lack of knowledge of an end point at the beginning of the batting innings, in this case the total number of sprints to be completed, affected both the performance of the batsmen, and the adoption of a more suitable pacing strategy. Following the trial, a confidentiality declaration was signed by the batsmen in order to prevent information being shared with the other batsmen partaking in this study (See Appendix A, pg 105).

3.4.1 ORDER OF TRIALS

The control trial was completed first and thus used as a reference trial. Batsmen were then randomly assigned to one of two pre-planned 'order of trials'. This stated the order in which batsmen would be required to complete the remaining two trials, namely the deceptive and unknown trials (CT; UT; DT or CT; DT; UT). The purpose of this was to prevent any learning effect as well as the ability of the batsmen to pre-anticipate the workload of each trial.

3.4.2 DESIGN MATRIX

Table I: Design matrix of the study

	CT	UT	DT
SKILLED			
LESS-SKILLED			

Where, CT = control trial, UT = unknown trial and DT = deceptive trial

3.5 DEPENDENT AND INDEPENDENT VARIABLES

3.5.1 DEPENDENT VARIABLES

Measures of Rating of Perceived Exertion (RPE), sprint time (of each shuttle run), and electromyography (EMG) of the selected muscles were used to analyze the presence of possible pacing during the performance of the three experimental trials. The muscles selected for the study were the vastus medialis (VM), vastus lateralis (VL), the biceps femoris (BF) and the semitendinosus (ST) muscles.

3.5.2 INDEPENDENT VARIABLES

Independent variables included the level of skill or experience of the batsmen and the three experimental trials (see 3.4, pg 26).

3.5.2.1 Level of skill or experience of the batsmen

Classifying skilled verse less-skilled batsmen poses many challenges due to a number contributing factors. Components such as accuracy, confidence, and ability to pre-anticipate ball trajectory and pitch, concentration, and general fitness, all influence the performance of batsmen when sprinting between the wickets (Woolmer *et al*., 2008). All these contributing components can be improved through practice (trial and error learning) and consistent exposure to the demands of a batting innings. The level of experience of a player was therefore selected based on the batsmen’s position in the batting order as well as the level at which the batsmen compete. Opening batsmen are more ‘skilled’ then lower order batsmen not only due to their success in striking the ball, but rather to their ability to read and manipulate the ball as well as the game situation. This ‘skill’ or quality develops through continuous exposure and practice (Matschiner *et al.,* 1998; Tucker and Collins, 2012). Opening batsmen spend more time, in both practice and real match situation, facing bowlers than lower order batsmen. This exposure allows batsmen to develop the ability to pre-anticipate the demands of the batting innings, thus eliciting a superior performance during the performance of the shuttle sprints. For the purpose of this study, opening batsmen will be classified as ‘skilled’ batsmen and lower order batsmen, will be classified as ‘less-skilled’ batsmen.

3.6 PLAYER SELECTION

Two sample groups were selected for the study. The first group consisted of experienced or skilled batsmen (n=12), and the second group consisted of the inexperienced or less-skilled batsmen (n=12).

3.6.1 INCLUSION CRITERIA

Male batsmen (n=24), between that age of 18 – 25 years, positioned in either the top five (skilled) or the bottom five (less-skilled) of the batting order of their current teams. These teams consisted of the Rhodes University cricket teams or Rhodes University Internal League teams. Batsmen completed the testing protocol within the training and competition season to make sure batsmen were of similar fitness during the time of testing.

Only batsmen with no history of recent injury (6 months) or illness were recruited. This was ensured by asking batsmen to complete a physical activity questionnaire (PAR-Q). The physical activity questionnaire was used to obtain information regarding the health status of the batsmen as well as their injury history. The physical activity questionnaire thus ensured that all batsmen were healthy and free of injury during the time of testing. Additionally, this information guaranteed that each batsman would be able to perform optimally throughout the data collection (Appendix A, pg 118).

3.7 ETHICS

Ethical approval was granted by the Department of Human Kinetics and Ergonomics, Rhodes University committee. In order to adequately assess the adoption of a pacing strategy during this protocol, deception is necessary. If batsmen were correctly informed of the total number of shuttle sprints to be completed in each of the trials, they will be able to pre-anticipate the performance requirements and develop a suitable pacing strategy prior to the commencement of each trial. Knowledge of the hypothesis of the study would therefore invalidate the testing. Deceiving batsmen is not to be taken lightly, however, deception has been used in many pacing-related studies (Ansley *et al.,* 2004; Billaut *et al.,* 2011 and St Clair Gibson *et al.,* 2006), and certain measures were put in place to ensure the safety and well-being of the batsmen in the study. Measures included maintaining the same total work output in all three trials. The total number of shuttle sprints to be completed by the batsmen therefore remained the same in each trial. Batsmen selected for the study were cricketers (specifically batsmen), and therefore familiar with the intermittent nature of batting.The deceptive nature of this study resulted in the need for two participant information letters and consent forms. The reason for this was not only to avoid ethical discrepancies but also to prevent players from informing other players about the deceptive nature of the experimental trials. Batsmen were therefore given both a pre-information letter and consent form. A verbal explanation of the testing requirements and procedures were also given to batsmen and batsmen were then asked to sign a participant consent form if they felt comfortable with the testing protocol (Appendix A, pg 106- 117). Participation in this study was therefore voluntary and batsmen were able to withdraw at any stage of the testing protocol if they felt it necessary to do so. See Appendix A and C for a detailed explanation of the ethical considerations, participants consent, information letters, the justification for the use of deception, and the anonymity of the results (Appendix A, pg 105-117 and Appendix C, pg 126).

3.8 TESTING ENVIRONMENT

Testing was held in the Department of Human Kinetics and Ergonomics, Rhodes University, Grahamstown, South Africa. In order to replicate a game situation, batsmen were required to perform shuttle sprints across a plywood runway, 17.68m in length (the length of a cricket pitch) (Figure 6A and B, pg 31). The runway was made of plywood which provided sufficient grip to prevent any slip, trip and fall incidents from occurring during the experimental trials (Figure 6A, pg 31). Other equipment included cricket nets surrounding the pitch to prevent any ball-related injuries and an LED (light emitting diode) timing system, used to measure the sprint time of each shuttle sprint performed by batsmen (Figure 6B, pg 31).

A) **B)**

Figure 6: Laboratory where the experimental trials were conducted with A) batsmen at batting crease with EMG electrode placement and B) the view of the batsmen performing a shuttle sprint on the walkway with net and LED system visible.

3.9 MEASUREMENTS AND EQUIPMENT

3.9.1 ANTHROPOMETRIC AND DEMOGRAPHIC MEASURES

During the habituation session, demographic and anthropometric data of each batsman were collected. Measures included stature, body mass and body mass index. Additionally, batsmen were also required to complete a physical activity screening questionnaire (PAR-Q) (Appendix A, pg 118).

3.9.1.1 Stature

Stature was measured using a Harpenden stadiometer (Holtain Ltd, Crymych, United Kingdom) and measured to the nearest millimetre (mm). In order to ensure standardisation, batsmen were requested to remove their shoes, stand in an upright position with their heels, shoulders and backs against the stadiometer. Batsmen were further requested to ensure that their head was in the Frankfort horizontal plane during the measuring process.

3.9.1.2 Body mass

The body mass was measured using a calibrated Toledo® electronic scale (Model 8142, Port Melbourne, Australia) during the habituation session. Batsmen were requested to remove clothing and accessories that were considered non-essential to this particular study. Non-essential items included shoes and heavy jackets. Each batsman was requested to stand as still as possible at the centre of the scale. Mass was recorded to the nearest 0.01 kilogram (kg). Batsmen were then required to put their full cricket kit on and follow the same weighing produced. Mass with kit was then recorded to the nearest 0.01 kilogram (kg).

3.9.1.3 Questionnaires

Batsmen were required to complete a PAR-Q and injury questionnaire (Appendix A, pg 118). These documents were used to assess whether batsmen had any previous injuries or medical conditions which may have interfered with the performance of the batsmen. An additional questionnaire was also administered pertaining details of each batsmen’s age, years of experience, position in the batting order and average number of runs made throughout their cricketing career were recorded (Appendix B, pg 124).

3.9.2 PHYSIOLOGICAL MEASURES

Muscle activity was recorded throughout each experimental trial.

3.9.2.1 MUSCLE ACTIVITY

An electromyography (EMG) device, specifically the biometrics Data Logger (Ltd DataLOG W4X 8, Gwent, United Kingdom), was used throughout the experimental trials to assess the batsmen’s level of muscle activation during the shuttle sprints.

3.9.2.1.1 Muscles selected for the study

The lower limb muscles, specifically the quadriceps and the hamstring muscle complexes were evaluated during the study. Four muscles were selected based on their role in lower limb propulsion as well as their close proximity to the skin surface. The two hamstring muscles selected for the study were the biceps femoris (BF) and the semitendinosus (ST) muscles, and the two quadriceps muscle chosen for the study were the vastus medialis (VM) and the vastus lateralis (VL) muscles (Figure 7 and 8, pg 34).

3.9.2.1.2 Electromyography procedures

The biometrics Ltd Data LOG W4X 8 uses analogue channels which were placed on the selected muscles. Four analogue channels were used in this study, one analogue for each of the selected muscles and one digital channel which was connected to a neutral electrode placed on an uninvolved or inactive muscle. In order to prevent interference with the EMG signals, any hair on the batsmen’s skin was removed by shaving. Alcohol based swabs were used to clean the shaven areas. The electrodes could then be placed on a smooth clean surface. The researcher then placed the electrodes on the muscle belly of the selected muscles. Information regarding the muscle activity was then transferred via infrared telemetry, and stored on a laptop. Batsmen were required to perform all-out maximal sprints to record their muscle activity. These measures were used as baseline measures and as points of reference throughout the experimental trials. The process of obtaining baseline measures is known as normalization and is an essential requirement when analyzing data collected from the EMG device. The baseline measures for each sprint in each trial were then recorded and compared by calculating the average EMG of each muscle measured.

Figure 7: Electrode placement for the quadriceps musculature, vastus medialis (right) and vastus lateralis (left) (Muscle Tester “Mega ME6000P16”, Mega Electronics Ltd, Finland).

Figure 8: Electrode placement for the hamstring musculature, biceps femoris (right) and semitendinosus (left) (Muscle Tester “Mega ME6000P16”, Mega Electronics Ltd, Finland).

3.9.3 PERCEPTUAL MEASURES

Ratings of Perceived Exertion (RPE) were obtained from each batsman throughout all three experimental trials:

3.9.3.1 RATING OF PERCEIVED EXERTION (RPE)

Exertion is based on the physical sensations experienced by an individual during physical activity (Borg, 1982). The Borg Rating of perceived Exertion Scale rates exertion on a level from six to 20, with level six representing minimal effort and level 20 representing maximal effort or complete exhaustion. PRE can be both ‘central’ and ‘local’ in nature. ‘Central’ Ratings of Perceived Exertion (RPE) are ratings representing the central cardio-respiratory strain and ‘local’ RPE are ratings representing the perceptions of muscular effort (Appendix B, pg 123). The Borg scale is a subjective measure however the ratings collected from each batsmen, facilitated in providing a fairly good estimate of the perceived muscle fatigue experienced during each trial. RPE was therefore used to determine the batsmen's perceived physical effort experienced during the batting protocol in all three trials. During testing, batsmen were required to rate both 'central' and 'local' RPE to determine their level of perceived exertion. Ratings took place after every over (after every six balls), during the allocated rest period, in all three trials. The reason for obtaining both RPE ratings is to allow for the comparison between the cardiovascular strain and muscular strain experienced. These comparisons further facilitated in assessing whether the knowledge of an exercise end point may in fact influence these perceptual measures.

3.9.4 PERFORMANCE MEASURES

Sprint times were recorded during each experimental trial and used as an indicator of each batsman's sprinting performance.

3.9.4.1 SPRINT TIMES

An LED (light emitting diode) timing system (developed within the Human Kinetics and Ergonomics department, Rhodes University, Grahamstown, South Africa) was used throughout the trials to monitor the speed at which batsmen sprinted between the wickets (a double shuttle run). The LED system consists of a beam between two points and was positioned at the batting crease. The timer would be stopped through a sensor feedback system and recorded on the completion of a shuttle sprint (Figure 6B, pg 31). The recorded time was then used as a performance measure and as an indicator that the batsmen had returned to the batting crease.

3.10 EXPERIMENTAL PROCEDURES

Batsmen were required to attend one introductory and habituation session and three experimental trial sessions. All sessions were held in the Department of Human Kinetics and Ergonomics, Rhodes University, Grahamstown, South Africa.

3.10.1 INTRODUCTORY AND HABITUATION SESSION

The purpose of the introductory session was to verbally inform batsmen of the aims, purpose and experimental procedures of the study. Batsmen were then given a letter of information and the opportunity to ask any questions pertaining to the study.

Batsmen were then requested to sign a consent form which expressed their understanding of the testing procedures as well as their willingness to participate in the study. This was followed by the habituation session. The purpose of this session was to familiarize batsmen with both the equipment used and the procedures followed in the study. The anthropometric data were then collected. These measures included the body mass, stature and body mass index of the batsmen. A calibrated Toledo® electronic scale was used to measure each batsman's mass. Batsmen were required to remove their shoes and stand on the centre of the electronic scale. Stature was measured using a Harpenden stadiometer. Once the basic anthropometric data had been recorded, the Borg Ratings of Perceived Exertion (RPE) scale was explained in great detail to each batsman. The correct interpretation of the values on this scale formed a vital part of the data collection. It was therefore essential that all batsmen understood what each value on the scale represented in order to obtain accurate data during the testing sessions. Batsmen were then habituated to Electromyography and the associated electrode placement protocol. This introduction and habituation session lasted approximately 30 minutes.

3.10.1.2 Electromyography Normalization

In order to analyze the raw EMG obtained from the study, a data reduction tool, Data Analysis Version 4.08, was used (Goebel, Human Kinetics and Ergonomics department, Rhodes University, Grahamstown, South Africa). The average EMG of each muscle was first calculated and then reduced using Data Analysis Version 4.08. The data obtained from the data reduction tool was then analyzed further in Statistica (StatSoft, Inc. (2013) STATISTICA© Version 11.0).

3.10.2 EXPERIMENTAL SESSIONS (3 TRIALS)

The three trial sessions were held in the Department of Human Kinetics and Ergonomics, Rhodes University, Grahamstown, South Africa. The batsmen were required to complete the three experimental trials on non-consecutive days. Batsmen were required to arrive in full kit. Firstly the researcher shaved the necessary areas on the batsmen's' legs in order to place EMG electrodes on the belly of the selected muscles. Batsmen were then required to complete a 5 minute warm up which consisted of a two minute jog and a full body stretch. In order to obtain baseline EMG measures, batsmen were then required you to complete an all-out maximal shuttle sprint across the length of the wooden runway. Following this the actual testing session commenced.

The control trial, deceptive trial and the unknown trial each consisted of 7 overs or 42 deliveries (14 shuttle sprints or 28 runs). Trials were therefore identical in work load however differed with regards to the information provided to batsmen prior to the commencement of each trial. All batsmen were required to complete the control trial first. This trial therefore acted as a reference point. Batsmen were then randomly assigned to one of two ‘order of trials’ thus ensuring an even split between the skilled and less-skilled batsmen. The randomization of the order of the trials further aimed to prevent batsmen from indentifying any patterns which may have revealed the hypothesis of the study. Batsmen were therefore either required to complete the unknown trial (provided with no knowledge pertaining to the total number of sprints to be completed) or the deceptive trial (incorrect information regarding the total number of sprints to be completed), following the completion of the control trial. Regardless of the trial being performed, the protocol involved batsmen facing six balls; these balls were delivered at a constant speed to the batsmen, by the same research assistant. These six balls faced represented one over of real match play and therefore batsmen were expected to face a total of 7 overs (42 deliveries). After every third ball, batsmen were required to complete a double shuttle sprint at an all out sprint effort. This was ensured through continuous verbal encouragement, proved by the researcher. The time of each shuttle-sprint was recorded with the help of the LED timing system. Perceptual data, namely ‘central’ and ‘local’ RPE information were collected after each over using the RPE scale.

Noteworthy, all batsmen received the pre-protocol information letter and the pre-protocol informed consent prior to testing. Declaration letters were given to batsmen following both the deception trial and the unknown trial. Additionally, on completion of the final trial, batsmen were given both the post information letter and the post consent form.

3.11 STATISTICAL ANALYSES

Statistical analyses were performed using Statistics software (StatSoft, Inc. (2013) STATISTICA© Version 11.0). Prior to statistical analyses, descriptive analyses and tests to determine normal distribution were conducted using STATISTICA. Two-way Analyses of Variance (ANOVA) with repeated measures for group and sprints were used to compare the average musculoskeletal, physiological and perceptual measures of both group in each trial. Additionally, a one-way ANOVA with repeated measures for sprints were used to compare the musculoskeletal, physiological and perceptual measures of each group individually across all three trials (Table II, pg 38). Post hoc Tukey analyses were used to highlight where the significance was situated. The level of significance was set at 0.05, associated with a confidence interval of 95%.

Table II: Statistical methods used to determine the following effects

	Effect	**Statistical Method of Analysis**
Group Effect (individual trials, both groups)	Group	**Two-way ANVOA**
	Sprints	
	Sprints*Group	
Trial/Sprints Effect (CT, DT, UT)	Sprints	**One-way ANOVA**

3.11.1 KEY CONSIDERATIONS FOR STATISTICAL INTERPRETATION

Throughout the results chapter, *group*, *sprints*, and *sprints*group* effects will be referred to.

The effect of *group* or *group* effect refers to the difference in responses between the two experimental groups: skilled and less-skilled batsmen, corresponding to the three experimental trials. This effect is considered in the analysis of the performance of the groups in each of the three trials when analyzed separately.

The effect of *sprints* or *sprints* effect refers to differences in performance over time in each trial. The *sprints* effect is considered in the analysis of the performance of the groups over the sprint series in each trial separately.

The *sprints*group* effect refers to the interaction between the groups (skilled and less-skilled) performance (dependent variables) over time in each of the experimental trials. This analysis will indicate whether the dependent variables are affected by the skill level of batsmen or rather, are independent of skill.

3.11.2 STATISTICAL HYPOTHESES

The following hypotheses are valid for all effects under investigation in this study when all three experimental trials (Control Trial, Deceptive Trial and Unknown Trial) are analysed separately:

GROUP EFFECTS

Physiological measures (muscle activity of the semitendinosus muscle, muscle activity of the biceps femoris muscle, muscle activity of the vastus medialis muscle and muscle activity of the vastus lateralis muscle), perceptual measures (‘central’ and ‘local’ ratings of perceived exertion) and performance measures (sprint times).

Control Trial, Deceptive Trial and Unknown Trial

Hypothesis 1:

Ho: $\mu_S = \mu_{LS}$

Ha: Not all equal

Where: S = skilled batsmen and LS = less-skilled batsmen

SPRINTS/TRIAL EFFECT

The following hypothesis is relevant for both the skilled and less-skilled batsmen for the following measurements under investigation when all three experimental trials (Control Trial, Deceptive Trial and Unknown Trial) are analyzed separately:

Physiological measures (muscle activity of the semitendinosus muscle, muscle activity of the biceps femoris muscle, muscle activity of the vastus medialis muscle and muscle activity of the vastus lateralis muscle), perceptual measures (‘central’ and ‘local’ ratings of perceived exertion) and performance measures (sprint times).

Control Trial, Deceptive Trial and Unknown Trial

Hypothesis 2:

Ho: $\mu_1 = \mu_{L2} = \mu_3 = \mu_4 .... = \mu_{14}$

Ha: Not all equal

Where: S1-S14 represents sprint 1 to sprint 14

CHAPTER IV

RESULTS

4.1 INTRODUCTION

The aim of this investigation was to assess whether the absence of a known end point at the beginning of a batting innings influenced how batsmen paced themselves when sprinting between the wickets. The results are presented as baseline information relevant to player characteristics followed by the responses of the two groups (skilled verse less-skilled) across trials, starting with the performance measure of sprinting times and moving to the other dependent variables of interest ('central' RPE, 'local' RPE and the muscle activation of all four muscles).

4.2 BASELINE MEASURES

Table III: Mean anthropometric and demographic data of skilled batsmen

MEASURE	MEAN	SD	CV (%)
Age (years)	21.20	2.14	10.09
Stature (mm)	1762.00	54.04	3.06
Mass without kit (kg)	73.91	7.72	10.44
Mass with kit (kg)	76.32	7.86	10.29
BMI ($kg.m^2$)	24.16	2.36	9.76

BMI=Body Mass Index, SD=Standard Deviation, CV=Coefficient of Variance

Table IV: Mean anthropometric and demographic data of less-skilled batsmen

MEASURE	MEAN	SD	CV (%)
Age (years)	21.42	1.82	8.49
Stature (mm)	1718.35	43.98	2.55
Mass without kit (kg)	71.19	3.35	4.70
Mass with kit (kg)	73.66	3.32	4.51
BMI ($kg.m^2$)	24.13	1.21	5.01

BMI=Body Mass Index, SD=Standard Deviation, CV=Coefficient of Variance

Table III and IV illustrate the general anthropometric and demographic measurements of both the skilled and less-skilled batsman. A total of twelve skilled and 12 less-skilled batsmen, with the mean ages of 21.20 (±2.14) and 21.42 (±1.82) years respectively, agreed to participate in the study. Tables III and IV indicates a low variability within and between all baseline measures.

4.3 SUMMARISED GROUP AND SPRINTS EFFECTS

Table V provides a summary of the significant group and sprints effects for the dependent variables measured. Additionally, Table V summarises the significant group and sprint interactions and thus provides a good overview of the significant findings of the study.

Table V: Summary of significant group, sprints, sprints*group, effects for dependent variables (**S** denotes skilled batsmen, **L** denotes less-skilled and ^{X} denotes a significant difference, where $p<0.05$).

	Effect	Muscle Activity				Sprint Times	RPE	
		S	BF	VM	VL		(local)	(central)
Control Trial	Group					X	X	X
	Sprints	L^{X}	L^{X}		L^{X}	S^{X}	L, S^{X}	L, S^{X}
	group*sprints		X		X		X	X
Deceptive Trial	Group					X		X
	Sprints	L^{X}		L^{X}			L, S^{X}	L, S^{X}
	group*sprints	X						X
Unknown Trial	Group					X		X
	Sprints		S^{X}	L,S^{X}	S^{X}		L, S^{X}	L, S^{X}
	group*sprints							X

L^{X} and S^{X} indicate significant trial effects within each group

For L^{X} and S^{X} statistical tables see Appendix D, pg 129-152 (Tables 1-37 and A-V)

4.4 SPRINT TIMES

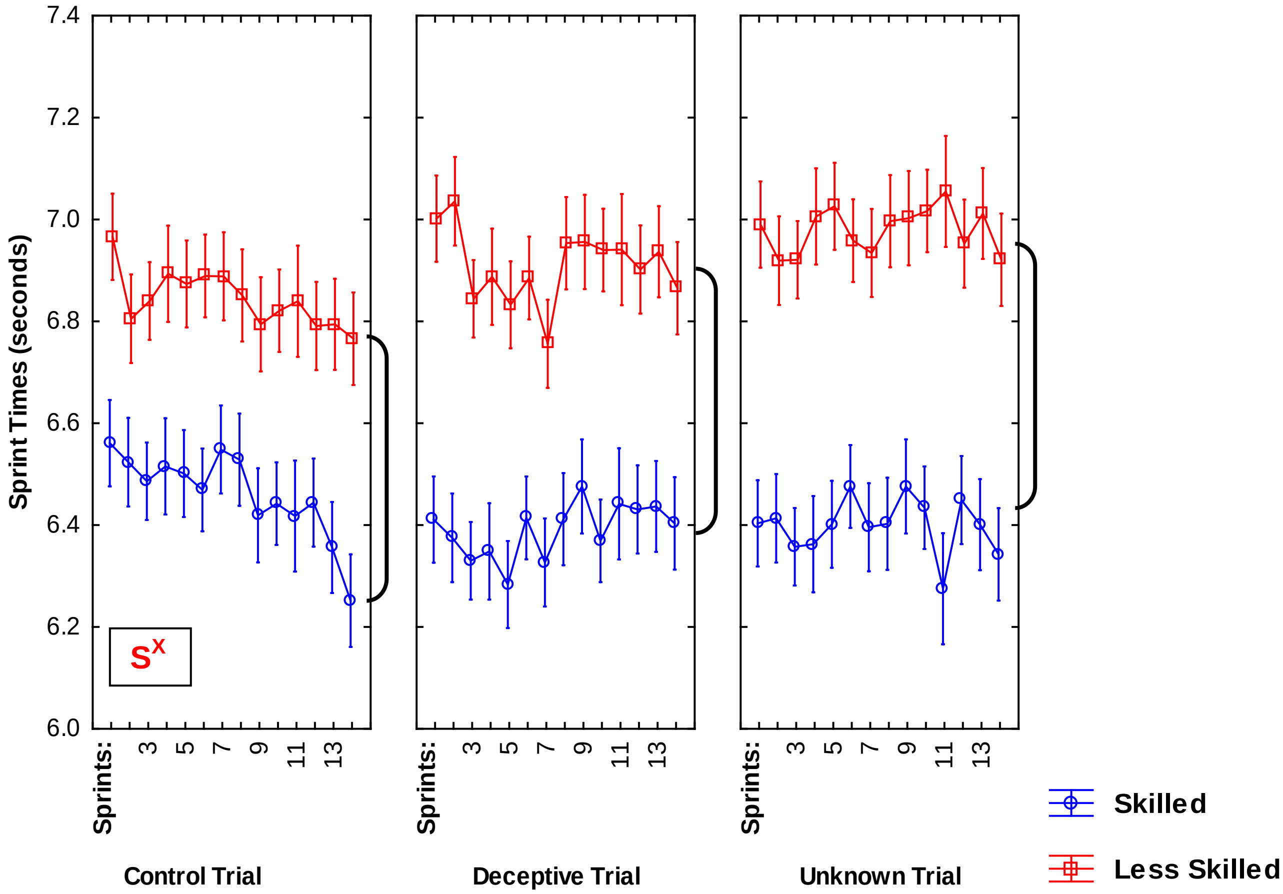

Figure 9: Mean sprint times (seconds) of both groups throughout the shuttle sprint series in all the three trials, ( ] represents a significant difference between the groups (Appendix D, pg 129), and S^X and L^X represents significant sprints/trial effects, see Appendix D, pg 137. $p<0.05$; Error bars denote 95% confidence interval).

4.4.1 GROUP EFFECT

When analysing the sprint times of both groups in each trial separately, a significant group effect was apparent, where skilled batsmen obtained faster mean sprints times in comparison to the less-skilled batsmen in all three trials (CT, p=0.000; DT, p=0.000, and UT, p=0.000) (Appendix D, pg 129; Figure 9)

In the control trial, skilled batsmen had the faster mean (6.46s) sprint time compared to the less skilled batsmen (6.84s). Noteworthy, sprint times got faster in both groups over the 14 shuttle sprints. Specifically, when comparing the change in sprint times over the sprint series, from shuttle 1 to shuttle 14, results showed that less-skilled batsmen had a 0.19s decrease in sprint time and skilled batsmen a 0.30s decrease in sprint time. Noteworthy is that the fastest shuttle for the less-skilled batsmen was the last shuttle (6.76s) and likewise for the skilled batsmen (6.25s).

In the deceptive trial, skilled batsmen obtained the fastest overall sprints times (a mean of 6.40s) in comparison to the less-skilled batsmen (a mean of 6.90s). Noteworthy, batsmen were under the impression that there were only 7 shuttle sprints to be completed in this trial. Thus when comparing the sprint times of shuttle 1 and shuttle 7, results indicated that skilled batsmen decreased their sprint time by 0.08s and less-skilled batsmen by 0.25s. However, when comparing the change in sprint times between shuttle 7 and shuttle 14, skilled batsmen had a 0.07s increase and less-skilled a 0.10s increase in sprint times. Noteworthy, the fastest shuttle for the less-skilled batsmen was shuttle 7 (6.75s) which was 0.11s faster than the final shuttle. Additionally, skilled batsmen obtained their fastest sprint time during shuttle 5 (6.28s) which was 0.12s faster than the sprint time obtained during the final shuttle sprint.

In the unknown trial, skilled batsmen, once again, obtained the fastest sprints times (a mean of 6.39s) compared to the less-skilled batsmen (a mean of 6.97s). Generally, both groups presented with fairly consistent times over all 14 shuttle sprints. When comparing the sprint times between shuttle 1 and shuttle 14, very little change over time was seen, with less-skilled batsmen had a 0.07s decrease and skilled batsmen a 0.06s decrease in sprint times. Both groups thus got faster over the 14 shuttle sprints in the series. Noteworthy is that the fastest shuttle for the less-skilled batsmen was the last shuttle (6.92s) while the fastest shuttle for the skilled batsmen was shuttle 11, which was 0.07s faster than shuttle 14, the last shuttle.

4.4.2 SPRINTS/TRIAL EFFECT

Skilled Batsmen:

When analysing the sprint times of the skilled batsmen in the control trial separately, a significant ($p=0.001$) decrease in sprint times over the 14 shuttle sprints was apparent. More specifically, post hoc analyses revealed that shuttle 14 was significantly faster than shuttle 1, shuttle 2, shuttle 4, shuttle 5, shuttle 7 and shuttle 8

(Appendix 4D, pg 129 and A, pg 137). Interestingly, when comparing the change in sprint times between shuttle 14 and shuttle 1, batsmen had a 0.30s decrease over time. However, of those 0.30s, 0.19s of that decrease occurred between shuttle 12 and 14 which may indicate a possible end spurt. There were no significant differences between the sprint times in both the deceptive and the unknown trial, where mean sprint times were similar and consistent over the 14 shuttle sprints (Table V, Figure 9).

Noteworthy, in the deceptive trial, skilled batsmen had a 0.08s decrease between shuttle 1 and shuttle 7, however between shuttle 7 and shuttle 14, batsmen showed a 0.09s increase in sprint times and thus a slowing down was evident When, however, comparing the overall change in sprint times, (sprint times between shuttle 1 and shuttle 14), batsmen had a 0.01s decrease, thus managing to become faster over the sprint series regardless of the deception in the trial.

Likewise for the unknown trial, although the end point was not known prior and throughout this work bout, batsmen were able to achieve a fairly stable sprint performance. Batsmen become faster over the sprint series with a 0.05s decrease in initial sprint times. This result suggests that batsmen were not in a fatigued state following the 14 shuttle sprints regardless of the lack of information pertaining to the exercise end point.

Less-skilled Batsmen:

When analysing the sprint times of the less-skilled batsmen in each trial separately, there were no significant differences over time, in all three trials (Table V, Figure 9).

In the control trial, although sprint times remained fairly consistent throughout the sprint series, a decrease over time was still apparent with shuttle 14 being the fastest shuttle of the series (6.76s). Interestingly, the largest decrease in sprint times was evident between shuttles 1 and 2, where batsmen had a 0.16s decrease. It is probable that this immediate decrease in sprint times may have been a consequence of the unfamiliarity batsmen experienced with the testing procedures as this trial, the control trial, was the first trial completed by batsmen. Noteworthy is that batsmen were also ‘less-skilled’ implying that perhaps following their first ‘all out’ shuttle sprint, they realised they would have to decrease their intensity as they would not be able to maintain that performance throughout without experiencing fatigue.

In the deceptive trial, a comparison of the first 7 shuttle times with the last 7 shuttle times indicated that performance was not negatively affected by the misleading information provided to batsmen. From shuttle 1 to shuttle 7, they were able to achieve a 0.24s decrease in sprint times thus becoming faster. Batsmen then had a 0.10s increase in sprint times over the second sprint series. However, when comparing shuttle 1 and shuttle 14, there was a 0.13s decrease in initial sprint times thus becoming faster over the trial series.

Lastly, in the unknown trial, batsmen demonstrated a consistent performance throughout, where shuttle 1 (6.99s) and shuttle 14 (6.92s) were comparable regardless of the lack of knowledge pertaining to the total number of shuttle sprints. Noteworthy, shuttle 14 was the fastest sprint of the sprint series which may suggest a possible learning effect as presumably, batsmen were unaware that shuttle 14 was their final sprint of the sprint series.

4.5 CENTRAL RATINGS OF PERCEIVED EXERTION

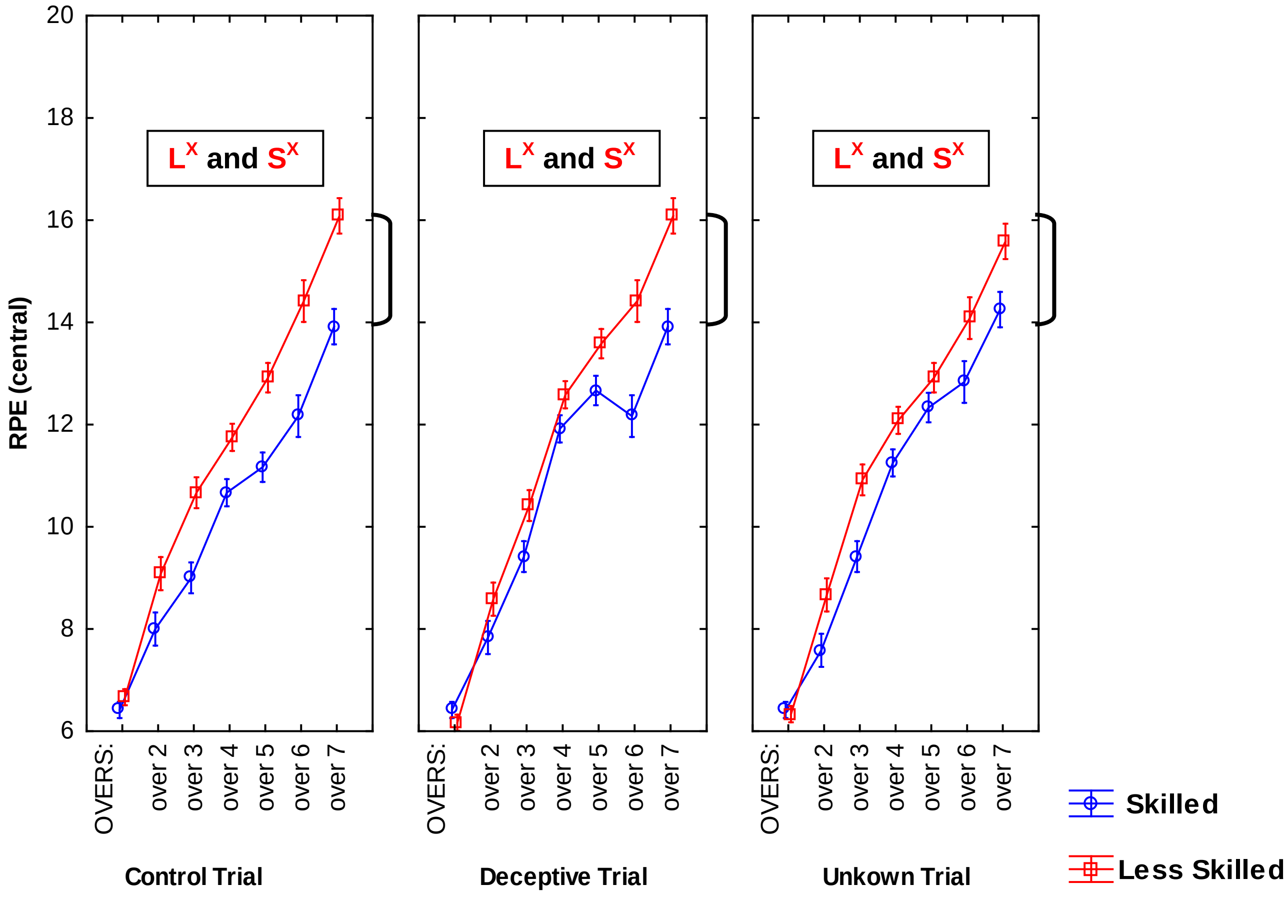

Figure 10: Mean 'central' RPE of both groups throughout the 7 overs in all the three trials, ( ] represents a significant difference between the groups (see Appendix D, pg 130), and **S**[x] and **L**[x] represents significant sprints/trial effects, see Appendix D, 130 and 138 pg p<0.05; Error bars denote 95% confidence interval).

4.5.1 GROUP EFFECT

Significant group effects were evident in all three trials, where less-skilled batsmen obtained higher mean 'central' RPE ratings in comparison to the skilled batsmen (CT, p=0.000; DT, p=0.002, and UT, p=0.002) (Appendix D, pg 130; Figure 10).

Looking specifically at the control trial, less-skilled batsmen reported a mean 'central' RPE of 11.65 compared to skilled batsmen who reported an RPE rating of 10.19. Both groups illustrated a significant (p=0.000) increase in mean ratings over the 7 overs in the trial (Appendix D, pg 130).

Furthermore, overs and group (*overs*group*) interacted significantly (p=0.000), where both groups had an increase in RPE ratings from over 1 to over 4. Following over 4, less-skilled batsmen continued to increase steadily, whereas the skilled batsmen had a more gradual increase over time (Table V, Figure 10 and Appendix D, pg 130).

Likewise, less-skilled batsmen obtained higher mean ‘central’ RPE rating (11.69) compared to skilled batsmen (10.61) in the deceptive trial. A significant (p=0.000) overs and group interaction was evident, where both groups increased significantly from over 1 to over 4. Following over 4, groups diverged. Skilled batsmen had a decrease in ratings, specifically between over 5 and over 6. Following this decrease, RPE ratings were then seen to increase significantly between over 6 to over 7. Following over 4, less-skilled batsmen continued to rise at a more gradual rate for the remaining 3 overs (Appendix D, pg 130).

Furthermore, less-skilled batsmen once again had higher mean ‘central’ RPE (11.51) rating in comparison to skilled batsmen (10.58) in the unknown trial. Additionally, overs and group interacted significantly (p=0.000), where both groups had steady and significant increases in ‘central’ RPE from over 1 to over 7. Interestingly, less-skilled batsmen perceived their central RPE approximately one rating higher than skilled batsmen at each over throughout the trials (Appendix D, pg 130).

4.5.2 SPRINTS/TRIAL EFFECT

Skilled Batsmen:

General trends indicated that skilled batsmen perceived their highest mean ‘central’ RPE ratings in the deceptive trial (10.61) and the lowest in the control trial (10.19). This was to be expected due to the nature of both of these trials with regards to the anticipated exercise requirements (Figure 10).

When looking at the ‘central’ RPE ratings of the skilled batsmen in each trial separately, significant (CT, p=0.000; DT, p=0.000, and UT, p=0.000) increases in ‘central’ ratings were apparent over the overs in all three trials. In the control trial, ‘central’ RPE ratings increased significantly from over 1 to over 7, excluding between over 2 and 3, and between over 4 and 5, and over 5 and 6, where no significant differences between ratings were evident (Appendix 8D, pg 130 and B, pg 138). The highest ratings (13.91) were reported following over 7. According to the Borg scale, batsmen perceived their cardiovascular strain to be ‘somewhat hard.’

Likewise, in the deceptive trial, ‘central’ RPE ratings increased significantly from over 1 to over 7, excluding over 4 and 5, over 4 and 6, and over 5 and 6, where ratings were not significant. The step-like progression of the reported ratings may be attributed to the deception evident in the trial. Batsmen constantly had to readjust contributing components such as template RPE, rate of RPE increase, work rate and the interpretation of afferent feedback. Interestingly, ratings were reported as 11.91 following shuttle 7 which suggests that batmen perceived their cardiovascular strain to be between ‘fairly light’ and ‘somewhat hard’. Following the final over, skilled batsmen reported a rating of 13.91 with a verbal anchor of between ‘somewhat hard’ and ‘hard’ (Appendix 9D, pg, 130 and C, pg 138).

Finally, in the unknown trial, post hoc analyses found significance (p=0.000) between over 1 to over 7, excluding over 5 and 6 where no significance was evident (Appendix 10D pg, 131 and D, pg 139). Highest ratings (14.25) were apparent following over 7 and indicated that skilled batsmen perceived their cardiovascular effort to be between ‘somewhat hard’ and ‘hard’.

Less-skilled Batsmen:

General trends indicated that less-skilled batsmen reported their highest mean ‘central’ ratings in the deceptive trial (10.69) and the lowest in the control trial (10.51), which was the same as the skilled batsmen (Figure 10).

Similarly to skilled batsmen, when analysing the ‘central’ RPE ratings in each trial separately, significant (CT, p=0.000; DT, p=0.000, and UT, p=0.000) increases in ratings were apparent over the overs in all three trials. Post hoc analyses found significances between all 7 overs in both the control and the unknown trial, where ratings increased over the sprint series. Noteworthy, less-skilled batsmen illustrated a more rapid increase over the overs in the control trial, compared to the increase evident in the unknown trial which followed a more gradual increase. Following shuttle 14, batsmen perceived similar cardiovascular strain in both the control

(16.08) and the unknown (15.58) trial. According to the Borg scale, batsmen perceived their exertion to be between ‘hard’ and ‘very hard’ (Appendix 11D, pg 131 and E, pg 139).

Additionally, a significant (p=0.000) increase between the overs in the deceptive trial was also apparent; however no significance was evident between over 5 and 6 (Appendix 12D, pg 131 and F, pg 140). Interestingly, following the deception in the trial (over 4), ratings continued to increase until over 5 where a slight decrease in slope was seen. This may illustrate that less-skilled batsmen took longer to readjust their template RPE. Following over 7, batsmen reported a ‘central’ RPE rating of 16.08 indicating a perceived exertion of ‘hard.’ This rating may be attributed to the addition of the 7 unexpected shuttle sprints.

Noteworthy is that RPE ratings were seen to increase over time in all trials yet effort was meant to remain the same as intensity was requested to be an all out effort throughout each trial. Other measured responses such as sprint times and muscle activation also changed over time however, these variable, displayed saw smaller changes. This thus suggests that RPE appears to increase as a function of exercise duration.

4.6 LOCAL RATINGS OF PERCEIVED EXERTION

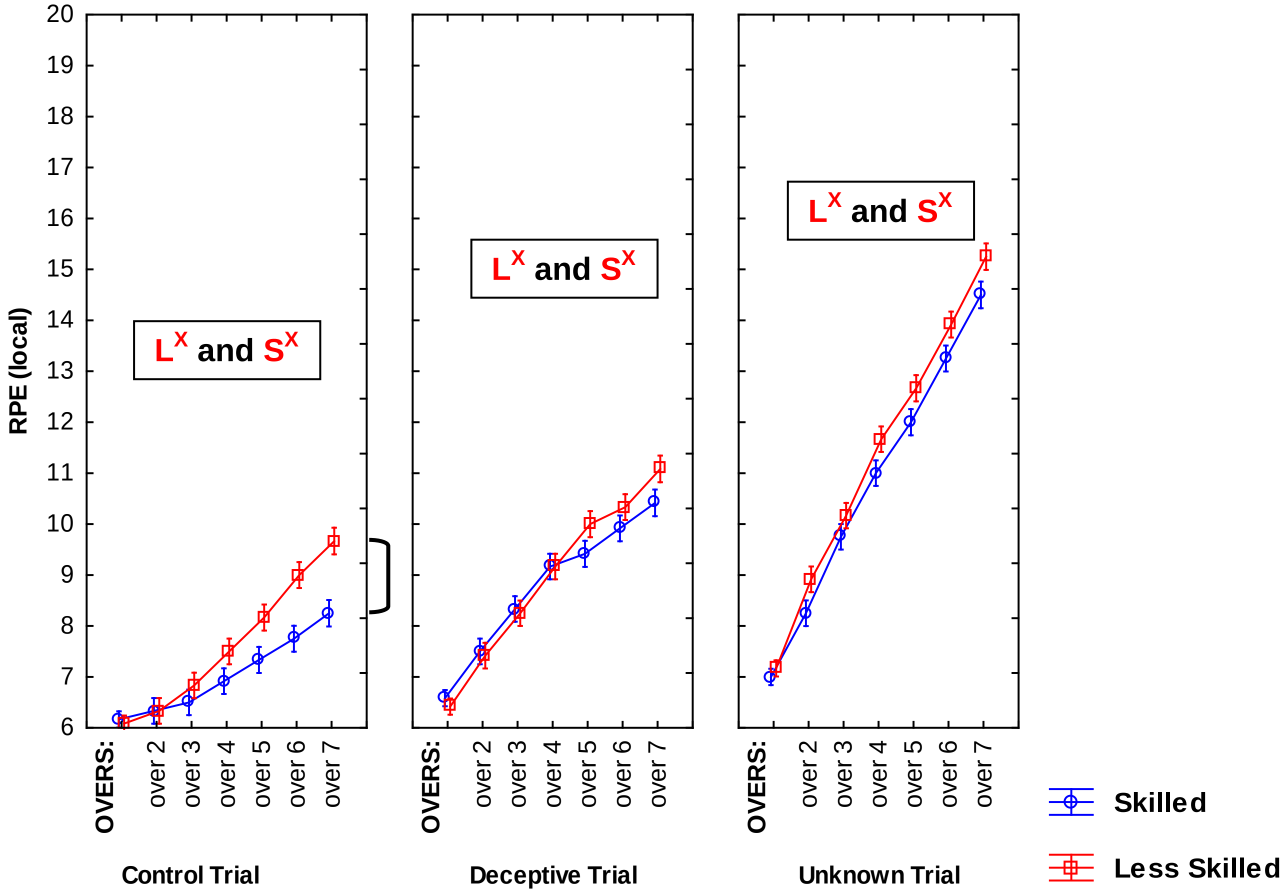

Figure 11: Mean 'local' RPE of both groups throughout the 7 overs in all the three trials, ( ] represents a significant difference between the groups (Appendix D, pg 131), and **S**^{X} and **L**^{X} represents significant sprints/trial effects, (see Appendix D, pg 132 and 141-143) p<0.05; Error bars denote 95% confidence interval).

4.6.1 GROUP EFFECT

When analysing the mean 'local' RPE of both groups in each trial separately, a significant (p=0.013) group effect was apparent in the control trial, where less-skilled batsmen obtained a higher local RPE (a mean of 7.65) compared to the skilled batsmen (a mean of 7.03). Additionally, a significant (p=0.000) interaction between *overs* and *group* (*overs*group*) was evident, where skilled and less-skilled batsmen demonstrated diverging RPE slopes over time. Following over 2, skilled batsmen had a more gradual increase in ratings compared to less-skilled batsmen who continued to increase at a steeper rate. Interesting, less-skilled batsmen reported a ‘local’ RPE of 9.66 in over 7, compared to skilled batsmen who reached a rating of 8.25 (Figure 11, Table V and Appendix D, pg 131-132).

Dissimilarly, no significant group effects were revealed in the deceptive trial, where skilled and less-skilled batsmen had similar ratings of perceived exertions. Less-skilled batsmen reported the higher mean ‘local’ RPE (8.95) compared to the skilled batsmen (8.76). Additionally, there were no significant interaction between *overs* and *group* (*overs*group*) however skilled and less-skilled batsmen had showed a similar increase in RPE ratings, from over 1 to 4. Following over 4, less-skilled batsmen continued to increase their ratings progressively although the ratings of the skilled batsmen were seen to increase at a more gradual rate. This may be attributed to the deception evident following over 4. Skilled batsmen may have readjusted their ‘template’ RPE to suit the addition of 7 more shuttle sprints. When comparing the ‘local’ RPE ratings of the batsmen following over 4, both groups reported ratings of 9.16. When comparing the ratings following over 7, less-skilled batsmen had higher RPE ratings (11.08) in comparison to the skilled batsmen (10.41) suggesting that less-skilled batsmen perceived the additional sprints as being more taxing on their lower limb muscles (Figure 11, Table V and Appendix 14D and 15D, pg 131-132).

In the unknown trial, there were no significant differences in the mean ‘local’ RPE between the groups, where skilled (a mean of 10.82) and less-skilled batsmen (a mean of 11.39) reported comparable ratings. Noteworthy, these ratings were considerably high especially in comparison to the control and the deceptive trial (Figure 11, Table V).

Although there was no significant interaction between *overs* and *group,* both skilled and less-skilled had a similar, consistent increase from over 1 to over 7. Both groups thus adopted a similar rate of RPE rise (Figure 11, Table V and Appendix 16D, pg 132).

Noteworthy, less-skilled batsmen obtained higher mean ‘local’ RPE ratings in all three trials however regardless; both groups reported their highest mean ratings in the unknown trial and their lowest in the control trial (Figure 11).

4.6.2 SPRINTS/TRIAL EFFECT

Skilled Batsmen:

When analysing the 'local' RPE of the skilled batsmen in each trial separately, significant (CT, p=0.000; DT, p=0.000, and UT, p=0.000) increases in ratings were apparent over the 7 overs in each of the experimental trials (Appendix D, pg 134 and 143). Skilled batsmen perceived their highest mean 'local' RPE in the deceptive trial (10.82) and the lowest in the control trial (7.03) which was the same for central RPE (Figure 11).

In the control trial, skilled batsmen had a gradual increase over the first 3 overs. Following over 3, the rate of RPE increase became less gradual. This may be indicative of conscious effort to increase performance over the final few shuttles in the trial. The final RPE rating was reported as 8.25, which indicates that the batsmen perceived their lower limb muscular strain to be 'very light' which is to be expected as batsmen would have pre-anticipated the exercise requirements prior to the commencement of the trial (Figure 11, Table V and Appendix 17D, pg 132 and H, pg 141).

Similarly, in the deceptive trial, batsmen had a significant (p=0.000) increase from over 1 to 4. Following over 4, batsmen showed a more gradual increase in ratings which may have resulted due to the deception present in the trial. It is probable that batsmen readjusted their existing 'template' RPE to ensure that they were able to complete the trial with a performance as close to optimal as possible. The final 'local' RPE rating recorded following over 7 was 10.41 ('fairly light'). Interestingly, following the 7th shuttle sprint, 'local' RPE ratings were reported as 9.00 which indicates that the deception in the trial did increase perceived muscular strain. Additionally, when comparing mean ratings between the control and the deceptive trial, it is evident that when batsmen were able to anticipate the correct number of shuttle sprints, they perceived their muscular strain to be less (Figure 11, Table V and Appendix 18D, pg 132 and I, pg 141).

Likewise, in the unknown trial, batsmen demonstrated a consistent increase from over 1 to 7 with no change in the rate of RPE increase. Thus, despite the tentative nature of the trial, batsmen had still selected a pre-determined rate of RPE increase.

Batsmen reported their final 'local' RPE rating as 14.5. This was the highest mean rating reported by the skilled batsmen, in comparison to the ratings reported in the control and the deceptive trial (Figure 11, Table V and Appendix 19D, pg 132 and J, pg 142).

Less-skilled batsmen:

Similarly to skilled batsmen, when analysing the 'local' RPE of the less-skilled batsmen in each trial separately, significant (CT, p=0.000; DT, p=0.000, and UT, p=0.000) increases in ratings were apparent over the 7 overs in each trial (Appendix D, pg 135 and 144). Noteworthy, the highest mean ratings were seen in the unknown trial (11.39) and the lowest mean ratings in the control trial (7.65). Noteworthy is that the highest mean 'central' RPE was evident in the deceptive trial (Figure 11, Table V).

Specifically, in the control trial, less-skilled batsmen had a significant (p=0.000) increase in 'local' RPE. Post hoc analyses revealed that all overs were significantly different to one another excluding over 1 to 2, and overs 2 to 3. Following over 2, the rate of RPE increase became more gradual throughout the remaining overs. The final rating was s 9.60 ('very light') and further suggests that batsmen had pre-anticipated the exercise requirements (Figure 11, Table V and Appendix 20D, pg 133 and K, pg 142).

In the deceptive trial, the 'local' RPE of the less-skilled batsmen increased significantly (p=0.000) from over 1 to 5. Following over 5, the rate of RPE increase became more gradual, specifically between over 5 and 6. This may be a consequence of the deception batsmen faced during the 4^{th} over. Interestingly between overs 6 and 7, the rate of RPE increase became less gradual suggesting that batsmen had adjusted their template RPE to the new requirements. Less-skilled batsmen perceived their final RPE rating as 11.08 or 'fairly light' (Figure 11, Table V and Appendix 21D, pg 133 and L, pg 143).

Furthermore, ratings increased significantly (p=0.000) from over 1 to 7 in the unknown trial, with the steepest rate of RPE increase evident between over 1 and 2. The final rating was reported as 15.25 or 'hard' which is to be expected due to the lack of knowledge pertaining to the total duration and number of shuttle sprints in the trial (Figure 11, Table V and Appendix 22D, pg 133 and M, pg 143).

4.7 SEMITENDINOSUS (ST) (Muscle activation)

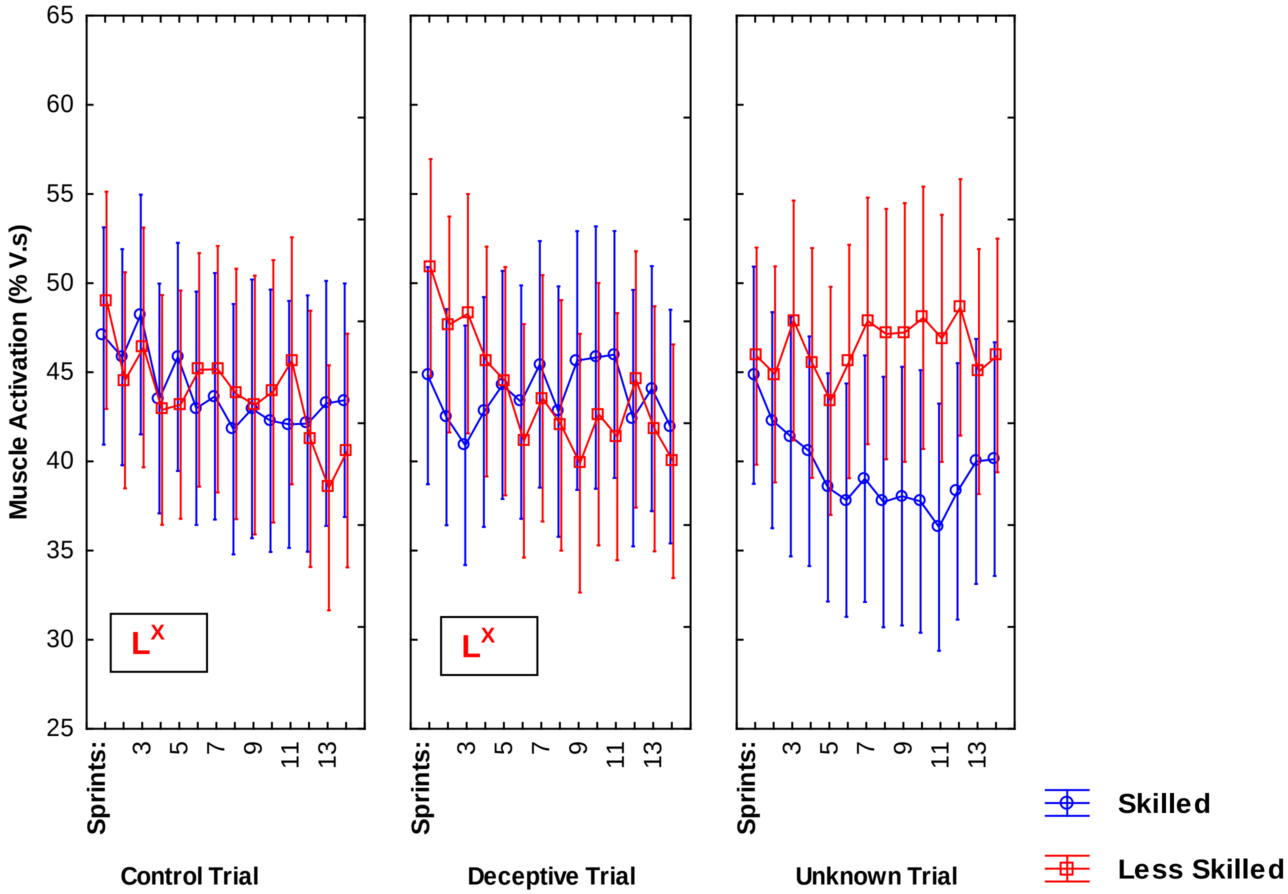

Figure 12: Mean muscle activation (semitendinosus muscle (ST) % V.s) of both groups throughout the sprints series in all the three trials, ( ] represents a significant difference between the groups (see Appendix D, pg 133), and **S**^{X} and **L**^{X} represents significant sprints/trial effects, (see Appendix D, pg 133 and 144) $p<0.05$; Error bars denote 95% confidence interval).

4.7.1 GROUP EFFECTS

There were no significant differences in the mean ST activation between the groups in each of the three trials (Table V, Figure 12 and Appendix D, pg 133). General trends did however indicate that less-skilled batsmen had the highest mean ST activation in all three trials in compared to the skilled batsmen. Furthermore, the ST activation decreased for both groups in all three trials.

Looking specifically at the control trial, a significant (p=0.014) decrease in muscle activation was evident over time. Less-skilled batsmen had a 8.43% decrease in activation and skilled batsmen a 3.6% decrease over the shuttle sprints series (Table V, Figure 12 and Appendix 23D, pg 133). Noteworthy, regardless of the decrease over time, both groups obtained their lowest ST activation during shuttle 14.

In the deceptive trial, there was no significant decrease in muscle activation for both groups over time. Interestingly, there was a significant (p=0.031) *sprints* and *group* interaction evident, where post hoc analyses revealed that the muscle activation of the less-skilled batsmen decreased significantly between shuttle 1 and shuttle 9 (Table V, Figure 12 and Appendix 24D, pg 133). Less-skilled batsmen had a 10.97% decrease between shuttle 1 and 9, as opposed to skilled batsmen who elicited a 0.84% increase between shuttle 1 and 9. Following shuttle 9, skilled batmen managed to maintain steady ST activation until the final few shuttles where activation was seen to decrease by 3.70%, ending the trial with 42.95% V.s. In contrast, less-skilled batsmen had a 0.11% increase in ST activation between shuttle 9 and shuttle 14 (40.01% V.s).

In the unknown trial, less-skilled batsmen presented with the highest mean ST activation (44.08% V.s) compared to that of the skilled batsmen (39.86% V.s). There was no significant decrease in ST muscle activation over the 14 shuttle sprints. However, when comparing the change in ST activation between shuttle 1 and 14, skilled batsmen had a 3.75% decrease as opposed to less-skilled batsmen who had a smaller decrease (0.59%) in ST activation over time. The consistency in muscle activation suggests that the tentative nature of this trial had very little fatiguing effects on the muscle activation patterns of both groups over the sprint series (Figure 12).

4.7.2 SPRINTS/TRIAL EFFECTS

Skilled Batsmen:

When analysing the ST activation of the skilled batsmen in each individual trial, there were no significant decreases in muscle activation apparent over time (shuttle sprint 1 to shuttle sprint 14). However, activation did decrease over the sprint series in all three trials. General trends revealed that mean ST muscle activation was in the unknown trial (39.48% V.s), and most in the control trial (43.93% V.s) (Table V, Figure 12 and Appendix D, pg 133).

Looking specifically at the control trial, batsmen presented with similar ST activation between shuttle 1 and shuttle 14. Batsmen had a 3.60% decrease in ST activation over time (Table V, Figure 12 and Appendix 23D, pg 133).

In the deceptive trial, muscle activation was also fairly consistent throughout the sprint series. When comparing the change in ST activation between shuttle 1 and shuttle 7, batsmen had a 0.63% increase in activation. However, over the following 7 shuttles, batsmen had a 3.49% decrease in activation (Table V, Figure 12 and Appendix 24D, pg 133).

In the unknown trial, batsmen illustrated a gradual decrease in ST activation over the sprint series. There was a 4.7% decrease in activation from shuttle 1 to shuttle 14. It is however important to note that the most decrease in activation occurred immediately after shuttle 1 (Figure 12).

Less-Skilled Batsmen:

General trends revealed that mean ST muscle activation was highest in the unknown trial (46.43% V.s) and least in the control trial (43.80% V.s). Interestingly, these activation trends were opposite to the trends seen in the ST activation of the skilled batsmen (Table V, Figure 12 and Appendix D, pg 133).

A significant (p=0.024) decrease in ST activation was apparent in the control trial. More specifically, there were significances between shuttle 1 and 13, where muscle activation was seen to decrease by 10.51% (Table V, Figure 12 and Appendix D). Furthermore, a sudden decrease in muscle activation between shuttle 11 and shuttle 13 was evident (Table V, Figure 12 and Appendix 25D, pg 134 and N, pg 144).

Additionally, a significant (p=0.014) decrease in ST activation was evident between shuttle 1 and 9, and shuttle 1 and 14 in the deceptive trial, where activation decreased by 10.96% and 10.86% respectively. Noteworthy, when comparing the duration of the decline in muscle activation, following the revealing of the deception (shuttle 7), less-skilled batsmen had the longest duration of decline in comparison to skilled batsmen. This indicates that less-skilled batsmen took longer to adjust to the new exercise requirements. It is also evident that less-skilled batsmen had a 10.85% decrease in ST muscle activation over the entire sprint series, with batsmen showing their least activation during the performance of shuttle 14 (Table V, Figure 12 and Appendix 26D, pg 134 and O, pg 145).

In the unknown trial, the mean ST activation of the less-skilled batsmen (44.08% V.s) was much greater than that of the skilled batsmen (39.86% V.s). Less-skilled batsmen appeared to take a different approach to the uncertainty experienced in the trial. Noteworthy, although less-skilled batsmen do not follow the same trend as the skilled batsmen, which is characterised as an immediate down regulation of muscle activation, less-skilled batsmen still managed to end off with a higher ST activation than that of shuttle 1 (Table V, Figure 12 and Appendix D, pg 134).

4.8 BICEPS FEMORIS (BF)

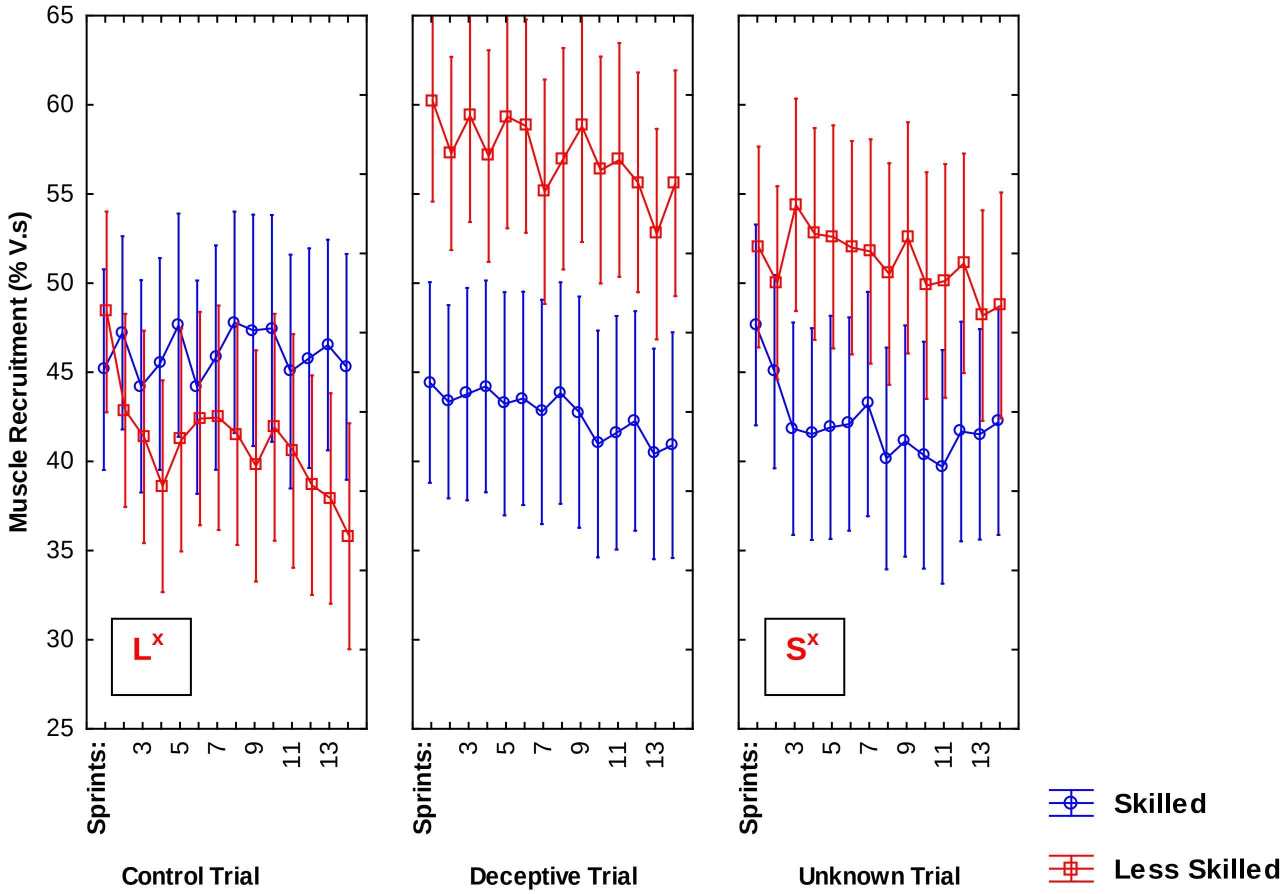

Figure 13: Mean muscle activation (biceps femoris (BF) muscle, % V.s) of both groups throughout the shuttle sprint series in all the three trials, ( ] represents a significant difference between the groups, and S^X and L^X represents significant sprints/trial effects, (see Appendix D, pg 134 and 146-147) $p<0.05$; Error bars denote 95% confidence interval).

4.8.1 GROUP EFFECTS

There were no significant differences between mean biceps femoris (BF) activation of the skilled and less-skilled batsmen (Table V, Figure 13). Additionally, no significant decreases were apparent over the 14 shuttle sprints for both groups in each of the three trials. General trends did reveal that BF activation experienced a decline over the sprint series in each of the three trials (Figure 13). Likewise, there were no significant interactions between *sprints* and *group* in each of the three experimental trials (Table V, Figure 13).

Looking at the control trial, skilled batsmen obtained a higher mean BF activation (46.06% V.s) in comparison to the less-skilled batsmen (40.96% V.s). Additionally, less-skilled batsmen had a 12.58% decrease in initial BF activation (shuttle 1 to 14). Interestingly, skilled batsmen had a 0.16% increase in BF activation (Table V, Figure 13).

In the deceptive trial, less-skilled batsmen elicited a higher mean BF activation (57.16% V.s) in comparison to the skilled batsmen (42.15% V.s) over the sprint series. Following shuttle 7, both groups presented with higher BF activation in comparison to the initial activation (shuttle 1). Skilled batsmen achieved a 1.06% increase in activation and less-skilled batsmen a 1.86% increase. Interestingly, skilled batsmen had a 1.86% decrease in BF activation between shuttle 7 and 14, as opposed to less-skilled batsmen who had a 0.48% increase in BF activation during this period (Table V, Figure 13).

In the unknown trial, although no significant differences in mean BF activation were evident between groups, less-skilled batsmen still had higher mean muscle activation (51.18% V.s) compared to the skilled batsmen (42.14% V.s).

Both skilled and less-skilled batsmen experienced very little changes in BF activation over the 14 shuttle sprints. Skilled batsmen had a 5.45% decrease between shuttle 1 and shuttle 14, compared to less-skilled batsmen who had a 3.24% decrease over time. Noteworthy, skilled batsmen had a 5.82% decrease in activation between shuttle 1 and 3 (Table V, Figure 13).

4.8.2 SPRINTS/TRIAL EFFECTS

Skilled Batsmen:

When analysing the BF activation of skilled batsmen in each trial separately**,** muscle activation showed no significant decreases over the sprint series in the control and deceptive trials. There was however a significant (p=0.005) decrease in activation in the unknown trial, where BF activation decreased over the sprint series. Trends indicate that BF was the most activated during the control trial (a mean of 46.07% V.s) and least activated during the unknown trial (a mean of 42.14% V.s) (Table V, Figure 13 and Appendix 27D, pg 134 and P, pg 146).

In the control trial, batsmen had steady BF activation throughout the sprint series. Additionally, there was no evidence of a down regulation in muscle activation during the last few shuttles leading up to the final shuttle, shuttle 14. When comparing the change of BF activation over time, there was a 0.15% increase in activation over the 14 shuttle sprints.

In the deceptive trial, skilled batsmen had consistent BF activation over the 14 shuttles. However, there was a 1.86% decrease in BF activation between shuttle 7 and 14 (Table V and Figure 13).

In the unknown trial, skilled batsmen had a significant (p=0.005) decrease in BF activation. Post hoc analyses found significances between shuttle 1 and shuttle 8 to shuttle 11. Additionally, an initial decrease in BF activation was apparent between shuttles 1 and 3 where activation showed a 5.82% decrease over time (Table V, Figure 13 and Appendix 27D, pg 134 and P, pg 146).

Less-Skilled Batsmen:
Overall less-skilled batsmen had a higher mean BF activation in the deceptive trial (57.16% V.s), and the least BF activation in the control trial (40.96% V.s) (Figure 13).

In the control trial, less-skilled batsmen had a significant (p=0.006) decrease in BF activation. More specifically, activation decreased significantly between shuttle 1 and 4, and shuttle 1 and 12 to 14. Overall, batsmen had a 12.58% decrease in BF activation between shuttle 1 and 14 (Table V, Figure 13 and Appendix 28D, pg 134 and Q, pg 147).

In the deceptive trial, less-skilled batsmen illustrated stable BF activation throughout regardless of the deception encountered. Noteworthy, BF activation was highest in this trial in comparison to the remaining two trials. Trends however indicate that batsmen had a slight down regulation in muscle activation during shuttle 7. Nonetheless, almost instantly, batsmen readjusted to the requirements of the additional 7 shuttle sprints and an increase in activation was seen. Less-skilled batsmen were able to complete the following 7 shuttles with a 0.47% increase in BF activation between shuttle 7 and 14. Overall, these batsmen had a 4.59% decrease from shuttle 1 to shuttle 14, which, considering the decrease evident in the control trial (12.58%), is indicative of a steady performance considering the nature of the trial (Figure 13).

In the unknown trial, muscle activation between shuttle 1 and shuttle 14 showed very little change. However, there was a 3.27% decrease in activation with the last shuttle (Figure 13).

4.9 VASTUS MEDIALIS (VM)

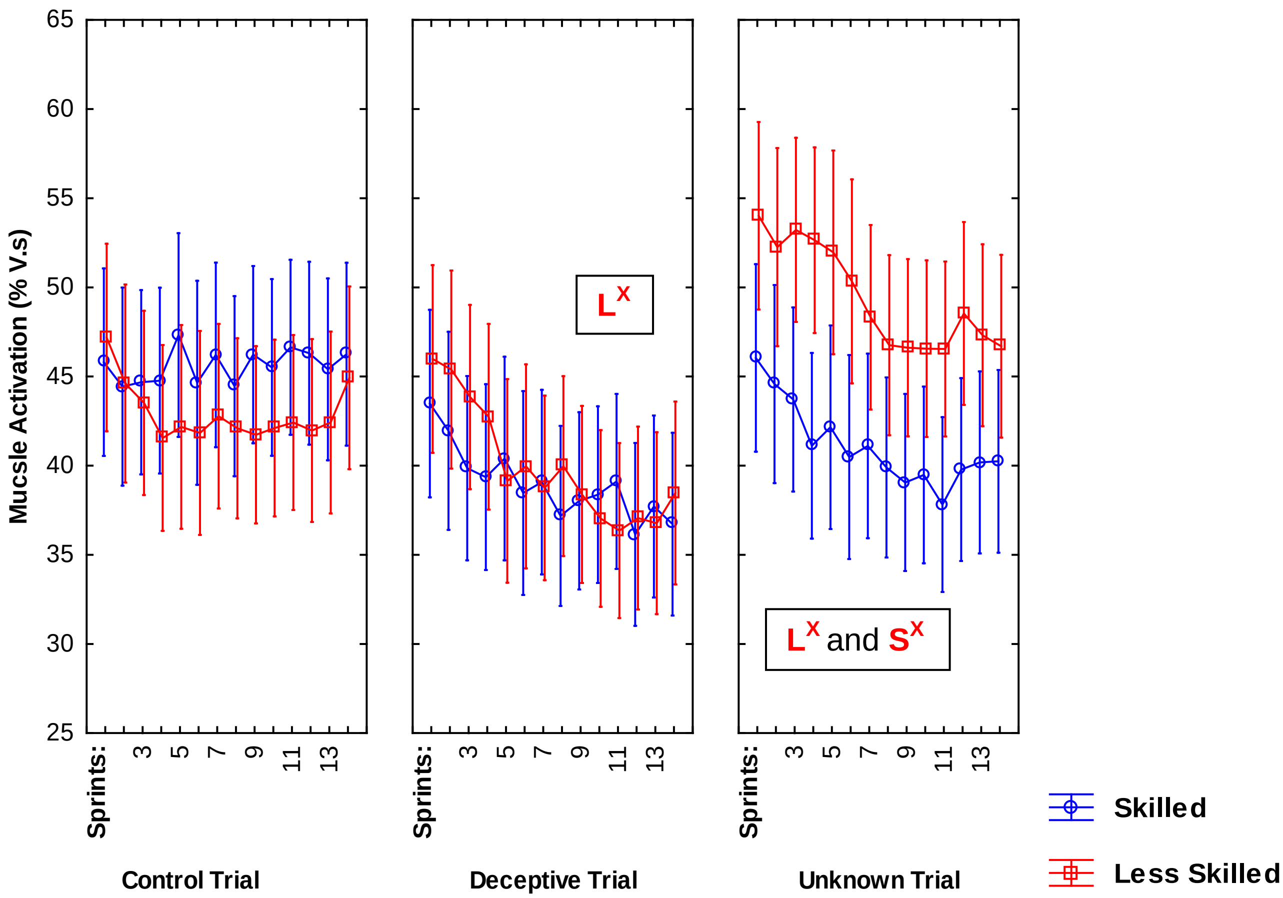

Figure 14: Mean muscle activation (vastus medialis (VM) muscle % V.s) of both groups throughout the shuttle sprints series in all the three trials, ( ] represents a significant difference between the groups, and **L^X** and **S^X** significant sprints/trial effects, (see Appendix D, pg 134 and 148-150) $p<0.05$; Error bars denote 95% confidence interval).

4.9.1 GROUP EFFECTS

Results revealed that there were no significant differences in mean vastus medialis (VM) activation between both groups in each of the three experimental trials when analysed separately (Table V and Figure 14). A significant decrease in mean activation over the sprint series was however evident in both the deceptive (p=0.000) and the unknown trial (p=0.000) (Table V, Figure 14 and Appendix D, pg 134 and 135).

More specifically, in the control trial, skilled batsmen had a higher mean VM (45.61% V.s) in comparison to the less-skilled batsmen (42.95% V.s). When comparing changes in activation between shuttle 1 and shuttle 14, a 0.45% increase in activation was observed in the skilled batsmen whereas there was 2.26% decrease over this time in the less skilled batsmen (Figure 14).

In the deceptive trial, VM activation decreased significant (p=0.000) over the sprint series. Noteworthy, less-skilled batsmen had a higher mean muscle activation (39.99% V.s) compared to the skilled batsmen (38.99% V.s) in the deceptive trial. When comparing shuttle 1 and shuttle 7, skilled batsmen had a 4.40% decrease in activation compared to less-skilled batsmen who a 7.23% drop during this time. Conversely, when comparing the second shuttle sprints series (shuttle 7 to shuttle 14), skilled batsmen showed the greatest decrements with a 2.36% decrease in activation, as opposed to less-skilled batsmen had a 0.28% decrease between shuttle 7 and shuttle 14. However, from shuttle 1 to shuttle 14, less-skilled batsmen experienced a greater decrease (7.52%) in VM activation in comparison to skilled batsmen (6.76%) (Figure 14 and Appendix 29D, pg 134).

A significant (p=0.000) decrease in VM was apparent in the unknown trial in both groups. Less-skilled batsmen had a higher mean VM activation (49.41% V.s) compared to the skilled batsmen (41.11% V.s). When comparing shuttle 1 and shuttle 14 there was 5.79% decrease in the skilled batsmen and a 7.32% decrease in VM activation over the 14 shuttles in the less skilled batsmen (Table V, Figure 14 and Appendix 30D, pg 135).

4.9.2 SPRINTS/TRIAL EFFECTS

Skilled batsmen:

Trends indicate that batsmen had a higher mean VM activation in the control trial (45.61% V.s) and the lowest mean activation in the deceptive trial (38.99% V.s) (Figure 14).

There was a 0.45% increase in VM activation between shuttle 1 and 14 with the more skilled players.

Likewise, VM activation showed no significant decreases over the 14 shuttle sprints although there was a 6.76% decrease in activation between shuttle 1 and 14. When comparing the decrease in activation before the deception (shuttle 7), there was a 4.4% decrease. Following the completion of the 7 additional shuttles, there was a further 2.35% decrease in VM activation. A significant (p=0.003) decrease in VM activation was apparent in the unknown trial. Post hoc analyses revealed significances between shuttle 1 and 9, and shuttle 1 and 11, where VM activation decreased by 7.98% and 8.23% respectively (Appendix 31D, pg 135 and R, pg 148). Overall, there was a 5.79% decrease which, considering the nature of the trial, was expected.

Less-Skilled Batsmen:

There was no significant difference in the VM activation over the sprint series in the control trial. There was however, significant decreases in VM activation over the 14 shuttle sprints in both the deceptive and the unknown trial (DT, p=0.004; UT, p=0.001). The greatest VM activation was evident in the unknown trial (a mean of 49.41% V.s), and least activation in the deceptive trial (a mean of 39.99% V.s) which was in contrast to the skilled batsmen.

Looking specifically at the control trial, VM activation was relatively steady and stable throughout the trial with a slight increase in activation evident between shuttles 13 and 14. Noteworthy was that sprint time was seen to decrease by 0.07s during from 13 to shuttle 14. This final increase may possibly indicate a pre-determined end spurt and thus suggest that batsmen had paced themselves throughout this trial. When comparing shuttle 1 and shuttle 14, less-skilled batsmen illustrated a 2.26% decrease in VM activation.

In the deceptive trial, a significant (p=0.004) decrease in VM activation was apparent. Specifically, significances existed between shuttle 1 and shuttle 9 to 14. Additionally, between shuttle 2 and shuttle 12 and 13, where VM decreased over time (Appendix 32D, pg 135 and S, pg 149). Furthermore, when comparing the first sprint series (shuttle 1 to shuttle7), with the second sprint series (shuttle 7 to shuttle 14), there was a 7.22% and 0.28% decrease in activation respectively. Additionally, when comparing shuttle 1 and 14, there was a 7.52% decrease in activation over time (Table V, Figure 14).

Likewise, significance (p=0.001) was found between the sprint series in the unknown trial where VM decreased over time. Post hoc analyses revealed significant differences between shuttle 1 and shuttle 7-14, shuttle 2 and shuttles 10 and 11 and shuttle 3 and shuttles 8 to 11, where muscle activation decreased significantly over time (Appendix 33D, pg 135 and T, pg 150). Overall, less-skilled batsmen had a 7.32% decline in VM activation over the course of the 14 shuttle sprints. Interestingly, the VM of the less-skilled batsmen was highest in this trial.

4.10 VASTUS LATERALIS (VL)

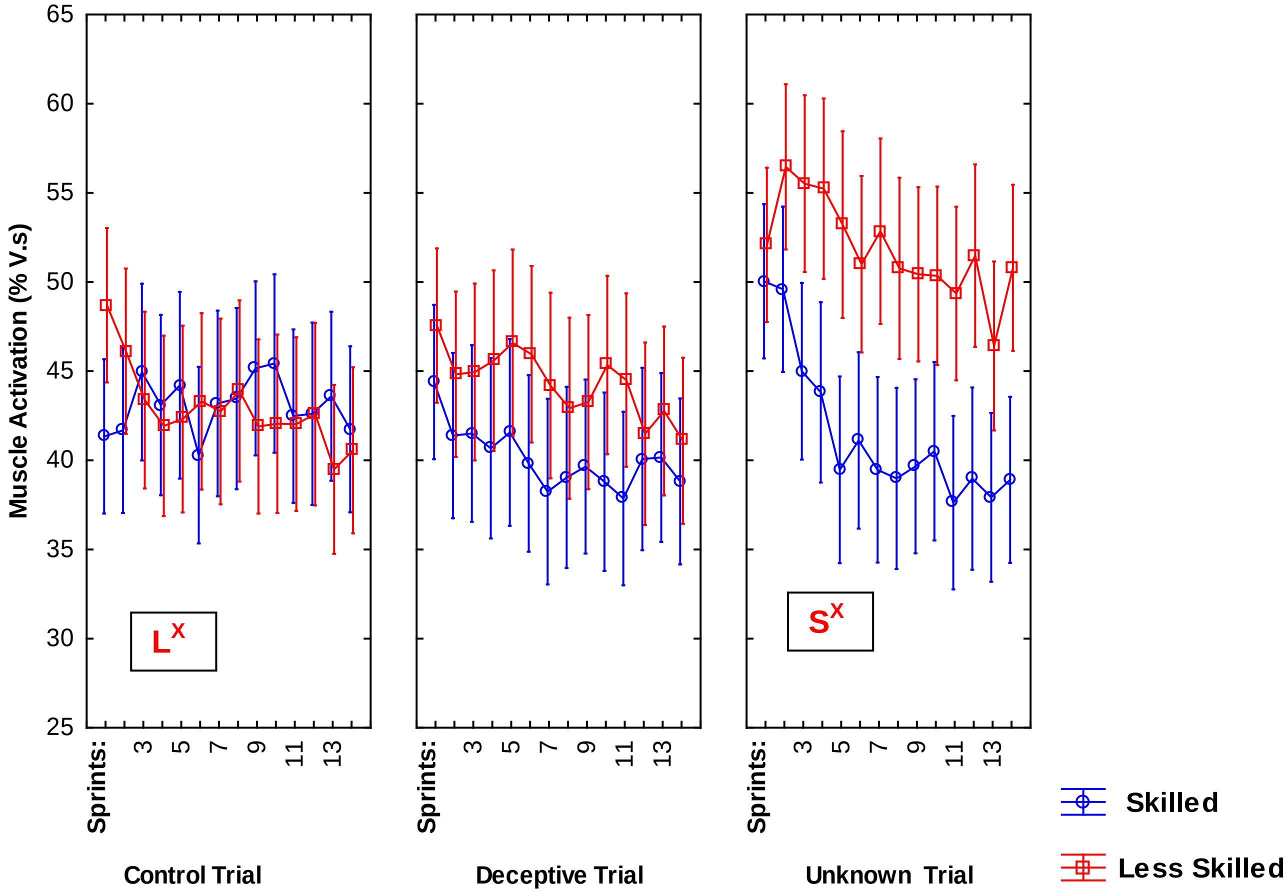

Figure 15: Mean muscle activation (vastus lateralis (VL) muscle; % V.s) of both groups throughout the shuttle sprints series in all the three trials, ( ] represents a significant difference between the groups, and **L**^{X} and **S**^{X} significant sprints/trial effects, (see Appendix D, pg 135-136) $p<0.05$; Error bars denote 95% confidence interval).

4.10.1 GROUP EFFECTS

There were no significant differences in mean vastus lateralis (VL) activation between the two groups in each of the three experimental trials (Table V and Figure 15). Trends however indicate that less-skilled batsmen had the higher mean muscle activation in the deceptive (44.36% V.s) and the unknown (51.85% V.s) trial, compared to the skilled batsmen. However, skilled batsmen obtained the highest mean activation in the control trial (43.08% V.s) (Table V, Figure 15).

With specific reference to the control trial, an interaction effect between *group* and *sprints* (*group*sprints*) (p=0.027) was evident (Appendix 34D, pg 135). When comparing the change in activation from shuttle 1 to shuttle 14, there was a 8.92% decrease over time in the less skilled players. In the deceptive trial, less-skilled batsmen (44.36% V.s) and skilled batsmen (40.14% V.s) obtained similar mean vastus lateralis activation levels. The non-significant (p=0.93) interaction between group and sprints (*group*sprints*) suggests that very little change was seen between the group's activation level, in addition to following a similar decline over time (Table V and Figure 15). Likewise, when comparing shuttle 1 and shuttle 7, there was a 6.15% decrease in activation compared to less-skilled batsmen (3.37% decrease) in VL activation over time. Following the deception, skilled batsmen then had a 0.57% increase in VL activation over the remaining 7 shuttles. Less-skilled batsmen however had a 3.10% decrease in muscle activation during the performance of the final sprint series.

In the unknown trial, less-skilled batsmen had the highest mean VL activation (51.85% V.s) compared to skilled batsmen (41.50% V.s). Comparison of muscle activity between shuttle 1 and 14, shows that less-skilled batsmen had a 1.28% decrease over time. The skilled batsmen had an 11.14% decrease (Table V, Appendix 35D, pg 136).

4.10.2 SPRINTS/TRIAL EFFECTS

Skilled Batsmen:

When looking at the vastus lateralis activation in each trial separately, trends indicate that skilled batsmen obtained their highest mean activation in the control trial (43.08 % V.s) and least in the deceptive trial (30.14% V.s). Noteworthy, there were no significant differences in VL activation over the sprint series in both the control and the deceptive trial. Dissimilarly for the unknown trial, VL activation decreased significantly (p=0.000) over the sprint series (Table V, Figure 15 and Appendix 36D, pg 136 and U, pg 151).

Looking specifically at the control trial, when comparing the change in activation between shuttle 1 and shuttle 14, there was a 0.4% overall increase in VL activation over time. An activation of 41.33% V.s was observed in the initial shuttle sprint and an activation of 41.73% V.s was observed during the final shuttle sprint.

In the deceptive trial, VL muscle activity was consistent throughout. There was no down regulation in muscle activation before shuttle 7. Skilled batsmen had a 6.15% decrease in VL activation between shuttle 1 and 7. There was then 0.56% increase in activation between shuttle 7 and 14 (Figure 15).

In the unknown trial, skilled batsmen had a significant (p=0.000) decrease in VL activation. The differences were between shuttle 1 and 5, shuttle 1 and shuttles 7 and 8 and shuttle 1 and shuttles 11-14. Additionally, a there was a significant decrease in VL activation between shuttle 2 and shuttles 5, 7 and 8, and between shuttle 2 and shuttles 11-14 (Appendix D, pg 136). There was evidence of down regulation in muscle activation from the initial shuttle to shuttle 5. From shuttle 5 onward, muscle activation started to stabilise and remained steady through the remainder of the trial (Figure 15). Overall, batsman experienced an 11.13% decrease in VL activation over the sprint series.

Less-Skilled Batsmen:

Trends show that the less-skilled batsmen had the highest mean VL activation in the unknown trial (51.85% V.s) and the lowest in the control trial (42.92% V.s). Noteworthy, there were no significant differences in mean VL activation over the sprint series in each of the three experimental trials (Figure 15).

Looking specifically at the control trial, muscle activation showed a significant decrease over time (p=0.021). The significances were between shuttle 1 and 13, and shuttle 1 and 14, where VL activation decreased by 9.20% and 8.13% respectively (Table V, Figure 15 and Appendix 37D, pg 136 and V, pg 152).

In the deceptive trial, less-skilled batsmen experienced a more gradual decline in VL activation over time. During the first sprint series (shuttle 1 to 7) there was a 3.36% decrease, and during the second sprint series (shuttle 7 to 14), there was an additional 3.09% decrease. Overall, there was a 6.44% decrease in VL activation (Figure 15).

Lastly, in the unknown trial, fluctuations in activation levels were evident. Interestingly, less-skilled batsmen experienced a minor, 1.28% decrease in VL activation over the trial.

4.11 SUMMARY OF SIGNIFICANT FINDINGS

4.11.1 GENERAL FINDINGS

Group effects were evident for sprint times and, ‘central’ and ‘local’ RPE, where skilled batsmen obtained the faster mean sprint times, and less-skilled batsmen reported the higher mean ‘central’ and ‘local’ RPE values in each of the three experimental trials. Interestingly, there were no significant group effects for muscle activation. Trends were that, over time (shuttle 1 to 14), sprint times decreased, muscle activation decreased and RPE (‘central’ and ‘local’) ratings increased, regardless of the experimental trials.

4.11.2 SKILLED VERSES LESS-SKILLED

When comparing skilled verses less-skilled batsmen, skilled batsmen elicited faster mean sprint times, with the least mean muscle activation, whilst reporting the lower mean RPE ratings (‘central’ and ‘local’). In contrast, less-skilled batsmen, for the most part, experienced higher mean muscle activation levels coupled with slower mean sprint times and higher levels of perceived exertion (‘central’ and ‘local’).

Table VI: Mean sprint times, RPE ('central' and 'local'), and muscle activation for all four muscle, over the three trials for skilled batsmen.

SKILLED	CT	DT	UT
BF (% V.s)	Highest (46.06)	Middle (42.72)	Lowest (42.14)
ST (% V.s)	Highest (43.93)	Middle (43.76)	Lowest (39.48)
VL (% V.s)	Highest (43.08)	Lowest (40.14)	Middle (41.51)
VM (% V.s)	Highest (54.61)	Lowest (38.99)	Middle(41.12)
Sprint time (sec)	Slowest (6.46)	Fastest (6.38)	Middle(6.39)
RPE (local)	Lowest (7.03)	Middle (8.77)	Highest (10.82)
RPE (central)	Lowest (10.19)	Highest (10.61)	Middle (10.58)

BF=Biceps Femoris, ST=Semitendinosus, VL=Vastus Lateralis, VM=Vastus Medialis, Sprint times and RPE=Ratings of Perceived Exertion

Skilled Batsmen:

Specifically, when looking at the sprint times of the skilled batsmen, sprint times were seen to decrease significantly (p=0.001) over the sprint series in the control trial. There were no significant changes in sprint times over the sprint series in the deceptive and unknown trial. However, shuttle 14 was always faster than sprint 1. Overall, skilled batsmen experienced their fastest mean sprint times in the deceptive trial (6.38 seconds) and slowest in the control trial (6.46 seconds). Noteworthy is that the faster sprint times were apparent in the middle of the deceptive trial due to the incorrect information pertaining to the number of shuttle sprint to be completed. When looking at muscle activation, the hamstring complex muscles (ST and BF), appeared to behave similarly across the 14 shuttle sprints in all three trials, with both muscles eliciting the highest mean activation levels in the control trial (ST, 43.93% V.s and BF, 46.06% V.s), and lowest in the unknown trial (mean ST, 39.48% V.s and mean BF, 42.14% V.s). Correspondingly, quadriceps complex muscles (VL and VM) behaved similar across trials, with higher mean muscle activation in the control trial (VL, 43.08% V.s and VM, 45.61 % V.s) and lowest in the deceptive trial (VL, 40.14% V.s and VM, 38.99% V.s). Interestingly, both muscles showed a significant (VM, p=0.007; VL, p=0.000) decrease in activation level over time (VM in both the deceptive and unknown trial, and VL in the unknown trial). 'Central' RPE, ratings increased significantly over the overs in each trial. The higher mean perceived exertion was in the deceptive trial (10.61) and the lowest in the control trial (10.19). Mean 'local' RPE was reported to be highest in the deceptive trial (10.82) and lowest in the control trial (7.03) (Table VI, pg 70).

Less-Skilled Batsmen:

Interestingly, results of the less-skilled batsmen showed a large amount of disparity in comparison to the results of the skilled batsmen.

Table VII: Mean sprint times, RPE ('central' and 'local'), and muscle activation for all four muscle, over the three trials for less-skilled batsmen.

LESS SKILLED	CT	DT	UT
BF (% V.s)	Lowest (40.96)	Highest (57.16)	Middle (51.18)
ST (% V.s)	Lowest (43.80)	Middle (43.85)	Highest (46.43)
VL (% V.s)	Lowest (42.92)	Middle (44.36)	Highest (51.85)
VM (% V.s)	Middle (42.95)	Lowest (39.99)	Highest (49.41)
Sprint time (sec)	Fastest (6.84)	Middle (6.90)	Slowest (6.98)
RPE (local)	Lowest (7.65)	Middle (8.86)	Highest (11.39)
RPE (central)	Middle (11.65)	Highest (11.69)	Lowest (11.51)

BF=Biceps Femoris, ST=Semitendinosus, VL=Vastus Lateralis, VM=Vastus Medialis, Sprint times and RPE=Ratings of Perceived Exertion

Firstly, when looking at sprint times, there were no significant differences in sprint times over the shuttle sprint series in each trial. However, their faster mean sprint time was in the control trial (6.84 seconds) and slowest in the unknown trial (6.97 seconds). With regards to mean muscle activation, there was no uniformity within muscle complexes, with ST eliciting opposing activation trends to the BF. ST was most activated in the unknown trial (a mean of 46.32% V.s) and least activated in the control trial (a mean of 43.80% V.s), and BF was most activated in the deceptive trial (a mean of 56.97% V.s) and least in the control trial (a mean of 40.96% V.s). Similarly, discrepancies between the quadriceps complex muscles were apparent, with VL having the highest mean activation in the unknown trial (a mean of 51.81% V.s) and lowest in the control trial (a mean of 42.92% V.s). VM was seen to be most activated in the unknown trial (a mean of 49.41% V.s) and least in the deceptive trial (a mean of 39.99% V.s). Although distinct patterns were not clear among muscle activation patterns for the less-skilled batsmen, all muscles experienced significant decreases over time. Finally, less-skilled batsmen reported their highest 'central' RPE in the deceptive trial (a mean of 11.69), paired with their highest 'local' RPE (a mean 10.60). The lowest 'central' RPE was reported in the unknown trial (a mean of 11.50) and lowest rating for 'local' RPE was evident in the control trial (a mean of 10.19) (Table VII).

4.12 SUMMARY OF SPRINTS/TRIAL EFFECTS

The relationship of the dependent variables measured in each trial, suggests that skilled batsmen performed best in the deceptive trial. Skilled batsmen obtained the lowest mean VL and VM activation, paired with the second highest mean ST and BF activation levels, fastest mean sprint times, highest mean ‘central’ RPE and second highest mean ‘local’ RPE. Skilled batsmen thus showed superior performance when trial requirements were unclear. Less-skilled batsmen however, were seen to experience decrements in performance when information regarding the end point was unknown or misleading. Less-skilled batsmen performed best in the control trial. Less-skilled batsmen had the lowest mean BF, ST and VL muscle activation, the second highest mean VM activation, the fastest mean sprint times, lowest mean ‘local RPE’ and second highest mean ‘central’ RPE (Table VI and VII, pg 70 and 71).

CHAPTER V
DISCUSSION

5.1 INTRODUCTION

This study aimed to compare the performance (sprint times), physiological (level of muscle activation) and perceptual (RPE) responses of batsmen during three experimental trials (a control trial, a deceptive trial and an unknown trial). The study further compared skilled and less-skilled batsmen’s responses. This chapter will thus firstly discuss possible reasons for the group effects found in the investigation and then further explore the performance of each group separately, within each trial.

5.2 GENERAL FINDINGS (Group Effects)

Results showed significant group effects for three of the four dependent variables. These variables included sprint times and ‘central’ and ‘local’ RPE. Specifically, skilled batsmen obtained faster mean sprint times compared to less-skilled batsmen in all three trials. Less-skilled batsmen however had higher ‘central’ and ‘local’ RPE ratings in all three trials. Interestingly, no significant differences in muscle activation between skilled and less-skilled batsmen were apparent. Trends did, however, reveal that less-skilled batsmen had higher muscle activation in comparison to the skilled batsmen in all three trials.

There are numerous possible explanations for these differences and include factors such as level of motivation, familiarity with the task, as well as morphological and anthropometrical attributes (Brehm and Self, 1989; Higgins, 1991; Woolmer *et al.,* 2008; Matschiner, 1998; Portus and Farrow, 2011; Tucker and Collins, 2012).

Specifically, individuals possess certain traits which increase their ability to perform superiorly during a task or exercise work bout (Hulleman, De Koning, Hettinga and Foster, 2007; Tucker and Collins, 2012). When looking at the attainment of superior sprinting performance, attributes such as a higher ratio of fast twitch type II muscle fibres, increased agility, faster reaction times and greater mobility, all assist in improving sprinting performance (Bruton, 2002; Woolmer *et al.,* 2008). It is therefore probable that the skilled batsmen may possess these attributes. However, due to the invasive procedures needed to isolate and indentify some of these traits, it was not feasible to attain this data. It would therefore be inaccurate to assume that the skilled batsmen possessed some of these favourable intrinsic attributes.

Furthermore, familiarity of the task and therefore specificity training may be another contributing factor to faster sprint times, lower activation and lower ratings of perceived exertion (MacDougall, Elder, Sale, Moroz and Sutton, 1980; MacDougall, 1986; Rose and Rothstein, 1982) in the skilled group. According to the 'Practice Sufficiency Model,' expert performance is the result of the accumulation of hours of deliberate practice (Tucker and Collins, 2012). Broadly, the model predicts that with practice, inter-individual differences will disappear and thus allow every individual the chance to achieve sporting success by means of sufficient training time. The accumulated hours of practice, essentially increase batsmen's familiarity with the requirements of batting and improves their ability to select the appropriate responses such as the correct muscle activation patterns (Noakes and Durandt, 2000; Woolmer *et al.,* 2008; Tucker and Collins, 2012). A weakness of this investigation is that practice time was not measured and, as such, no causation can be assumed. For example, it is plausible that some of the skilled batsmen had a lower, overall accumulation of practice times than the less-skilled. Furthermore and in contrast to the 'Practice Sufficiency Model, another model known as the 'Genetic Ceiling Model' suggests the importance of genetic factors in the exploration of expert performance.
The 'Genetic Ceiling Model' proposes that either the absence or presence of specific genetic sequence variants predisposes or conversely, limits individuals to sporting success (Tucker and Collins, 2012). This model proposes that individuals have innate factors which determine the level of performance reached for specific tasks. These innate factors can be manipulated and altered through training however reach a level beyond which athletes cannot improve, hence the ceiling model (Tucker and Collins, 2012). Further, those who are genetically predisposed to superior sprint ability may be attracted to intermittent sporting activities such as cricket and thus have practiced more. In summary, performance is far more complex than being constrained by dedication to practice. Genetic factors should be equally accountable in the achievement of sporting success (Tucker and Collins, 2012).

Additionally, it is further probable that specificity training of repeat sprint ability, results in musculoskeletal and neurological changes (MacDougall *et al.,* 1980; Hermansen and Wachtlova, 1971). Looking specifically at musculoskeletal changes, skeletal muscle has adaptive potential and is therefore capable of modifying its structure in response to environmental change (Enoka, 1996; Bruton, 2002). Due to specificity training, skilled batsmen may have a higher ratio of type II muscle fibres, characterized as fast contractile fibres which facilitate with high intensity activities such as sprinting. This may also be genetically determined and thus these batsmen may have favoured a sport of an intermittent nature and thus have practiced more. This genetic consideration cannot be ignored and needs to be investigated further. Furthermore, studies have suggested that not only does training alter the ratio of muscle 'type' but also improves neural adaptations. With appropriate training, muscle activation patterns become more automatic and improvements in muscle co-ordination and mobilization result, enhancing the athlete's performance (Enoka, 1996; Jiang, Ohira, Roy, Nguyen,Iiyina-Kakueva, Oganov and Edgerton, 1992). In addition to the physical changes and adaptive processes of the muscle fibres, specificity training allows skilled batsmen to become familiar with the physiological and psychological demands of training. Skilled batsmen will thus be more familiar with the physical demands of batting resulting in them perceiving less 'central' and 'local' strain.

With specific reference to 'central' RPE, familiarity and training status may also influence a batsman's perceived exertion when sprinting between the wickets. It is presumed that skilled batsmen have a greater general level of training due to more time spent sprinting between the wickets. Batsmen will therefore be more familiar with both the physiological exertion associated with sprinting as well as more familiar with their own physiological limits. Skilled batsmen may therefore be able to maintain a higher level of performance for extended periods without perceiving the task requirements as being unattainable. In addition, training status has been said to influence motivational responses. Motivation is an additional mediator of perceived exertion (St Clair Gibson, *et al.,* 2003) where performances have been seen to increase due to the motivation that feedback brings (Mauger, Jones and Williams, 2009; Williams, Bailey and Mauger, 2012). Furthermore, highly trained athletes may use physiological reserve capacities irrespective of competition or performing alone

(Corbett, Barwood, Ouzounoglou, Thelwell and Dicks, 2012). It has to be acknowledged that a weakness of this investigation is that training status was not assessed and this should be considered in further investigations.

With specific reference to perceived muscular effort and thus 'local' RPE, the protocol required batsmen to complete a number of repeated shuttle sprints. These shuttle sprints require repeated eccentric muscle activity which is associated with muscle fibre damage causing discomfort, specifically in the musculature of the lower limbs (Enoka, 1996; Nicol *et al.,* 1991; Byrne, Twist and Eston, 2004). It can be presumed that both groups were at risk of experiencing some sort of lower limb muscle damage which could become progressively worse as the number of shuttle sprints increases. In addition, and of interest, RPE is determined at the onset of exercise via a feed-forward mechanism. This feed-forward mechanism utilizes previous experience, knowledge of the exercise duration and physiological feedback – thus, more skilled batsmen may be able to change their performance to ensure the exercise is completed with no bodily harm; something which has been reported by other authors on different sports people (Albertus *et al.,* 2005; Tucker, 2009; Williams, Jones, Sparks, Marchant, Micklewright and Mc Naughton, 2013).

Another important finding was that both groups displayed a similar inverse relationship between muscle activation and sprint times in all three trials. Specifically, muscle activation decreased over the 14 shuttle sprints whereas, sprint times were seen to increase over the sprint series with shuttle 14, for the most part, being faster than shuttle 1 (Figure 9, pg 43, Figure 12, pg 55, Figure 13, pg 59, Figure 14, pg 62 and Figure 15, pg 66).

A decrease in muscle activation over time is expected due to the increasing demands placed on the musculature of the lower limbs during repeated sprints between the wickets (Noakes and Durandt 2000). According to the biomechanical model proposed by Noakes and Durandt (2000), performance may be influenced partly by the elastic energy return of muscles during exercise. Eccentric muscle actions influence the ability of muscles to return elastic energy, which in the presence of higher repetitions of accelerating and decelerating within sprinting bouts, decrements are elevated (Noakes and Durandt, 2000). For this reason, a decline in muscle activation level over the 14 shuttles is expected due to the muscles lack of ability to return elastic energy. Skilled batsmen may have the ability to resist eccentric fatigue due to genetic factors and training resulting in the subconscious selection of fewer muscle fibres, or a down regulation in muscle activation, thus decreasing exposure to muscle damage.

Additionally, in support of a central regulation of exercise intensity, numerous studies have shown that variations in power output, specifically those observed during prolonged self-paced exercise, are paralleled by changes in integrated surface electromyography (iEMG) (Robinson, 1982; Tucker *et al.,* 2004). St Clair Gibson *et al.* (2001) found that reductions in iEMG were equivalent to the decline in power output during repeated 1 and 4 km high intensity bouts performed during a 100 km cycling trial. Likewise, MacDougall *et al.* (1980), Bruton, (2002) and Billaut *et al.* (2011), also suggested that higher levels of muscle activation elicited greater mechanical output. When a larger volume of muscle fibres are activated, increases in both work and power output become apparent (MacDougall *et al.,* 1980; Enoka, 1996). This however, was not apparent in the findings of this study as decreasing EMG activity was associated with an increase in performance, specifically; sprint times became faster over time (Figure 9, pg 43).

In a study by Hettinga, De Koning, Broersen, Van Geffen and Foster (2006), iEMG was seen to increase despite a decline in power output towards the end of middle distance (4000m) cycling time trials. iEMG of the vastus lateralis and biceps femoris was seen to progressively increase throughout the trial irrespective of an evoked negative, positive or even pacing strategy (Hettinga *et al.,* 2006). These results therefore suggest that fatigue, and subsequent variations in pacing strategies during short and middle distance events are not essentially dictated by a centrally controlled down regulation of muscle activation, but also by physiological changes within the muscle itself (Hettinga *et al.,* 2006). Additionally, iEMG has been found to parallel changes in power output during prolonged self-paced exercise but not necessarily during short and middle distance events (St Clair Gibson *et al.,* 2001). These findings thus support the findings from the current investigation even though power output could not be measured. Billaut *et al.* (2011) showed this in a cycle ergometry protocol where peak power output (W) and mechanical work (kJ) were calculated for each sprint completed. Additionally, the total work and percentage decrements over the repeated sprints for work (Wdec) and power (Pdec) were also calculated, thus allowing for a more realistic interpretation of the relationship between EMG activity and sprint times (Billaut *et al.,* 2011). The findings from this study will be discussed later on in the chapter.

5.3 GENERAL FINDINGS (effect of trial)

Although overall effects illustrate that skilled batsmen achieved faster sprint times between the wickets, it is necessary to isolate the groups and assess the performance of each group over the three trials. The isolation of each group's performance over the three trials will identify how the groups coped with the varying information presented in each trial, and further highlight the impact that experience has on the selection of suitable pacing strategies.

5.3.1 IDENTIFYING PACING DURING EXERCISE

There are certain features evident within a work bout which indicates the presence of pacing. Indicative features are however highly dependent on the requirements or demands of the work bout. The three experimental trials completed by batsmen had the same work load (7 overs, 14 shuttle sprints), however differed with regards to the nature of information provided to the batsmen both prior and during the trials. It was expected that this varied information would induce different responses in the dependent variables measured. Additionally, perhaps the impact of experience would further result in discrepancies between the skilled and the less-skilled batsmen's responses.

Billaut *et al.* (2011) conducted a similar study examining the influence of knowledge of the end point of exercise on selected physiological responses and pacing during short repeated sprints in cyclists. Findings from this study revealed that in the anticipation of performing fewer sprints (deceptive trial), muscle recruitment and mechanical output was highest during the first five sprints (5 of 10 sprints). Dissimilarly, when participants had no information regarding the number of sprints to be completed in the trial (unknown trial), less muscle activity was apparent in addition to a lower mechanical output profile. In support of these findings, and according to the anticipatory feedback model, in the presence of a known end point, both skilled and less-skilled batsmen were able to select a suitable pacing strategy which would ensure an optimal performance throughout the work bout (control trial). When, however, the end point was unknown or unclear, performance decrements became apparent (unknown and deceptive trial) which is supported by the work of others (Tucker, 2009: Williams *et al.,* 2013).

With specific reference to this investigation; the attainment of the fastest sprint times and low muscle activation in each trial may be suggestive of a superior performance. Skilled batsmen therefore performed the best in all three trials as they obtained significantly faster sprint times in comparison to the sprint times obtained by the less-skilled batsmen (Figure 9, pg 43). Furthermore, skilled batsmen had lower muscle activation levels. When, however, looking at the performance of each group over the three trials separately, results revealed that skilled batsmen performed best in the deceptive trial while less-skilled batsmen performed best in the control trial. However, superior performance cannot be isolated to fast sprint times and low muscle activation levels only. The relationship of these two variables with the perceived exertions reported by the batsmen, also need to be taken into consideration when determining performance.

During exercise, sensations of exertion are consciously interpreted by drawing upon mental representations and beliefs that have been constructed and reinforced through similar previous occurrences (Lambert, St Clair Gibson and Noakes, 2005). Athletes' performance beliefs can potentially influence their governance of efferent muscular control (Micklewright, Papadopoulou, Swart and Noakes, 2010). Furthermore, any mismatch between an athlete's afferent sensations and expected outcomes will cause elevated RPE levels. If however athletes' have conscious determination to persist based upon knowledge from previous experience, they can achieve a specific level of performance (Micklewright *et al.,* 2010). It can therefore be presumed that skilled batsmen possess this conscious determination to achieve a superior performance due to their ability to draw upon mental representations and beliefs from previous experiences. Skilled batsmen are thus able to interpret and report more accurate 'central' and 'local' RPE ratings. Lower ratings indicate that batsmen are performing within their physiological and psychological limits, and perceive the task requirements as attainable.

5.3.2 Deceptive trial

According to the anticipatory feedback model, when the actual length of exercise exceeds the expected duration, decrements in performance become apparent (Tucker, 2009). Factors such as the initial work rate, the generation of 'template' RPE and the rate of RPE increase, will be selected based on the expectation of a shorter exercise bout (Tucker, 2009; Morton 2009). Once, however the actual duration exceeds the expected duration, the brain indentifies the discrepancy between the 'template' RPE and 'conscious' RPE and makes the necessary changes to rectify this discrepancy. The extent to which performance is jeopardized is dependent on the time taken for the athletes to rectify the mismatch between the 'template' and 'conscious' RPE.

However, in order to assess which group dealt with the deception best, a comparison of the sprint times elicited in the first shuttle sprint series (shuttle 1 to 7), and the sprint times elicited in the second shuttle sprint series (shuttle 7 to 14), was determined. This comparison highlighted which group was able to rectify the discrepancy between the RPE values and minimize any decrements associated with the deception of the trial (Figure 9, pg 43).

Table VIII: Change in performance (sprint times) of both skilled and less-skilled batsmen in the deceptive trial (seconds, % increase or decrease)

BETWEEN SPRINTS	**1 and 7**	**7 and 14**
Skilled	14.4% **decrease**	7.5% **increase**
Less-skilled	24.59% **decrease**	19.2% **increase**

According to Table VIII (pg 80), less-skilled batsmen may have performed optimally in the first 7 shuttles, evident through a 24.59% decrease in initial sprint time. Following shuttle 7, it can however be presumed that less-skilled batsmen selected the incorrect 'template' RPE, initial work rate and rate of RPE increase, which resulted in a sudden increase in sprint times. Table VIII illustrates that less-skilled batsmen showed a 19.2% increase in sprint times over the performance of the final 7 shuttle sprints. Skilled batsmen however, experienced a much smaller increase in sprint times over this period (a 7.5% increase) (Table VIII, pg 80). It is probable that less-skilled batsmen lacked the ability to successfully adapt and adjust to the additional 7 shuttle sprints in the trial. Skilled batsmen however experienced less severe decrements in their performance, (increase in sprint times) thus suggesting they had a greater ability to rapidly adjust to the new exercise requirements and overcome the negative effects of deception.

Another possibility as to why skilled batsmen elicited faster sprint times in the presence of deception may be attributed to the psychological component (Billaut *et al.,* 2011). Previous research suggests that the assumption of fewer shuttle sprints may have increase an athlete's motivation to achieve superior performance (Billaut *et al.,* 2011; Williams *et al.,* 2013). Participants in the Billaut *et al.* (2011) study may have been more motivated to exert additional effort in comparison to the conscious effort exerted by participants in the control trial. This was evident through a higher mechanical output and rating of perceived exertion. In support of this, recent literature states that a higher level of motivation is essential in establishing optimal performance (Hulleman *et al.,* 2007; Tucker and Collins, 2012). Thus, in order to optimize the gains received during practice, a high level of motivation must be present (Matschiner *et al.,* 1998; Hodges and Williams, 2005). According to the 'Athletic Performance Model' put forward by Tucker and Collins (2012), athletes may have certain intrinsic factors which predispose their ability to be motivated. However, it is the addition of extrinsic factors such as verbal encouragement, coaching and certain training techniques which allow batsmen to achieve a higher level of motivation which transcends into the confidence which enables an athlete to complete an exercise task (Bandura, 1997) without catastrophic failure (Portus and Farrow, 2011; Foster, Hendrickson, Peyer, de Koning, Lucia, Battista, Hettinga, Porcari and Wright, 2009; Renfree, West, Corbett, Rhoden and St Clair Gibson, 2012). It is therefore presumed that skilled batsmen, who have greater exposure to these extrinsic factors, are more motivated which facilitates in the attainment of superior performance when sprinting between the wickets. This could then translate to intrinsic motivation to perform better.

Furthermore, higher RPE ratings are generally observed in deceptive trials due to the incongruity between the information provided and what is expected (Paterson and Marino, 2004; Williams *et al.,* 2013). Likewise, with regards to this investigation, ‘central’ RPE was reported as being highest for both batsmen in the deceptive trial. Figure 10 (pg 47) clearly illustrates how the addition of 7 shuttle sprints altered both groups perceptions of their perceived effort. Following the deception, skilled batsmen showed a decrease in their perceived exertion, specifically between over 4 and 5 (Figure 10, pg 47). This temporary decrease in ratings may suggest that batsmen were re-assessing the trial requirements and thus altering their existing ‘template’ and ‘conscious’ RPE. ‘Central’ ratings were then seen to continue to increase throughout the remainder of trial. Similar findings were seen by Micklewright *et al.* (2010), where although a mismatch between the participants’ afferent sensations and their expected outcomes caused elevated RPE levels, participants still had a conscious determination to persist based upon knowledge from previous experience that they can achieve a specific level of performance (Micklewright *et al.,* 2010). Likewise, Billaut *et al.* (2011) proposed that the higher mechanical output evident in the deceptive trial may have been attributed to the participants’ psychology. Participants believed that the deceptive trial required only 5 sprints as apposed to ten. This information therefore motivated participants to exert more effort in comparison to the conscious effort exerted by participants in the control trial (Billaut *et al.,* 2011). The same could be said for the skilled batsmen in this study.

In contrast, less-skilled batsmen showed no signs of a readjustment period following the reveal of the deception evident in the trial (Figure 10, pg 47). RPE ratings were seen to continue to increase significantly following the addition of the 7 shuttle sprints. Additionally, mean ‘central’ ratings were highest (11.69) in this trial suggesting that less-skilled batsmen perceived their efforts to be greater following the addition of the unexpected 7 shuttle sprints, compared to the perceived effort exerted in the other two trials.

Presumably, less-skilled batsmen lack previous experience which is said to facilitate in the rapid adoption and adjustment of the ‘template’ RPE (Tucker, 2009; Williams *et al.,* 2013). In support of this, previous literature has suggested that if there is an absence or lack of experience, then perhaps pacing strategies become more dependent on the interpretation of sensory afferent feedback or RPE (Baden, Mclean and Tucker, 2005; Tucker, 2009; Micklewright *et al.,* 2010).

Additionally, the level of experience of the batsmen may affect how the batsmen interpret both the actual demands of the trials, as well as how they interpret their own perceived exertion. Previous experience is suggested to be an important variable in exercise performance (Wulf, Chiviacowsky and Lewthwaite, 2010) and a possible mediator for perceived exertion (St Clair Gibson *et al.,* 2003). During exercise, sensations of exertion are consciously interpreted by drawing upon mental depictions, representations and beliefs that have been constructed and reinforced through similar previous occurrences (Lambert *et al.,* 2005). These mental depictions thus form part of an athlete's subconscious. Over time, athlete's become reliant on the memory of the fatigue which contributes to the establishment of accurate tolerance levels and sufficient reserve capacities during exercise (St Clair Gibson *et al.,* 2003; Lambert, *et al.,* 2005; Mauger *et al.,* 2009; Micklewright *et al.,* 2010).

Skilled batsmen therefore draw from previous experience which ensures the selection of a more accurate and realistic interpretation of both the exercise requirements and their perceived exertion. In contrast, less-skilled batsmen may over exaggerate their perceived exertions due to their lack of experience with regards to time spent at the crease and sprinting between the wickets. Lack of experience and exposure prevents batsmen from being able to accurately compare their current state of exertion with similar exertions experienced during previous work bouts of a similar nature. Less-skilled batsmen thus rely primarily on conscious processes with little influence from subconscious processes. The lack of reliance on subconscious process, will further affect batsmen's confidence levels, which will transcend into decrements in performance.

With regards to muscle recruitment, both groups had a greater decline in activation between shuttle 1 and 7. Following shuttle 7, activations levels continued to decrease however at a steadier rate. These results were expected due to the nature of the trial. The impact of skill, however, may have been evident through skilled batsmen obtaining their lowest quadriceps complex activation in the deceptive trial (VL, 40.14% V.s and VM, 38.99% V.s). Additionally, lower levels of muscle activation may be another indication of the stronger presence of subconscious control (St Clair Gibson *et al.,* 2003). The change in trial requirements may have resulted in skilled batsmen making use of their subconscious processes which automatically select a more economical approach to pacing and thus reduce muscle activation.

5.3.3 Control trial

According to the anticipatory feedback theory, when the end point is known, variables such as the correct allocation of energy resources, timing of muscle recruitment patterns, initial work rate and changes in power output can all be determined prior to the commencement of the work bout (Noakes, 2004; Tucker *et al*., 2006; Tucker, 2009). Performance will therefore be optimal as athletes will have sufficient time to select the most suitable pacing strategy (Mauger *et al.,* 2009; Wulf *et al.,* 2010; Williams *et al.,* 2013).

Results from the control trial were interesting in that skilled and less-skilled batsmen had opposing responses for muscle activity and sprint times. More specifically, less-skilled batsmen obtained their fastest sprint times and lowest muscle activation in comparison to their times and muscle activity achieved in the other two trials. In contrast, skilled batsmen obtained their slowest sprint times and highest muscle activation in comparison to the times and activation achieved in the other two trials. Furthermore, skilled batsmen perceived both cardiovascular (10.19) and muscular (7.03) exertion to be lowest in comparison to the other two trials. Likewise, less-skilled batsmen also perceived their muscular exertion to be lowest (7.65) however cardiovascular exertion was reported as 11.65 which was second highest in comparison to the other two trials (Table VI and VII, pg 70 and 71).

Looking specifically at the skilled batsmen, the relationship observed between the dependent variables is suggestive of a modest performance. However, in contrast, less-skilled batsmen achieved what could be seen as their best performance through the attainment of their fastest sprint times, whilst perceiving their muscular exertion to be low. Perhaps, and as seen with the skilled batsmen, the expected nature of the trial provided batsmen the opportunity to pre-determine the exercise requirements. Less-skilled batsmen were therefore able to consciously pre-determine their pacing strategy which ensured they were able to complete the trial well within their physiological and psychological capabilities. Less-skilled batsmen were therefore in control of their performance and thus perceived their efforts to be tolerable. In the other two trials (DT and the UT), the lack of prior planning and accurate interpretation of the trial's demands, required less-skilled batsmen to rely more heavily on their subconscious control. However, due to less-skilled batsmen's lack of experience with regards to performing in an environment where the exact end point is known, perceived exertions may have been less accurate. This was evident through an increase in less-skilled batsmen's sprint times, higher muscle activity and their higher RPE ratings (Table VI and VII, pg 70 and 71).

5.3.4 Unknown trial

According to the anticipatory feedback model, when an athlete is unaware of the absolute distance or duration of a task, athletes' utilize their resources more economically by reducing their initial work rate (Tucker, 2009). A slow initial work rate along with a slow rate of RPE increase ensures a constant substrate reserve. Variables such as power output, energy substrate allocations and heart rate thus remain fairly constant and within the athlete's physiological limits (Baden *et al.,* 2005; Tucker *et al*., 2007; Tucker, 2009; Billuat *et al.,* 2011; Coquart and Garcin, 2008; Mauger *et al.,* 2009). The initial work rate is therefore reduced in comparison to the work rate which would have been selected if the end point was known prior to the commencement of a work bout (Tucker, 2009). This reduction in initial work rate essentially results in an overall underperformance, similar to that observed when actual duration performed by the athlete is shorter than expected (Tucker, 2009; Mauger *et al.,* 2009). With specific reference to this investigation, both groups displayed a more modest performance in comparison to the other two trials (CT and DT). This was evident through the batsmen's' mixed responses, more specifically, their restrained sprint times, low muscle activation and low RPE ratings (Table VI and VII, pg 70 and 71).

Although both groups elicited a more reserved performance, skilled batsmen achieved the better performance of the two groups. Skilled batsmen adopted a more economical pacing strategy and had the lowest muscle activation in this trial in comparison to the other two trials (CT and DT). Billaut *et al.* (2011) found comparable findings, where participants were seen to recruit or activate less muscle and thus elicited lower mechanical outputs, when the number of sprints to be completed was unknown prior to the start of the work bout. Additionally, it can be presumed that skilled batsmen possess a higher level of confidence, partly attributed to their familiarity with sprinting between the wickets. Confidence may be reinforced through repeated performances or experience; the memory of which has been proposed to be one of the determinants of perceived exertion and effort regulation during a subsequent similar exercise task (St Clair Gibson *et al.,* 2003). With regards to this investigation, the confidence apparent amongst skilled batsmen may result in an automatic reliance on subconscious processes. Through exposure to match situations and trial and error, skilled batsmen automatically adopt a more economical approach to pacing when the end point is unknown. This economical approach can be seen in the 'U-shaped' muscle activation elicited by the skilled batsmen in this trial (Figure12-15, pg 55- 66). Batsmen first showed a slow initial decrease in muscle activation. This decrease was then followed by a more steady consistent activation pattern, which was maintained throughout the remainder of the trial. Although these responses and thus results are not optimal, they are still favourable in these circumstances. These results further suggest that skilled batsmen are comfortable with performing in open loop environments.

In contrast, when looking at the performance elicited by less-skilled batsmen, and with specific reference to muscle activation, less-skilled batsmen had their highest level of muscle activation in this trial. This higher level of muscle activation can be seen as an attempt by the batsmen to overcompensate to ensure they are prepared regardless of the exercise requirements (Table VI and VII, pg 70 and 71).

It can therefore be presumed that less-skilled batsmen make a conscious decision to take a more 'protective approach.' This type of approach aims to ensure that resources, and specifically the availability of muscle fibres, is utmost, such as to avoid premature fatigue. This approach further suggests that less-skilled batsmen lack confidence in their abilities when placed in an environment associated with uncertainty. Furthermore, the lack of experience prevents less-skilled batsmen from automatically making use of a pre-existing pacing strategy. Less-skilled batsmen therefore lack the ability to draw from subconscious processes, as seen with skilled batsmen.

With regards to RPE ratings, less-skilled batsmen reported their lowest ‘central’ RPE and highest ‘local’ RPE in the unknown trial (Table VI and VII, pg 70 and 71). Firstly, by reporting their lowest ‘central’ RPE ratings in this trial, it can be presumed that batsmen perceived their cardiovascular strain to be tolerable during the performance of this trial. This may further suggest they were consciously reserving their performance based on the uncertainty associated with the trial. These reservations resulted in slower sprint times in comparison to the other two trials (Table VI and VII, pg 70 and 71). It can thus be presumed that they batsmen were essentially underperforming which according to the anticipatory feedback theory, is expected. The low ‘central’ RPE ratings further confirm they made a conscious effort to reserve performance and remain well within their physiological limits.

Furthermore, less-skilled batsmen reported their highest ‘local’ RPE in comparison to the other two trials. These results highlight the impact that lack of experience has on pacing and the interpretation of affect feedback (Williams *et al.,* 2013). Less-skilled batsmen thus lack the ability to draw from previous mental representations or occurrences which may results in them over exaggerating their perceived exertions to justify their poor performance (slower sprint times). Additionally, the lack of experience or exposure to sprinting between the wickets prevents less-skilled batsmen from knowing their physical and physiological limits. Less-skilled batsmen thus highlight how, the lack of dependency on subconscious processes may in fact limit performance.

5.4 SUMMARY

In conclusion, the attainment of faster sprint times, lower muscle activation and low RPE ratings is usually reflective of a superior performance during an exercise bout (Tucker, 2009; Williams *et al.,* 2013) and so skilled batsmen, in this study, achieved the more superior performance in all three trials.

With respect to pacing, less skilled batsmen were better able to pace themselves when the end point was known (CT). When the exercise environment changed (deceptive trial and unknown trial), their performance decreased. In contrast, skilled batsmen paced themselves better across all trials and particularly when the end point was unclear or unknown prior to the start of the trial. These batsmen performed well under deception which is what typically happens when a batsman arrives at the crease. Perhaps this indicates the strong presence and influence of the skilled batsmen's subconscious control. Through previous experience, the selection of more appropriate pacing strategies is established. Skilled batsmen thus have the ability to automatically select a more suitable 'template' RPE, initial work rate and rate of RPE increase, in comparison to less-skilled batsmen who were seen to act irrationally and placed more emphasis on conscious control. Less-skilled batsmen are less experienced and do not have accurate references to draw from, due to their lack of exposure to the specific task and which is reflected in their performance (Table VI and VII, pg 70 and 71).

CHAPTER VI

SUMMARY AND RECOMMENDATIONS

6.1 SUMMARY OF RESULTS

Significant group effects were found for sprint times, ‘central’ and ‘local’ RPE. More specifically, skilled batsmen were significantly faster than the less-skilled batsmen in all three trials. Less-skilled batsmen however, reported significantly higher RPE (‘central’ and ‘local’) ratings than skilled batsmen in all three trials. Furthermore, skilled and less-skilled batsmen elicited similar mean muscle activation (ST, BF, VM and VL) thus no significant group effect was found. Trends showed that less-skilled batsmen had the higher level of muscle activation for all four muscle groups in all three trials (Table VI and VII, pg 70 and 71).

Looking specifically at sprint times, skilled batsmen obtained faster sprint times (6.41 sec) compared to the less skilled batsmen (6.91 sec) in all three trials (Figure 9, pg 43). Likewise, sprint times also showed a significant ($p<0.05$) decrease over time and therefore over the 14 shuttle sprints. Batsmen thus become faster over the performance of the sprints in the sprint series. This decrease in sprint times over the shuttle sprint series may indicate that they were not fatigued following the completion of these trials, and perhaps may be further evidence that both groups attempted to adopt some form of pacing to ensure optimal performance throughout each trial.

Likewise for RPE ratings, a significant group effect was revealed for both ‘central’ and ‘local’ RPE (Figure 10 and 11, pg 47 and 51). Less-skilled batsmen obtained higher ratings in comparison to the skilled batsmen in all three trials. Furthermore, both groups displayed a significant increase over time for both ‘central’ and ‘local’ RPE, with the highest ratings reported in the final over. Additionally, ‘central’ RPE was greater than ‘local’ RPE yet both ratings followed similar rates of increase both between and within trials.

No significant group effects were apparent for muscle activation in all three trials. Less-skilled batsmen did however elicit higher muscle activation in comparison to the skilled batsmen in all three trials. Nonetheless, significant decreases in muscle activation (ST, BF, VM and VL) were evident over time. Once again, less-skilled batsmen had the greater percentage decrease in muscle activation over time (Table VI and VII, pg 70 and 71).

Noteworthy, muscle activation and sprint times showed an inverse relationship in all three trials. More specifically, muscle activation (ST, BF, VM and VL) decreased over the shuttle sprint series however sprint times were seen to increase over time.

In addition to these group effects and trends, when looking at each group separately, skilled batsmen achieved their superior performance in the deceptive trial. This was evident through faster sprint times and low muscle activation, in comparison to the times and activation levels obtained in the other two trials. Less-skilled batsmen however showed superior performance in the control trial, evident through the attainment of their fastest sprint times and lowest muscle activation, compared to the values observed in the other two trials (Table VI and VII, pg 70 and 71).

6.2 STATISTICAL HYPOTHESES

6.2.1 With respect to Hypothesis 1:

The results of the muscle activity of the semitendinosus, biceps femoris, vastus medialis, and vastus lateralis indicated no difference between the groups (skilled and less-skilled batsmen). These results therefore accept the null hypothesis.

When looking at the results of the sprint times, 'central' and 'local' RPE, a significant ($p<0.05$) difference between groups (skilled and less-skilled batsmen) was evident. These results therefore reject the null hypothesis.

6.2.2 With respect to Hypothesis 2:

The results of the muscle activity of the semitendinosus, biceps femoris, vastus medialis, and vastus lateralis, sprint times, central and local RPE, all indicated a significant ($p<0.05$) change over the time (shuttle 1 to shuttle 14). These results therefore reject the null hypothesis.

6.3 CONCLUSION

According to the anticipatory feedback model, previous experience is suggested to be an important variable in exercise performance (Tucker, 2009; Wulf *et al.,* 2010). Results from this study support the notion that previous experience facilitates in the obtainment of an improved performance, especially when the end point is unknown. This was concluded through the assessment of the relationship of the dependent variables (sprint times, RPE and muscle activation) in the performance of the batsmen in all three trials.

6.4 RECOMMENDATIONS

With regards to future studies assessing pacing in an intermittent sport such as cricket, the following recommendations need to be taken into consideration:

Future batting-specific research should consider a larger sample for both skilled and less-skilled batsmen in order to increase statistical power of the study. It is further suggested that in order to ensure a more heterogeneous sample of cricket players, skilled batsmen should be drawn from the South African National Training Academy team (elite) and less-skilled batsmen will be drawn from sub-elite league cricket teams. The discrepancy between the levels of play of theses two sample groups would further strengthen the validity of the findings.

More recent time-motion analyses should be done to accurately represent present one-day matches. It was probable that the experimental trials used in this investigate, were too short in duration to allow for a true reflection of the impact of pacing during repeated sprints between the wickets. Batsmen were required to perform a single shuttle sprint (2 runs) every third ball within an over. These conditions are not representative of typical workloads during a batting innings; therefore it is recommended that future research aim to incorporate work bouts of varying intensities thus more representative of an *in situ* one-day cricket match.

It is also recommended that all three experimental trials be randomized, as opposed to only the randomization of the unknown and the deceptive trial. The randomization of all three trials would eliminate or prevent any possible learning effect which may occur.

Perhaps more research *in situ* is required in order to accurately assess the physiological, muscular and perceptual demands placed on the batsmen. This study was conducted in the Human Kinetics and Ergonomics Department, Rhodes University, Grahamstown, South Africa, which lacked authenticity in the replication of a 'real-life scenario' which are major contributing factors to physiological, musculoskeletal and psychological strain and/or fatigue. Laboratory equipment such as the wooden runway prevents batsmen from exerting maximal effort due to the decreased friction as cricket studs were not worn during this investigation.

Furthermore, the method used to measure muscle activity is coupled with a number of limitations. More specifically, the dynamic nature of the protocols causes additional movements and excessive sweating which interferes with the conductivity between the muscle and the skin's surface. Additionally, the EMG is also highly restrictive in nature and may interfere with the usual gait of the batsmen when sprinting between the wickets. In order to eradicate the 'noise' and improve the accuracy of this measure, perhaps a neuromuscular performance test could be included into the experimental procedures as a neuromuscular performance test is representative of 'true' muscle activation.

Lastly, the selected protocol used in this investigation is not specifically cricket related in that it cannot truly be translated to batting where pace is determined by many other external factors. These factors include game dynamics, type of bowlers and field placement. It can however be used by other intermittent sports which require repeated sprints bout.

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APPENDICES

APPENDIX A: GENERAL INFORMATION

- Ethical Approval
- Pre-Protocol Information Letter
- Pre-Consent Form
- Confidentiality Declaration
- Post-Protocol Information Letter
- Post-Consent Form
- Physical activity screening questionnaire (PAR-Q)
- Pre-test instructions to participants
- Equipment Checklist

APPENDIX B: DATA COLLECTION

- Order of procedures
- Rating of Perceived Exertion Scale and explanation
- Data collection sheets

APPENDIX C: ETHICAL APPLICATION FORMS

- Ethics application form

APPENDIX D: STATISTICAL TABLES

- Statistical tables

Appendix A:

Human Kinetics and Ergonomics Ethics Committee Report

RHODES UNIVERSITY
Where leaders learn

Student Name: Andrea Elliott

Type of Research: Masters Research Project

Project Title: Impact of batting skill on pacing during repeated sprints between the wickets

Supervisor: Dr Christie

Application received: December 2012

Report Compiled: 23 January 2013

Approved	Approved, on condition that suggestions have been effected ✓	Request for rework and resubmission	Rejected

Remarks:

The ethics committee is happy with your application.

Signed

AI Todd
Chair: Human Kinetics and Ergonomics Ethics Committee

PRE-PROTOCOL INFORMATION LETTER

RHODES UNIVERSITY
Grahamstown • 6140 • South Africa

HUMAN KINETICS AND ERGONOMICS

Cell: 072 115 0719 Fax: (046) 603 8934 E-mail: g08e0069@campus.ru.ac.za

Dear: ______________________,

Thank you for offering to participate in my masters degree research projected entitled:

Impact of batting skill on pacing during repeated sprints between the wickets

The purpose of this study is to investigate whether pacing is present in an intermittent sporting activity such as batting. A cricket batting protocol will be employed in a laboratory setting to mimic a batting session in a match situation. The protocol used for the study has been carefully devised based on match evaluations and the calculation of the average number of runs per over at a semi-professional level. As a participant in this study, you will be required to sprint between the wickets on a simulated cricket pitch when instructed to do so by the researcher. The batting work-bout will not exceed an average batting session mimicked from a semi-professional level. In order to assess whether pacing is present in an intermittent context such as during a batting innings, deception is sometimes necessary. If this is the case it is only used in circumstances where the information cannot be obtained in any other manner.

PROCEDURES

You will be required to attend four sessions (one introduction and habituation session and three experimental sessions at the Human Kinetics and Ergonomics Department at Rhodes University, Grahamstown, South Africa.

The first session will be a briefing session where an explanation of the testing procedures, requirements and project aims will be explained to you in detail. You will then be asked to sign a consent form, stating that you are comfortable with the procedures and giving your permission to participate in the study. Data such as age, stature and mass will then be collected. The habituation session will then follow. The aim of the habituation session is to familiarize you with the testing procedures as well all equipment used in the study. You will also be familiarised with the muscle activity baseline measures protocols. This will require the placement of the necessary electromyography (EMG) electrodes and the performance of a single all-out maximal sprint across the length of the cricket pitch. Furthermore, it is important to note that on arrival to the habituation session, you will be given a participant code number which will ensure that all your personal data collected during the study, remains anonymous. This habituation session should be no longer than 30 minutes.

You will then be required to participate in session two, three and four at the Human Kinetics and Ergonomics Department at Rhodes University. During these three sessions you will be instructed to complete one of the three test trials each time. You will be required to bring, and wear, all cricket kit as in a real match situation. The placement of the EMG electrodes will then occur followed by a warm up and stretch session. In order to obtain the baseline muscle activity measurements, you will then be required you to complete an all-out maximal sprint across the length of the pitch. This will be repeated twice, once before the trial and once after the trial. Following this you will be required to sprint between the wickets when instructed to do so by the researcher. Each work bout consists of 7 overs or 42 deliveries. Perceptual data will be collected after each over, using the rating of perceived exertion scale (RPE) which will be explained in detail to you during the habituation session.

Risks associated with the study:

a) Muscular or joint-related injury: This study requires you to perform a number of shuttle sprints between the wickets. You are therefore subjected to rapid acceleration and deceleration movements. DOMS is predominately a result of these excessive eccentric muscle contractions and is recoverable after a few days (4-7days), however if muscle fibre damage is severe, injury may result. To avoid injury, you will perform the three trials with a three to five day gap in between each trial to prevent DOMS from affecting your performance. In order to further reduce the risk of injury, you are required to perform a cricket specific warm-up as to reduce the chance of any serious muscle damage. It is also important to note that the batting-protocol allows for sufficient rest breaks in between both balls delivered and batting overs. These allocated rest breaks will prevent muscle damage caused by over use and fatigue which are the two main contributors to the development of DOMS. You are also at less risk of developing DOMS as being a cricket player; you are familiar with the rapid acceleration and deceleration movements.

b) Slip, trip and fall accidents: The batting protocol will take place at in the Human Kinetics and Ergonomics Laboratory. You will be required to wear rubber soled cricket shoes during testing which will provide sufficient grip so as to avoid the occurrence of any slip, trip or fall accidents.

c) Cricket ball-related injuries: A Slazenger ball was used throughout the entire duration of the experimental protocol. A bowler will deliver each ball to you. You are therefore required to wear full cricket kit to avoid or minimise any possible ball-related injuries.

d) Skin discomforts

Skin irritations: In order to ensure optimal conduction during testing, EMG electrode cream is placed on the EMG electrodes which are then placed on your skin. Sensitive skin may experience minor skin irritations. In such a case, the electrode cream will be removed from the skin. EMG electrode cream is however aqueous based and should therefore not affect the skin.

Benefits associated with the study:

a) Knowledge (education): Participation in this study will allow you to obtain knowledge about your anthropometric and morphological data. You will be exposed to the processes, procedures and equipment used during the experimental sessions as well as the results obtained from the trials. This information may increase your understanding with regards to the dynamic and intermittent nature of cricket. The results will also contribute to your knowledge of both the sport and your own personal capabilities. This information may then be used to enhance your performance through the adoption of more suitable pacing strategies.

Additional Information:

Please note that the information obtained during the study will be kept confidential and will only be used for statistical analysis. You will receive feedback in writing once the study is complete. If at any time you feel uncomfortable and cannot continue with the study, please feel free to withdraw. The data will be stored in the Human Kinetics and Ergonomics department and may be used for further research purposes, however your anonymity is still ensured.

Thank you for showing interest and participating in this study. If there are any questions that you may have please do not hesitate to contact me in the Human Kinetics and Ergonomics department.

Yours sincerely,

Andrea Elliott
Human Kinetics and Ergonomics
072 115 0719
g0e0069@campus.ru.ac.za

PRE-CONSENT FORM

RHODES UNIVERSITY
Grahamstown • 6140 • South Africa

HUMAN KINETICS AND ERGONOMICS

Cell: 072 115 0719 Fax: (046) 603 8934 E-mail: g08e0069@campus.ru.ac.za

PARTICIPANT CONSENT FORM

I, ______________________________, agree that I have been informed as far as possible, both verbally and in writing, of the procedures required in this research project entitled:

Impact of batting skill on pacing during repeated sprints between the wickets

I have read the information sheet and fully understand the testing procedures that will take place during this study. I understand that the aim of this study is to indentify the presence of pacing strategies and that each condition will differ. I am aware that deception may need to be employed in this type of research. The risks and benefits associated with the study have also been brought to my attention. I have further been given the opportunity to ask questions or express my concerns regarding the testing procedures. By voluntarily consenting to participate in this research project I accept responsibility together with the Human Kinetics and Ergonomics Department, whereby should injury or accident occur as a result of the protocol being performed, the Human Kinetics Department will cover any fees incurred and provide support to ensure my rehabilitation. If however injury it is shown to be self inflicted, or not directly related to the study, the department will waiver any recourse against the researchers of Rhodes University. I further understand that all information gained from this study will be treated confidentially and that my anonymity will be protected at all times. I am aware that data obtained from this study may be used and published for statistical and scientific purposes. I realize that if I experience distress at any time during the study, I may withdraw.

I have read and fully understood that above information, as well as the information in the letter accompanying this form.

I therefore consent to voluntarily participate in this study.

PARTICIPANT (OR LEGAL REPRESENTATIVE):

______________________	______________________	______________________
(Print name)	(Signed)	(Date)

PERSON ADMINISTERING INFORMED CONSENT:

______________________	______________________	______________________
(Print name)	(Signed)	(Date)

WITNESS:

______________________	______________________	______________________
(Print name)	(Signed)	(Date)

WITNESS:

______________________	______________________	______________________
(Print name)	(Signed)	(Date)

CONFIDENTIALITY DECLARATION

RHODES UNIVERSITY
Grahamstown • 6140 • South Africa

HUMAN KINETICS AND ERGONOMICS

Cell: 072 115 0719 Fax: (046) 603 8934 E-mail: g08e0069@campus.ru.ac.za

DECLARATION

I, _______________________, as a participant in the study entitled:

Impact of batting skill on pacing during repeated sprints between the wickets

recognize my responsibility in maintaining the confidentiality of this trial and hereby agree to the following:

- I will not reveal the nature of this trial to any other participant recruited for this study, until all experimentation is complete.
- I acknowledge that revealing this information would render this study null and void.
- I agree that obtaining this information is vital to the scientific progress in the assessment of intermittent sports, in this case, cricket, and failure to obtain valid and reliable data during this study may negatively impact the sport itself.
- If asked by fellow participants, I agree that I am permitted to share that the condition consisted of a number of shuttle runs, however am not permitted to share the exact number of runs completed in this trial.
- I agree that this confidentiality agreement shall be binding up to and including the moment at which I receive an email from the researcher thanking the

sample for participation in the study and thus declaring the research complete.

PARTICIPANT (OR LEGAL REPRESENTATIVE):

____________________	____________________	____________________
(Print name)	(Signed)	(Date)

PERSON ADMINISTERING CONFIDENTIALITY DECLARATION:

____________________	____________________	____________________
(Print name)	(Signed)	(Date)

WITNESS:

____________________	____________________	____________________
(Print name)	(Signed)	(Date)

WITNESS:

____________________	____________________	____________________
(Print name)	(Signed)	(Date)

POST-PROTOCOL INFORMATION LETTER

RHODES UNIVERSITY
Grahamstown • 6140 • South Africa

HUMAN KINETICS AND ERGONOMICS

Cell: 072 115 0719   Fax: (046) 603 8934   E-mail: g08e0069@campus.ru.ac.za

Dear: ______________________,

Thank you for participating in my masters degree research projected entitled:

Impact of batting skill on pacing during repeated sprints between the wickets

The aim of this study is to investigate whether pacing is present during an intermittent sport such as cricket, focusing specifically on batting.

The exact mechanism by which pacing strategies regulate exercise performance is not yet known however based on the integration of the RPE, physiological functions and performance measures researched in various studies, the 'anticipatory feedback' model has been proposed. This model examines how the conscious perception of effort regulates exercise performance in order to protect athletes' from harm. The model further ensures that athletes' are able to maintain optimal performance throughout the entire duration of the exercise bout. The model utilizes previous experience, which is usually reflective of an athlete's level of expertise, anticipation of exercise distance or exercise duration, and physiological feedback to regulate performance and pacing strategy.

The question addressed in this investigation was to therefore establish whether previous experience, usually reflective of an athlete's level of expertise, allows for the adoption of a more suitable pacing strategy which ensures optimum performance throughout the duration of the batsmen's batting innings.

In order to achieve this you were required to complete a cricket batting protocol reflective of a batting session in a match situation. The protocol used for the study was carefully devised based on match evaluations and the calculation of the average number of runs per over at a semi-professional level. In order to adequately assess the adoption of a pacing strategy, deception was employed in two of the trials, the unknown and the deceptive trial. This could not be highlighted to you as the awareness of this deception would have meant that a different pacing strategy would have been adopted. You were selected to participate in this study as you are familiar with the intermittent nature of cricket, are well-trained and therefore able to complete the selected work bouts without acquiring any fatigue-related injuries.

Thank you for showing interest and participating in this study. If there are any questions that you may have please do not hesitate to contact me in the Human Kinetics and Ergonomics department.

Yours sincerely,

Andrea Elliott
Human Kinetics and Ergonomics
072 115 0719
g0e0069@campus.ru.ac.za

POST-CONSENT FORM

RHODES UNIVERSITY
Grahamstown • 6140 • South Africa

HUMAN KINETICS AND ERGONOMICS

Cell: 072 115 0719 Fax: (046) 603 8934 E-mail: g08e0069@campus.ru.ac.za

PARTICIPANT POST-CONSENT FORM

I, ____, having participated in the study entitled:

Impact of batting skill on pacing during repeated sprints between the wickets

I am now fully aware that deception was employed in two of the three trials, in attempt to adequately assess whether pacing strategies were adopted by the batsmen participating in the study. I am also aware that without the use of deception, specifically during intermittent activity such as batting, pacing could not have been accurately assessed, as knowledge of an exercise end point, and in this case the total number of runs to be completed, would essentially alter the batsmen's performance. By voluntarily consenting to participate in this research I accept responsibility together with the Human Kinetics and Ergonomics Department, whereby should injury or accident occur as a result of the protocol being performed, the Human Kinetics Department will cover any fees incurred and provide support to ensure my rehabilitation. If however injury it is shown to be self inflicted, or not directly related to the study, the department will waiver any recourse against the researchers of Rhodes University. I further understand that all information gained from this study will be treated confidentially and that my anonymity will be protected at all times. I am aware that data obtained from this study may be used and published for statistical and scientific purposes. I was also aware that if I experience distress at any time during the study, I can withdraw immediately.

I have read and fully understood that above information, as well as the information in the letter accompanying this form, and any questions I may have had, have been answered by the researcher to my satisfaction.

PARTICIPANT (OR LEGAL REPRESENTATIVE):

______________________	______________________	______________________
(Print name)	(Signed)	(Date)

PERSON ADMINISTERING THE POST- INFORMED CONSENT:

______________________	______________________	______________________
(Print name)	(Signed)	(Date)

WITNESS:

______________________	______________________	______________________
(Print name)	(Signed)	(Date)

WITNESS:

______________________	______________________	______________________
(Print name)	(Signed)	(Date)

PHYSICAL ACTIVITY SCREENING QUESTIONNAIRE (PAR-Q)

Name:__________________________

Code:__________________________

MEDICAL HISTORY

Tick any of the following conditions, diseases or disorders that you have had in the past or are presently being treated for by a physician or health professional.

- ◻ Heart problems
- ◻ Anaemia
- ◻ Eye problems
- ◻ Peripheral vascular disorders
- ◻ Asthma
- ◻ Hypoglycaemia
- ◻ High/low blood pressure
- ◻ Emphysema
- ◻ Diabetes
- ◻ Epilepsy
- ◻ Migraine
- ◻ Hyperthyroidism
- ◻ Other (specify):____

Have you had any recent medical problems? If so give details below:

____
____
____

Are you currently suffering from any orthopaedic disorder problem? If so briefly describe the problem:

____
____
____

Are there any other concerns, medical or otherwise, that you feel are worth mentioning:

____
____
____

Please indicate any prescribed or over the counter medication that you are currently taking or have taken in the past 6 months:

____
____
____

OTHER HABITS

Please tick appropriate box:

Do you smoke?

YES	NO

If Yes, how many cigarettes per day:_______

EXERCISE HISTORY

Do you exercise regularly?

YES	NO

How many days per week do you normally spend performing at least 20 minutes of moderate to strenuous exercise:

1	2	3	4	5	6	7	0

Do you experience shortness of breath or chest discomfort with exercise?

YES	NO

Provide a rough average of the number of organised/scheduled physical activity sessions you participate in during the week. Tick the appropriate block(s) and fill the number of sessions in next to the particular activity:

□ Jogging_____ □ Hockey_____ □ Rowing_____

□ Swimming_____ □ Tennis_____ □ Rugby_____

□ Cricket_____ □ Soccer_____ □ Squash_____

□ Other_____

PRE-TEST INSTRUCTIONS

Please inform the researcher of any factors that you think may impact or influence your results on the day of testing, for example if you are ill, asthmatic or are taking any prescription medication. Please also note that if you have any lower limb injuries, it is advised that you do not participate in this study. In order to ensure that the results obtained during this study are accurate, I require that you please follow the following instructions before completing the test:

FOR 24 HOURS PRIOR TO TESTING:

- Do not drink alcohol.
- Do not take medication (such as aspirin, painkillers, flu tables etc).
- Do not participate in strenuous exercise.
- Try get at least 8 hours of sleep the night before the testing.

ON THE DAY OF TESTING:

- Eat a substantial meal about 2 hours before the testing.
- Do not eat anything 1.5 hours before the testing.
- Bring a sweat towel and water bottle to testing.
- Wear appropriate cricket attire

Please try to comply with the above instructions to ensure that the data obtained is a true reflection of performance. Your cooperation is greatly appreciated.

EQUIPMENT CHECKLIST

- Datalogger with new batteries, electrodes (five including neutral)
- Fiximol adhesive
- Razor
- Alcohol swabs
- LED timing system
- Stopwatch
- Harpenden Stadiometer
- Toledo Electronic scale
- Slazenger practice balls
- Data collection sheets
- RPE scales

Appendix B:

ORDER OF PROCEDURES

Session I: Introduction and Habituation Session

- Introduction and welcoming (introduce assistants)
- Explanation of procedures and equipment
- Issue letters of information and informed consent and allow for reading time
- Habitude participants to all equipment
- Allow for questions
- Signing of informed consent
- Record all baseline measures (stature, mass, age)
- Complete PAR-Q and additional participant information sheet

Session II and III: Experimentation

- Welcome participant
- Re-inform participant of protocol
- Prepare dominate limb for electrode attachment
- Attach electrodes with fiximol taping
- Ensure Datalogger and its associated cables are working
- Perform warm up (5 minutes)
- Provide time participant to put cricket kit on
- Perform the pre-protocol EMG protocol
- Start experimental trial (randomised order of trials)
- Record muscle activity and sprint time during every sprint (ball 3 and ball 6)
- Record RPE following every over
- End of testing
- Remove cricket kit and equipment (datalogger)
- Thank participants for their participation in the study and organise the following testing date

RATING OF PERCEIVED EXERTION SCALE AND EXPLANATION

RPE SCALE

6.	
7.	VERY, VERY LIGHT
8.	
9.	VERY LIGHT
10.	
11.	FAIRLY LIGHT
12.	
13.	SOMEWHAT HARD
14.	
15.	HARD
16.	
17.	VERY HARD
18.	
19.	VERY, VERY HARD
20.	

EXPLANATION TO PARTICIPANTS

You will be required to complete seven overs with a certain number of shuttle sprints to be performed each over. The number of sprints performed each over is dependent on the trial. Following each over, the researcher will ask you to estimate how hard you feel you are working. The first measure is ‘central’ RPE therefore referring to how much strain your cardio respiratory system is working (heart and lungs). The second measure is ‘local’ RPE and refers to how much strain or effort you perceive your lower limb muscles to be working. A rating of 6 corresponds to your feelings of exertion when standing still, and a rating of 20 corresponds to maximal exertion.

DATA COLLECTION SHEETS

Demographic and anthropometric information collection forms

Name: Order of testing:

Age (years): Participant Code:

Anthropometric Data

Stature (mm):

Mass (kg):

BMI:

Handiness:

Cricket History:

Practice Schedule (Number per week and activities performed during sessions):

Number of matches per season:

EXPERIMENTAL TRIAL COLLECTION SHEET: (note over 1 to over 7)

During Over

	EMG		
	Start time	**End time**	**Sprint time**
Sprint 1			
Sprint 2			

Completion of over

	Central	Local
RPE		

Appendix C:

Attachment from Ethics application form-

APPENDIX 4

THE USE OF DECEPTION IN THIS STUDY

In order to adequately assess the adoption of a pacing strategy during this protocol, deception is necessary. If batsmen were correctly informed of the total number of shuttle sprints to be completed in each of the conditions, they will be able to pre-anticipate the performance requirements and develop a suitable pacing strategy prior to the commencement of each condition. Knowledge of the hypothesis of the study would therefore invalidate the testing.

Deceiving batsmen is not to be taken lightly, however, deception has been used in many pacing-related studies (Ansley *et al.,* 2004; Billaut *et al.,* 2011 and St Clair Gibson *et al.,* 2006), and certain measures have been put in place to ensure the safety and well-being of the batsmen in the study. Measures include maintaining the same total work output in all three trials. The total number of shuttle sprints to be completed by the batsmen therefore remains the same in each trial, but the order of information presentation may differ for each trial. Batsmen selected for the study will be cricketers (specifically batsmen), and therefore familiar with the intermittent nature of batting. Testing will also take place in the cricketing season therefore ensuring that all batsmen are well-trained and at their peak fitness. These criteria contribute to ensuring that players will be able to complete the three trials without great difficulty.

Data collected from the deceptive and unknown trials will not be used until the batsmen have been fully informed about the nature of the study and agreed to their use of their data. Batsmen will therefore receive a post-information letter followed by the post-consent form. The information letter and consent forms can be found in Appendix A.

APPENDIX 6

RISKS AND BENEFITS ASSOCIATED WITH THE STUDY

6a) In order to effectively observe the presence of pacing strategies in an intermittent context, deception is needed as there is no other accurate means of obtaining the requisite response data via physiological and perceptual measures, as knowledge of the exercise end point will provide the athlete the opportunity to pre-anticipate the exercise requirements.

The inclusion criteria for this study stipulates that all participants are cricketers and therefore familiar with the intermittent nature of the game. Testing will take place during the cricketing season to ensure that all batsmen are well-trained and at their peak fitness. This will further ensure that any performance decrements (sprint times) seen during testing, are a result of lack of pacing, as apposed to the lack of fitness of the players'. Batsmen will therefore be able to complete the required trials without fatiguing, as this which would jeopardize the results of the study. Batsmen must also have no recent history of injury (6 months), with specific reference to musculo-skeletal injuries, as these too would prevent optimal physical performance throughout the testing sessions.

Risks related to the study:

a) Deception:

In order to assess the presence of pacing, batsmen have to be deceived, as the knowledge of an exercise end point, in this case the total number of shuttle sprints, would alter the batsmen performance. The batsmen can therefore not be fully informed of the details pertaining to the protocol which may pose as a risk to the players. The inclusion criteria for this study have however been carefully selected as they facilitate in minimizing the risks associated with the use of deception in a study.

Batsmen will therefore be cricketers and thus familiar with the intermittent nature of the game. Batsmen will also be tested during the cricketing season to ensure that they are well-trained and at peak fitness. This fitness component is important as each trial consists of 28 shuttle sprints. The main purpose of the study is to assess each batsman's ability to implement suitable pacing strategies based on the information given at the beginning of each trial. If batsmen are not well-trained and of moderate fitness, the performance measures obtained during testing may in fact be a consequence of physical fatigue, as appose to the lack of ability, which is reflective of level of experience, to pre-anticipant performance requirements and thus not be able to adopt a suitable pacing strategy. Furthermore, heart rate responses will be continuously monitored throughout the testing procedure in order to observe the physiological demand placed on the players. If these values increase to what would be considered dangerous, testing will be terminated immediately.

Participation is also voluntary and batsmen are reminded that they may withdraw from the study if they feel it is necessary to do so. Thus, should a batsmen deem the deception used in the study unacceptable, they may withdraw on the basis of principle and their data will be disposed.

Due to the nature of the study, batsmen will be given a pre-information letter and consent form which is partly deceptive in nature. Following the completion of the deceptive and unknown trials, batsmen will be asked to sign a declaration form, asking them not to inform the other batsmen of the deceptive protocol use in this study as this may influence their performance. A post-information letter will also be given to batsmen explaining the necessity for the deception and if batsmen are comfortable with this information and are willing to carry on with the study, a post-consent letter will then be signed.

Appendix D:

STATISTICAL TABLES

Factors which had statistically significant (95% confidence interval) for both group and trial effects are presented here. For a complete set of the statistical worksheets please contact the author. Highlighted text represents significant difference.

1. Repeated measures analysis of variance (ANOVA) of sprint times of the players (skilled and less skilled) during the **control trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
Sprint times	INTERCEPT	14870.7	1	14870.7	17479.21	0.000000
	GROUP	12.25	1	12.25	14.40	0.000993
	ERROR	18.72	22	0.85		
	SPRINTS	1.29	13	0.10	3.80	0.000005
	SPRINTS*GROUP	0.25	13	0.02	0.75	0.712625
	ERROR	7.36	286	0.03		

2. Repeated measures analysis of variance (ANOVA) of sprint times of the players (skilled and less skilled) during the **deceptive trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
Sprint times	INTERCEPT	14857.71	1	14857.71	15952.00	0.000000
	GROUP	22.70	1	22.70	24.38	0.000061
	ERROR	20.49	22	0.93		
	SPRINTS	0.97	13	0.07	2.67	0.001470
	SPRINTS*GROUP	0.29	13	0.02	0.79	0.666910
	ERROR	8.00	286	0.03		

3. Repeated measures analysis of variance (ANOVA) of sprint times of the players (skilled and less skilled) during the **unknown trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
Sprint times	INTERCEPT	15034.84	1	15034.84	16644.78	0.000000
	GROUP	28.26	1	28.26	31.28	0.000013
	ERROR	19.87	22	0.90		
	SPRINTS	0.32	13	0.02	0.56	0.881262
	SPRINTS*GROUP	0.44	13	0.03	0.77	0.688816
	ERROR	12.45	286	0.04		

4. One-way analysis of variance (ANOVA) of sprint times of the skilled players during the **control trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
Sprint times	INTERCEPT	7014.604	1	7014.604	5643.879	0.000000
	ERROR	13.672	11	1.243		
	SPRINTS	1.085	13	0.083	2.847	0.001144
	ERROR	4.191	143	0.029		

5. Repeated measures analysis of variance (ANOVA) of the 'central' RPE responses of the players (skilled and less skilled) during the **control trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
'central' RPE	INTERCEPT	**200043.01**	**1**	**200043.01**	**3285.098**	**0.000000**
	GROUP	**90.05**	**1**	**90.05**	**14.760**	**0.000886**
	ERROR	134.23	22	6.10		
	OVERS	**1190.87**	**6**	**198.48**	**288.355**	**0.000000**
	OVERS*GROUP	**17.99**	**6**	**3.00**	**4.345**	**0.000480**
	ERROR	90.86	132	0.69		

6. Repeated measures analysis of variance (ANOVA) of the 'central' RPE responses of the players (skilled and less skilled) during the **deceptive trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
'central' RPE	INTERCEPT	**20904.02**	**1**	**20904.02**	**4845.790**	**0.000000**
	GROUP	**48.21**	**1**	**48.21**	**11.177**	**0.002944**
	ERROR	94.90	22	4.31		
	OVERS	**1399.14**	**6**	**233.19**	**385.108**	**0.000000**
	OVERS*GROUP	**27.79**	**6**	**4.63**	**7.648**	**0.000000**
	ERROR	79.93	132	0.61		

7. Repeated measures analysis of variance (ANOVA) of the 'central' RPE responses of the players (skilled and less skilled) during the **unknown trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
'central' RPE	INTERCEPT	**20504.38**	**1**	**20504.38**	**6636.094**	**0.000000**
	GROUP	**36.21**	**1**	**36.21**	**11.720**	**0.002431**
	ERROR	67.98	22	3.09		
	OVERS	**1315.29**	**6**	**219.21**	**521.151**	**0.000000**
	OVERS*GROUP	**19.62**	**6**	**1.77**	**4.208**	**0.000661**
	ERROR	55.52	132	0.42		

8. One-way analysis of variance (ANOVA) of the 'central' RPE of the skilled players during the **control trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
'central' RPE	INTERCEPT	**8723.048**	**1**	**8723.048**	**1156.730**	**0.000000**
	ERROR	82952	11	7.541		
	OVERS	**473.119**	**6**	**78.853**	**88.387**	**0.000000**
	ERROR	58.881	66	0.892		

9. One-way analysis of variance (ANOVA) of the 'central' RPE of the skilled players during the **deceptive trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	P
'central' RPE	INTERCEPT	**9472.190**	**1**	**9472.190**	**1530.123**	**0.000000**
	ERROR	68.095	11	6.190		
	OVERS	**552.143**	**6**	**92.024**	**122.522**	**0.000000**
	ERROR	49.571	66	0.751		

10. One-way analysis of variance (ANOVA) of the ‘central’ RPE of the skilled players during the **unknown trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
‘central’ RPE	INTERCEPT	**9408.583**	**1**	**9408.83**	**1996.218**	**0.000000**
	ERROR	51.845	11	4.713		
	OVERS	**596.833**	**6**	**99.472**	**220.766**	**0.000000**
	ERROR	29.728	66	0.451		

11. One-way analysis of variance (ANOVA) of the ‘central’ RPE of the less-skilled players during the **control trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
‘central’ RPE	INTERCEPT	**11410.01**	**1**	**1140.01**	**2447.81**	**0.000000**
	ERROR	51.27	11	4.66		
	OVERS	**735.74**	**6**	**122.62**	**253.098**	**0.000000**
	ERROR	31.98	66	0.48		

12. One-way analysis of variance (ANOVA) of the ‘central’ RPE of the less-skilled players during the **deceptive trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
‘central’ RPE	INTERCEPT	**11480.05**	**1**	**11480.05**	**4710.286**	**0.000000**
	ERROR	26.81	11	2.44		
	OVERS	**874.79**	**6**	**145.80**	**316.981**	**0.000000**
	ERROR	30.36	66	0.40		

13. One-way analysis of variance (ANOVA) of the ‘central’ RPE of the less-skilled players during the **unknown trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
‘central’ RPE	INTERCEPT	**11132.01**	**1**	**1132.01**	**7591.128**	**0.000000**
	ERROR	16.13	11	1.47		
	OVERS	**729.07**	**6**	**121.51**	**311.017**	**0.000000**
	ERROR	25.79	66	0.39		

14. Repeated measures analysis of variance (ANOVA) of the ‘local’ RPE responses of the players (skilled and less skilled) during the **control trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
‘local’ RPE	INTERCEPT	**9064.024**	**1**	**9064.024**	**4067.586**	**0.000000**
	GROUP	**16.095**	**1**	**16.095**	**7.223**	**0.013449**
	ERROR	49.024	22	2.228		
	OVERS	**163.643**	**6**	**27.274**	**144.143**	**0.000000**
	OVERS*GROUP	**12.238**	**6**	**2.040**	**10.780**	**0.000000**
	ERROR	24.96	132	0.189		

15. Repeated measures analysis of variance (ANOVA) of the 'local' RPE responses of the players (skilled and less skilled) during the **deceptive trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
'local' RPE	INTERCEPT	**13179.43**	**1**	**13179.43**	**5032.145**	**0.000000**
	GROUP	1.52	1	1.52	0.582	0.453702
	ERROR	57.62	22	2.62		
	OVERS	**332.24**	**6**	**55.37**	**144.126**	**0.000000**
	OVERS*GROUP	4.48	6	0.75	1.942	0.078640
	ERROR	50.71	132	0.38		

16. Repeated measures analysis of variance (ANOVA) of the 'local' RPE responses of the players (skilled and less skilled) during the **unknown trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
'local' RPE	INTERCEPT	**20725.93**	**1**	**20725.93**	**5405.238**	**0.000000**
	GROUP	13.71	1	13.71	3.577	0.071838
	ERROR	84.36	22	3.83		
	OVERS	**1098.32**	**6**	**183.05**	**401.761**	**0.000000**
	OVERS*GROUP	1.54	6	0.26	0.562	0.760084
	ERROR	60.14	132	0.46		

17. One-way analysis of variance (ANOVA) of the 'local' RPE of the skilled players during the **control trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
'local' RPE	INTERCEPT	**4158.107**	**1**	**4158.107**	**1682.913**	**0.000000**
	ERROR	27.178	11	2.471		
	OVERS	**43.476**	**6**	**7.246**	**46.712**	**0.000000**
	ERROR	10.238	66	0.155		

18. One-way analysis of variance (ANOVA) of the 'local' RPE of the skilled players during the **deceptive trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
'local' RPE	**INTERCEPT**	**6448.762**	**1**	**6448.762**	**2688.924**	**0.000000**
	ERROR	26.381	11	2.398		
	OVERS	**134.238**	**6**	**22.373**	**59.979**	**0.000000**
	ERROR	24.619	66	0.373		

19. One-way analysis of variance (ANOVA) of the 'local' RPE of the skilled players during the **unknown trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
'local' RPE	INTERCEPT	**9836.679**	**1**	**9836.679**	**1930.973**	**0.000000**
	ERROR	56.036	11	5.094		
	OVERS	**518.57**	**6**	**86.429**	**205.825**	**0.000000**
	ERROR	27.714	66	0.420		

20. One-way analysis of variance (ANOVA) of the 'local' RPE of the less-skilled players during the **control trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
'local' RPE	INTERCEPT	**6448.762**	**1**	**6448.762**	**2688.924**	**0.000000**
	ERROR	26.381	11	2.398		
	OVERS	**134.238**	**6**	**22.373**	**59.979**	**0.000000**
	ERROR	24.615	66	0.373		

21. One-way analysis of variance (ANOVA) of the 'local' RPE of the less-skilled players during the **deceptive trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
'local' RPE	INTERCEPT	**6732.190**	**1**	**6732.190**	**2370.634**	**0.000000**
	ERROR	31.238	11	2.840		
	OVERS	**202.476**	**6**	**33.764**	**85.350**	**0.000000**
	ERROR	26.095	66	0.395		

22. One-way analysis of variance (ANOVA) of the 'local' RPE of the less-skilled players during the **unknown trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
'local' RPE	INTERCEPT	**10902.96**	**1**	**10902.96**	**4234.695**	**0.000000**
	ERROR	28.32	11	2.57		
	OVERS	**581.29**	**6**	**96.88**	**197.176**	**0.000000**
	ERROR	32.43	66	0.49		

23. Repeated measures analysis of variance (ANOVA) of the semitendinosus muscle activity of the players (skilled and less skilled) during the **control trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
ST	INTERCEPT	**646625.6**	**1**	**646625.6**	**85.95130**	**0.000000**
	GROUP	1.4	1	1.4	0.00018	0.989418
	ERROR	165509.6	22	7523.2		
	SPRINTS	**1238.9**	**13**	**95.3**	**2.09647**	**0.014430**
	SPRINTS*GROUP	443.1	13	34.1	0.74975	0.712836
	ERROR	13001.2	286	45.5		

24. Repeated measures analysis of variance (ANOVA) of the semitendinosus muscle activity of the players (skilled and less skilled) during the **deceptive trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
ST	INTERCEPT	**644997.5**	**1**	**644997.5**	**95.68501**	**0.000000**
	GROUP	0.7	1	0.7	0.00010	0.992150
	ERROR	148298.5	22	6740.8		
	SPRINTS	813.9	13	62.6	1.19756	0.280209
	SPRINTS*GROUP	**1278.5**	**13**	**98.3**	**1.88108**	**0.031980**
	ERROR	14952.3	286	52.3		

25. One-way analysis of variance (ANOVA) of the semitendinosus of the less-skilled players during the **control trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
ST	INTERCEPT	**322377.8**	**1**	**322377.8**	**29.91921**	**0.000195**
	ERROR	118524.4	11	10774.9		
	SPRINTS	**1054.0**	**13**	**81.1**	**2.00193**	**0.024454**
	ERROR	5791.2	143	40.5		

26. One-way analysis of variance (ANOVA) of the semitendinosus of the less-skilled players during the **deceptive trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
ST	INTERCEPT	**323155.2**	**1**	**323155.2**	**55.70983**	**0.000013**
	ERROR	63807.5	11	5800.7		
	SPRINTS	**1683.0**	**13**	**129.5**	**2.1522**	**0.014494**
	ERROR	8602.6	143	60.2		

27. One-way analysis of variance (ANOVA) of the biceps femoris of the skilled players during the **unknown trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
BF	INTERCEPT	**298399.2**	**1**	**298399.2**	**104.0329**	**0.000000**
	ERROR	31551.5	11	2868.3		
	SPRINTS	**661.9**	**13**	**50.9**	**2.4135**	**0.005686**
	ERROR	3016.7	143	21.1		

28. One-way analysis of variance (ANOVA) of the biceps femoris of the less-skilled players during the **control trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
BF	INTERCEPT	**281857.2**	**1**	**281857.2**	**85.16812**	**0.000002**
	ERROR	36403.6	11	3309.4		
	SPRINTS	**1353.1**	**13**	**104.1**	**2.38048**	**0.006409**
	ERROR	6252.8	143	47.7		

29. Repeated measures analysis of variance (ANOVA) of the vastus medialis muscle activity of the players (skilled and less skilled) during the **deceptive trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
VM	INTERCEPT	**524029.3**	**1**	**524029.3**	**187.2979**	**0.000000**
	GROUP	84.2	1	84.2	0.0301	0.863847
	ERROR	61552.4	22	2797.8		
	SPRINTS	**1901.2**	**13**	**246.2**	**3.3885**	**0.00072**
	SPRINTS*GROUP	344.7	13	26.5	0.6143	0.841804
	ERROR	12343.8	286	43.2		

30. Repeated measures analysis of variance (ANOVA) of the vastus medialis muscle activity of the players (skilled and less skilled) during the **unknown trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
VM	INTERCEPT	**688482.5**	**1**	**688482.5**	**97.58442**	**0.000000**
	GROUP	5781.8	1	5781.8	0.81950	0.375134
	ERROR	155215.5	22	7055.2		
	SPRINTS	**1919.4**	**13**	**147.6**	**4.98393**	**0.000000**
	SPRINTS*GROUP	165.2	13	12.7	0.42907	0.956893
	ERROR	8472.8	286	29.6		

31. One-way analysis of variance (ANOVA) of the vastus medialis of the skilled players during the **unknown trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
VM	INTERCEPT	**284039.7**	**1**	**284039.1**	**139.1050**	**0.000000**
	ERROR	22461.0	11	2041.9		
	SPRINTS	**805.9**	**13**	**62.0**	**2.5141**	**0.003937**
	ERROR	3526.1	143	24.7		

32. One-way analysis of variance (ANOVA) of the vastus medialis of the less-skilled players during the **deceptive trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
VM	INTERCEPT	**268700.0**	**1**	**269700.0**	**108.1475**	**0.000000**
	ERROR	27330.3	11	2484.6		
	SPRINTS	**1626.7**	**13**	**125.1**	**2.4558**	**0.004873**
	ERROR	7286.4	143	51.0		

33. One-way analysis of variance (ANOVA) of the vastus medialis of the less-skilled players during the **unknown trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
VM	INTERCEPT	**410224.6**	**1**	**410224.6**	**33.99109**	**0.000114**
	ERROR	132754.5	11	12068.6		
	SPRINTS	**1278.8**	**13**	**98.4**	**2.84364**	**0.001158**
	ERROR	4946.7	143	34.6		

34. Repeated measures analysis of variance (ANOVA) of the vastus lateralis muscle activity of the players (skilled and less skilled) during the **control trial** (14 shuttle sprints)

Factor	Effect	SS	DF	MS	F	p
VL	INTERCEPT	**621513.4**	**1**	**621513.4**	**156.9220**	**0.000000**
	GROUP	2.1	1	2.1	0.0005	0.981812
	ERROR	87134.3	22	3960.7		
	SPRINTS	372.6	13	28.7	0.9095	0.543517
	SPRINTS*GROUP	**786.0**	**13**	**66.5**	**1.9187**	**0.027900**
	ERROR	9012.3	286	31.5		

35. Repeated measures analysis of variance (ANOVA) of the vastus lateralis muscle activity of the players (skilled and less skilled) during the **unknown trial** (14 shuttle sprints)

Factor	**Effect**	**SS**	**DF**	**MS**	**F**	**p**
VL	INTERCEPT	**732121.6**	**1**	**732121.6**	**159.8953**	**0.000000**
	GROUP	8992.3	1	8992.3	1.9639	0.175045
	ERROR	100732.6	22	4578.8		
	SPRINTS	**2990.0**	**13**	**230.0**	**3.9650**	**0.000006**
	SPRINTS*GROUP	709.4	13	54.6	0.9407	0.511087
	ERROR	16590.3	286	58.0		

36. One-way analysis of variance (ANOVA) of the vastus lateralis of the skilled players during the **unknown trial** (14 shuttle sprints)

Factor	**Effect**	**SS**	**DF**	**MS**	**F**	**p**
VL	INTERCEPT	**289418.4**	**1**	**289418.4**	**63.9737**	**0.000007**
	ERROR	49764.2	11	4524.0		
	SPRINTS	**2591.8**	**13**	**199.4**	**3.64884**	**0.000054**
	ERROR	7813.4	143	54.6		

37. One-way analysis of variance (ANOVA) of the vastus lateralis of the less-skilled players during the **control trial** (14 shuttle sprints)

Factor	**Effect**	**SS**	**DF**	**MS**	**F**	**p**
VL	INTERCEPT	**309613.7**	**1**	**309613.7**	**69.80456**	**0.000004**
	ERROR	48789.8	11	4435.4		
	SPRINTS	**796.4**	**13**	**61.3**	**2.04492**	**0.021084**
	ERROR	4283.9	143	30.0		

A) One-way analysis of variance (ANOVA) of sprint times of the skilled players during the **control trial** (14 shuttle sprints)
Sprints Effect

Cell No.	Tukey HSD test; variable DV_1 (Spreadsheet5) Approximate Probabilities for Post Hoc Tests Error: Within MSE = .02931, df = 143.00										
	SPRINTS	{1} 6.5609	{2} 6.5236	{3} 6.4860	{4} 6.5153	{5} 6.5012	{6} 6.4691	{7} 6.5484	{8} 6.5284	{9} 6.4192	{10} 6.4421
1	Sprint 1		1.000000	0.998626	0.999995	0.999882	0.989891	1.000000	1.000000	0.750130	0.916427
2	Sprint 2	1.000000		1.000000	1.000000	1.000000	0.999959	1.000000	1.000000	0.969029	0.996771
3	Sprint 3	0.998626	1.000000		1.000000	1.000000	1.000000	0.999807	0.999998	0.999591	0.999997
4	Sprint 4	0.999995	1.000000	1.000000		1.000000	0.999994	1.000000	1.000000	0.984794	0.998926
5	Sprint 5	0.999882	1.000000	1.000000	1.000000		1.000000	0.999992	1.000000	0.996570	0.999896
6	Sprint 6	0.989891	0.999959	1.000000	0.999994	1.000000		0.997533	0.999891	0.999985	1.000000
7	Sprint 7	1.000000	1.000000	0.999807	1.000000	0.999992	0.997533		1.000000	0.853453	0.964077
8	Sprint 8	1.000000	1.000000	0.999998	1.000000	1.000000	0.999891	1.000000		0.955435	0.994338
9	Sprint 9	0.750130	0.969029	0.999591	0.984794	0.996570	0.999985	0.853453	0.955435		1.000000
10	Sprint 10	0.916427	0.996771	0.999997	0.998926	0.999896	1.000000	0.964077	0.994338	1.000000	
11	Sprint 11	0.736786	0.965422	0.999487	0.982701	0.995940	0.999979	0.843192	0.950727	1.000000	1.000000
12	Sprint 12	0.926389	0.997507	0.999998	0.999208	0.999931	1.000000	0.969433	0.995527	1.000000	1.000000
13	Sprint 13	0.164994	0.483567	0.849276	0.572873	0.719114	0.942523	0.250130	0.433060	0.999786	0.994594
14	Sprint 14	0.000818	0.007603	0.050142	0.011937	0.024556	0.102535	0.001784	0.005806	0.482684	0.264641

B) One-way analysis of variance (ANOVA) of the 'central' RPE of the skilled players during the **control trial** (14 shuttle sprints)

Overs Effect

Tukey HSD test; variable DV_1 (Spreadsheet5)
Approximate Probabilities for Post Hoc Tests
Error: Within MSE = .89214, df = 66.000

Cell No.	OVERS	{1} 6.4167	{2} 8.0000	{3} 9.0000	{4} 10.667	{5} 11.167	{6} 12.167	{7} 13.917
1	Over 1		0.002181	0.000128	0.000128	0.000128	0.000128	0.000128
2	Over 2	0.002181		0.144865	0.000128	0.000128	0.000128	0.000128
3	Over 3	0.000128	0.144865		0.001115	0.000134	0.000128	0.000128
4	Over 4	0.000128	0.000128	0.001115		0.851105	0.004311	0.000128
5	Over 5	0.000128	0.000128	0.000134	0.851105		0.144865	0.000128
6	Over 6	0.000128	0.000128	0.000128	0.004311	0.144865		0.000590
7	Over 7	0.000128	0.000128	0.000128	0.000128	0.000128	0.000590	

C) One-way analysis of variance (ANOVA) of the 'central' RPE of the skilled players during the **deceptive trial** (14 shuttle sprints)

Overs Effect

Tukey HSD test; variable DV_1 (Spreadsheet5)
Approximate Probabilities for Post Hoc Tests
Error: Within MSE = .75108, df = 66.000

Cell No.	OVERS	{1} 6.4167	{2} 7.8333	{3} 9.4167	{4} 11.917	{5} 12.667	{6} 12.167	{7} 13.917
1	Over 1		0.003007	0.000128	0.000128	0.000128	0.000128	0.000128
2	Over 2	0.003007		0.000705	0.000128	0.000128	0.000128	0.000128
3	Over 3	0.000128	0.000705		0.000128	0.000128	0.000128	0.000128
4	Over 4	0.000128	0.000128	0.000128		0.353640	0.991810	0.000133
5	Over 5	0.000128	0.000128	0.000128	0.353640		0.792869	0.012817
6	Over 6	0.000128	0.000128	0.000128	0.991810	0.792869		0.000236
7	Over 7	0.000128	0.000128	0.000128	0.000133	0.012817	0.000236	

D) One-way analysis of variance (ANOVA) of the ‘central’ RPE of the skilled players during the **unknown trial** (14 shuttle sprints)
Overs Effect

Tukey HSD test; variable DV_1 (Spreadsheet5)
Approximate Probabilities for Post Hoc Tests
Error: Within MSE = .45058, df = 66.000

Cell No.	OVERS	{1} 6.4167	{2} 7.5833	{3} 9.4167	{4} 11.250	{5} 12.333	{6} 12.833	{7} 14.250
1	Over 1		0.001360	0.000128	0.000128	0.000128	0.000128	0.000128
2	Over 2	0.001360		0.000128	0.000128	0.000128	0.000128	0.000128
3	Over 3	0.000128	0.000128		0.000128	0.000128	0.000128	0.000128
4	Over 4	0.000128	0.000128	0.000128		0.003539	0.000131	0.000128
5	Over 5	0.000128	0.000128	0.000128	0.003539		0.536758	0.000128
6	Over 6	0.000128	0.000128	0.000128	0.000131	0.536758		0.000168
7	Over 7	0.000128	0.000128	0.000128	0.000128	0.000128	0.000168	

E) One-way analysis of variance (ANOVA) of the ‘central’ RPE of the less-skilled players during the **control trial** (14 shuttle sprints)
Overs Effect

Tukey HSD test; variable DV_1 (Spreadsheet5)
Approximate Probabilities for Post Hoc Tests
Error: Within MSE = .48449, df = 66.000

Cell No.	OVERS	{1} 6.6667	{2} 9.0833	{3} 10.667	{4} 11.750	{5} 12.917	{6} 14.417	{7} 16.083
1	Over 1		0.000128	0.000128	0.000128	0.000128	0.000128	0.000128
2	Over 2	0.000128		0.000136	0.000128	0.000128	0.000128	0.000128
3	Over 3	0.000128	0.000136		0.005485	0.000128	0.000128	0.000128
4	Over 4	0.000128	0.000128	0.005485		0.002184	0.000128	0.000128
5	Over 5	0.000128	0.000128	0.000128	0.002184		0.000154	0.000128
6	Over 6	0.000128	0.000128	0.000128	0.000128	0.000154		0.000130
7	Over 7	0.000128	0.000128	0.000128	0.000128	0.000128	0.000130	

F) One-way analysis of variance (ANOVA) of the 'central' RPE of the less-skilled players during the **deceptive trial** (14 shuttle sprints)

Overs Effect

	Tukey HSD test; variable DV_1 (Spreadsheet5) Approximate Probabilities for Post Hoc Tests Error: Within MSE = .45996, df = 66.000							
Cell No.	OVERS	{1} 6.1667	{2} 8.5833	{3} 10.417	{4} 12.583	{5} 13.583	{6} 14.417	{7} 16.083
1	Over 1		0.000128	0.000128	0.000128	0.000128	0.000128	0.000128
2	Over 2	0.000128		0.000128	0.000128	0.000128	0.000128	0.000128
3	Over 3	0.000128	0.000128		0.000128	0.000128	0.000128	0.000128
4	Over 4	0.000128	0.000128	0.000128		0.010130	0.000128	0.000128
5	Over 5	0.000128	0.000128	0.000128	0.010130		0.054257	0.000128
6	Over 6	0.000128	0.000128	0.000128	0.000128	0.054257		0.000129
7	Over 7	0.000128	0.000128	0.000128	0.000128	0.000128	0.000129	

G) One-way analysis of variance (ANOVA) of the 'central' RPE of the less-skilled players during the **unknown trial** (14 shuttle sprints)

Overs Effect

	Tukey HSD test; variable DV_1 (Spreadsheet5) Approximate Probabilities for Post Hoc Tests Error: Within MSE = .39069, df = 66.000							
Cell No.	OVERS	{1} 6.3333	{2} 8.6667	{3} 10.917	{4} 12.083	{5} 12.917	{6} 14.083	{7} 15.583
1	Over 1		0.000128	0.000128	0.000128	0.000128	0.000128	0.000128
2	Over 2	0.000128		0.000128	0.000128	0.000128	0.000128	0.000128
3	Over 3	0.000128	0.000128		0.000533	0.000128	0.000128	0.000128
4	Over 4	0.000128	0.000128	0.000533		0.027480	0.000128	0.000128
5	Over 5	0.000128	0.000128	0.000128	0.027480		0.000533	0.000128
6	Over 6	0.000128	0.000128	0.000128	0.000128	0.000533		0.000130
7	Over 7	0.000128	0.000128	0.000128	0.000128	0.000128	0.000130	

H) One-way analysis of variance (ANOVA) of the 'local' RPE of the skilled players during the **control trial** (14 shuttle sprints)

Overs Effect

Tukey HSD test; variable DV_1 (Spreadsheet2)
Approximate Probabilities for Post Hoc Tests
Error: Within MSE = .15512, df = 66.000

Cell No.	OVERS	{1} 6.1667	{2} 6.3333	{3} 6.5000	{4} 6.9167	{5} 7.3333	{6} 7.7500	{7} 8.2500
1	over 1		0.943560	0.380599	0.000419	0.000128	0.000128	0.000128
2	over 2	0.943560		0.943560	0.009653	0.000129	0.000128	0.000128
3	over 3	0.380599	0.943560		0.145486	0.000166	0.000128	0.000128
4	over 4	0.000419	0.009653	0.145486		0.145486	0.000166	0.000128
5	over 5	0.000128	0.000129	0.000166	0.145486		0.145486	0.000132
6	over 6	0.000128	0.000128	0.000128	0.000166	0.145486		0.041869
7	over 7	0.000128	0.000128	0.000128	0.000128	0.000132	0.041869	

I) One-way analysis of variance (ANOVA) of the 'local' RPE of the skilled players during the **deceptive trial** (14 shuttle sprints)

Overs Effect

Tukey HSD test; variable DV_1 (Spreadsheet2)
Approximate Probabilities for Post Hoc Tests
Error: Within MSE = .37302, df = 66.000

Cell No.	OVERS	{1} 6.5833	{2} 7.5000	{3} 8.3333	{4} 9.1667	{5} 9.4167	{6} 9.9167	{7} 10.417
1	over 1		0.008322	0.000128	0.000128	0.000128	0.000128	0.000128
2	over 2	0.008322		0.022198	0.000128	0.000128	0.000128	0.000128
3	over 3	0.000128	0.022198		0.022198	0.001042	0.000128	0.000128
4	over 4	0.000128	0.000128	0.022198		0.951692	0.054509	0.000214
5	over 5	0.000128	0.000128	0.001042	0.951692		0.421335	0.002946
6	over 6	0.000128	0.000128	0.000128	0.054509	0.421335		0.421335
7	over 7	0.000128	0.000128	0.000128	0.000214	0.002946	0.421335	

J) One-way analysis of variance (ANOVA) of the 'local' RPE of the skilled players during the **unknown trial** (14 shuttle sprints)

Overs Effect

Tukey HSD test; variable DV_1 (Spreadsheet2)
Approximate Probabilities for Post Hoc Tests
Error: Within MSE = .41991, df = 66.000

Cell No.	OVERS	{1} 7.0000	{2} 8.2500	{3} 9.7500	{4} 11.000	{5} 12.000	{6} 13.250	{7} 14.500
1	over 1		0.000362	0.000128	0.000128	0.000128	0.000128	0.000128
2	over 2	0.000362		0.000133	0.000128	0.000128	0.000128	0.000128
3	over 3	0.000128	0.000133		0.000362	0.000128	0.000128	0.000128
4	over 4	0.000128	0.000128	0.000362		0.006061	0.000128	0.000128
5	over 5	0.000128	0.000128	0.000128	0.006061		0.000362	0.000128
6	over 6	0.000128	0.000128	0.000128	0.000128	0.000362		0.000362
7	over 7	0.000128	0.000128	0.000128	0.000128	0.000128	0.000362	

K) One-way analysis of variance (ANOVA) of the 'local' RPE of the less-skilled players during the **control trial** (14 shuttle sprints)

Overs Effect

Tukey HSD test; variable DV_1 (Spreadsheet2)
Approximate Probabilities for Post Hoc Tests
Error: Within MSE = .37302, df = 66.000

Cell No.	OVERS	{1} 6.5833	{2} 7.5000	{3} 8.3333	{4} 9.1667	{5} 9.4167	{6} 9.9167	{7} 10.417
1	over 1		0.008322	0.000128	0.000128	0.000128	0.000128	0.000128
2	over 2	0.008322		0.022198	0.000128	0.000128	0.000128	0.000128
3	over 3	0.000128	0.022198		0.022198	0.001042	0.000128	0.000128
4	over 4	0.000128	0.000128	0.022198		0.951692	0.054509	0.000214
5	over 5	0.000128	0.000128	0.001042	0.951692		0.421335	0.002946
6	over 6	0.000128	0.000128	0.000128	0.054509	0.421335		0.421335
7	over 7	0.000128	0.000128	0.000128	0.000214	0.002946	0.421335	

L) One-way analysis of variance (ANOVA) of the 'local' RPE of the less-skilled players during the **deceptive trial** (14 shuttle sprints)

Overs Effect

Cell No.	Tukey HSD test; variable DV_1 (Spreadsheet2) Approximate Probabilities for Post Hoc Tests Error: Within MSE = .39538, df = 66.000							
	OVERS	{1} 6.4167	{2} 7.4167	{3} 8.2500	{4} 9.1667	{5} 10.000	{6} 10.333	{7} 11.083
1	over 1		0.004237	0.000128	0.000128	0.000128	0.000128	0.000128
2	over 2	0.004237		0.028988	0.000128	0.000128	0.000128	0.000128
3	over 3	0.000128	0.028988		0.011462	0.000128	0.000128	0.000128
4	over 4	0.000128	0.000128	0.011462		0.028988	0.000580	0.000128
5	over 5	0.000128	0.000128	0.000128	0.028988		0.850262	0.001526
6	over 6	0.000128	0.000128	0.000128	0.000580	0.850262		0.067759
7	over 7	0.000128	0.000128	0.000128	0.000128	0.001526	0.067759	

M) One-way analysis of variance (ANOVA) of the 'local' RPE of the less-skilled players during the **unknown trial** (14 shuttle sprints)

Overs Effect

Cell No.	Tukey HSD test; variable DV_1 (Spreadsheet2) Approximate Probabilities for Post Hoc Tests Error: Within MSE = .49134, df = 66.000							
	OVERS	{1} 7.1667	{2} 8.9167	{3} 10.167	{4} 11.667	{5} 12.667	{6} 13.917	{7} 15.250
1	over 1		0.000129	0.000128	0.000128	0.000128	0.000128	0.000128
2	over 2	0.000129		0.000972	0.000128	0.000128	0.000128	0.000128
3	over 3	0.000128	0.000972		0.000158	0.000128	0.000128	0.000128
4	over 4	0.000128	0.000128	0.000158		0.014353	0.000128	0.000128
5	over 5	0.000128	0.000128	0.000128	0.014353		0.000972	0.000128
6	over 6	0.000128	0.000128	0.000128	0.000128	0.000972		0.000425
7	over 7	0.000128	0.000128	0.000128	0.000128	0.000128	0.000425	

N) One-way analysis of variance (ANOVA) of the semitendinosus of the less-skilled players during the **control trial** (14 shuttle sprints)

	Tukey HSD test; variable DV_1 (Spreadsheet1) Approximate Probabilities for Post Hoc Tests Error: Within MSE = 40.498, df = 143.00														
Cell No.	SPRINTS	{1} 49.034	{2} 44.549	{3} 46.392	{4} 42.892	{5} 43.187	{6} 45.135	{7} 45.170	{8} 43.785	{9} 43.164	{10} 43.931	{11} 45.642	{12} 41.264	{13} 38.521	{14} 40.609
1	1		0.906987	0.999210	0.506746	0.592104	0.967853	0.970125	0.755054	0.585231	0.790113	0.990455	0.141240	0.004107	0.070148
2	2	0.906987		0.999986	0.999996	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.992918	0.539742	0.964987
3	3	0.999210	0.999986		0.987295	0.994406	1.000000	1.000000	0.999312	0.993996	0.999630	1.000000	0.784167	0.127667	0.610306
4	4	0.506746	0.999996	0.987295		1.000000	0.999868	0.999843	1.000000	1.000000	1.000000	0.998795	0.999997	0.922509	0.999839
5	5	0.592104	1.000000	0.994406	1.000000		0.999974	0.999968	1.000000	1.000000	1.000000	0.999642	0.999977	0.878477	0.999390
6	6	0.967853	1.000000	1.000000	0.999868	0.999974		1.000000	1.000000	0.999970	1.000000	1.000000	0.969659	0.376159	0.900944
7	7	0.970125	1.000000	1.000000	0.999843	0.999968	1.000000		1.000000	0.999963	1.000000	1.000000	0.967361	0.367158	0.895664
8	8	0.755054	1.000000	0.999312	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	0.999985	0.999520	0.751501	0.994878
9	9	0.585231	1.000000	0.993996	1.000000	1.000000	0.999970	0.999963	1.000000		1.000000	0.999602	0.999980	0.882507	0.999448
10	10	0.790113	1.000000	0.999630	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		0.999994	0.999125	0.713943	0.992151
11	11	0.990455	1.000000	1.000000	0.998795	0.999642	1.000000	1.000000	0.999985	0.999602	0.999994		0.921548	0.255541	0.806164
12	12	0.141240	0.992918	0.784167	0.999997	0.999977	0.969659	0.967361	0.999520	0.999980	0.999125	0.921548		0.998829	1.000000
13	13	0.004107	0.539742	0.127667	0.922509	0.878477	0.376159	0.367158	0.751501	0.882507	0.713943	0.255541	0.998829		0.999942
14	14	0.070148	0.964987	0.610306	0.999839	0.999390	0.900944	0.895664	0.994878	0.999448	0.992151	0.806164	1.000000	0.999942	

O) One-way analysis of variance (ANOVA) of the semitendinosus of the less-skilled players during the **deceptive trial** (14 shuttle sprints)

Sprints Effect

Tukey HSD test; variable DV_1 (Spreadsheet1)
Approximate Probabilities for Post Hoc Tests
Error: Within MSE = 60.154, df = 143.00

Cell No.	SPRINTS	{1} 50.869	{2} 47.676	{3} 48.282	{4} 45.602	{5} 44.499	{6} 41.151	{7} 43.538	{8} 42.022	{9} 39.900	{10} 42.652	{11} 41.388	{12} 44.597	{13} 41.829	{14} 40.010
1	1		0.999275	0.999929	0.928542	0.760643	0.114841	0.543424	0.227129	0.035020	0.343175	0.140035	0.779966	0.197483	0.039235
2	2	0.999275		1.000000	0.999995	0.999315	0.728492	0.990389	0.882999	0.439307	0.949906	0.777041	0.999510	0.854804	0.464594
3	3	0.999929	1.000000		0.999894	0.995894	0.590680	0.968275	0.782227	0.310108	0.886167	0.646281	0.996826	0.743565	0.331961
4	4	0.928542	0.999995	0.999894		1.000000	0.981508	0.999995	0.997628	0.876383	0.999692	0.988650	1.000000	0.996008	0.891362
5	5	0.760643	0.999315	0.995894	1.000000		0.998806	1.000000	0.999957	0.975503	0.999999	0.999452	1.000000	0.999899	0.980081
6	6	0.114841	0.728492	0.590680	0.981508	0.998806		0.999972	1.000000	1.000000	1.000000	1.000000	0.998393	1.000000	1.000000
7	7	0.543424	0.990389	0.968275	0.999995	1.000000	0.999972		1.000000	0.997210	1.000000	0.999992	1.000000	0.999999	0.997953
8	8	0.227129	0.882999	0.782227	0.997628	0.999957	1.000000	1.000000		0.999993	1.000000	1.000000	0.999933	1.000000	0.999996
9	9	0.035020	0.439307	0.310108	0.876383	0.975503	1.000000	0.997210	0.999993		0.999858	1.000000	0.970801	0.999998	1.000000
10	10	0.343175	0.949906	0.886167	0.999692	0.999999	1.000000	1.000000	1.000000	0.999858		1.000000	0.999998	1.000000	0.999910
11	11	0.140035	0.777041	0.646281	0.988650	0.999452	1.000000	0.999992	1.000000	1.000000	1.000000		0.999238	1.000000	1.000000
12	12	0.779966	0.999510	0.996826	1.000000	1.000000	0.998393	1.000000	0.999933	0.970801	0.999998	0.999238		0.999848	0.976060
13	13	0.197483	0.854804	0.743565	0.996008	0.999899	1.000000	0.999999	1.000000	0.999998	1.000000	1.000000	0.999848		0.999999
14	14	0.039235	0.464594	0.331961	0.891362	0.980081	1.000000	0.997953	0.999996	1.000000	0.999910	1.000000	0.976060	0.999999	

P) One-way analysis of variance (ANOVA) of the biceps femoris of the skilled players during the **unknown trial** (14 shuttle sprints)

Sprints Effect

Tukey HSD test; variable DV_1 (Spreadsheet1)
Approximate Probabilities for Post Hoc Tests
Error: Within MSE = 21.096, df = 143.00

Cell No.	SPRINTS	{1} 47.655	{2} 45.032	{3} 41.835	{4} 41.534	{5} 41.908	{6} 42.094	{7} 43.218	{8} 40.164	{9} 41.142	{10} 40.348	{11} 39.693	{12} 41.675	{13} 41.522	{14} 42.207
1	1		0.982256	0.104496	0.065793	0.116262	0.150694	0.505297	0.005050	0.033964	0.007422	0.001779	0.082111	0.064572	0.174954
2	2	0.982256		0.914816	0.845391	0.927885	0.954649	0.999538	0.342796	0.719135	0.409456	0.201055	0.881078	0.842187	0.966814
3	3	0.104496	0.914816		1.000000	1.000000	1.000000	0.999978	0.999812	1.000000	0.999950	0.997364	1.000000	1.000000	1.000000
4	4	0.065793	0.845391	1.000000		1.000000	1.000000	0.999795	0.999981	1.000000	0.999997	0.999454	1.000000	1.000000	1.000000
5	5	0.116262	0.927885	1.000000	1.000000		1.000000	0.999989	0.999698	1.000000	0.999913	0.996317	1.000000	1.000000	1.000000
6	6	0.150694	0.954649	1.000000	1.000000	1.000000		0.999998	0.999101	1.000000	0.999695	0.992019	1.000000	1.000000	1.000000
7	7	0.505297	0.999538	0.999978	0.999795	0.999989	0.999998		0.938880	0.998077	0.962285	0.837547	0.999923	0.999778	0.999999
8	8	0.005050	0.342796	0.999812	0.999981	0.999698	0.999101	0.938880		1.000000	1.000000	1.000000	0.999940	0.999982	0.998378
9	9	0.033964	0.719135	1.000000	1.000000	1.000000	1.000000	0.998077	1.000000		1.000000	0.999963	1.000000	1.000000	0.999999
10	10	0.007422	0.409456	0.999950	0.999997	0.999913	0.999695	0.962285	1.000000	1.000000		1.000000	0.999987	0.999997	0.999399
11	11	0.001779	0.201055	0.997364	0.999454	0.996317	0.992019	0.837547	1.000000	0.999963	1.000000		0.998809	0.999490	0.987840
12	12	0.082111	0.881078	1.000000	1.000000	1.000000	1.000000	0.999923	0.999940	1.000000	0.999987	0.998809		1.000000	1.000000
13	13	0.064572	0.842187	1.000000	1.000000	1.000000	1.000000	0.999778	0.999982	1.000000	0.999997	0.999490	1.000000		1.000000
14	14	0.174954	0.966814	1.000000	1.000000	1.000000	1.000000	0.999999	0.998378	0.999999	0.999399	0.987840	1.000000	1.000000	

Q) One-way analysis of variance (ANOVA) of the biceps femoris of the less-skilled players during the **control trial** (14 shuttle sprints)

Sprints Effect

Tukey HSD test; variable DV_1 (Spreadsheet1)
Approximate Probabilities for Post Hoc Tests
Error: Within MSE = 43.726, df = 143.00

Cell No.	SPRINTS	{1} 48.386	{2} 42.858	{3} 41.371	{4} 38.609	{5} 41.206	{6} 42.402	{7} 42.448	{8} 41.528	{9} 39.744	{10} 41.914	{11} 40.585	{12} 38.667	{13} 37.920	{14} 35.801
1	1		0.737319	0.341035	0.020508	0.302564	0.617255	0.630051	0.379912	0.079308	0.482092	0.181853	0.022116	0.008011	0.000283
2	2	0.737319		0.999999	0.952940	0.999998	1.000000	1.000000	1.000000	0.997099	1.000000	0.999900	0.957779	0.863153	0.330895
3	3	0.341035	0.999999		0.999157	1.000000	1.000000	1.000000	1.000000	0.999998	1.000000	1.000000	0.999328	0.992165	0.726772
4	4	0.020508	0.952940	0.999157		0.999564	0.981601	0.979546	0.998495	1.000000	0.994801	0.999980	1.000000	1.000000	0.998994
5	5	0.302564	0.999998	1.000000	0.999564		1.000000	1.000000	1.000000	0.999999	1.000000	1.000000	0.999660	0.995085	0.766757
6	6	0.617255	1.000000	1.000000	0.981601	1.000000		1.000000	1.000000	0.999441	1.000000	0.999993	0.983938	0.929618	0.447007
7	7	0.630051	1.000000	1.000000	0.979546	1.000000	1.000000		1.000000	0.999326	1.000000	0.999990	0.982089	0.924115	0.434517
8	8	0.379912	1.000000	1.000000	0.998495	1.000000	1.000000	1.000000		0.999994	1.000000	1.000000	0.998779	0.988179	0.686392
9	9	0.079308	0.997099	0.999998	1.000000	0.999999	0.999441	0.999326	0.999994		0.999941	1.000000	1.000000	0.999992	0.974311
10	10	0.482092	1.000000	1.000000	0.994801	1.000000	1.000000	1.000000	1.000000	0.999941		1.000000	0.995625	0.971409	0.581520
11	11	0.181853	0.999900	1.000000	0.999980	1.000000	0.999993	0.999990	1.000000	1.000000	1.000000		0.999986	0.999423	0.888767
12	12	0.022116	0.957779	0.999328	1.000000	0.999660	0.983938	0.982089	0.998779	1.000000	0.995625	0.999986		1.000000	0.998753
13	13	0.008011	0.863153	0.992165	1.000000	0.995085	0.929618	0.924115	0.988179	0.999992	0.971409	0.999423	1.000000		0.999955
14	14	0.000283	0.330895	0.726772	0.998994	0.766757	0.447007	0.434517	0.686392	0.974311	0.581520	0.888767	0.998753	0.999955	

R) One-way analysis of variance (ANOVA) of the vastus medialis of the skilled players during the **unknown trial** (14 shuttle sprints)

Sprints Effect

Tukey HSD test; variable DV_1 (Spreadsheet1)
Approximate Probabilities for Post Hoc Tests
Error: Within MSE = 24.658, df = 143.00

Cell No.	SPRINTS	{1} 46.042	{2} 44.576	{3} 43.713	{4} 41.118	{5} 42.156	{6} 40.483	{7} 41.107	{8} 39.901	{9} 39.057	{10} 39.480	{11} 37.817	{12} 39.779	{13} 40.184	{14} 40.244
1	1		0.999983	0.997204	0.458463	0.817496	0.254705	0.454562	0.127694	0.037191	0.071345	0.003926	0.108664	0.181786	0.195087
2	2	0.999983		1.000000	0.914413	0.995932	0.756170	0.912506	0.550303	0.265695	0.398217	0.053130	0.505281	0.654303	0.675650
3	3	0.997204	1.000000		0.992063	0.999965	0.948392	0.991748	0.837605	0.557414	0.710034	0.173808	0.804355	0.901593	0.912653
4	4	0.458463	0.914413	0.992063		1.000000	1.000000	1.000000	0.999998	0.999212	0.999938	0.939036	0.999994	1.000000	1.000000
5	5	0.817496	0.995932	0.999965	1.000000		0.999921	1.000000	0.997990	0.962643	0.989457	0.673001	0.996594	0.999509	0.999649
6	6	0.254705	0.756170	0.948392	1.000000	0.999921		1.000000	1.000000	0.999988	1.000000	0.989784	1.000000	1.000000	1.000000
7	7	0.454562	0.912506	0.991748	1.000000	1.000000	1.000000		0.999998	0.999254	0.999943	0.940522	0.999995	1.000000	1.000000
8	8	0.127694	0.550303	0.837605	0.999998	0.997990	1.000000	0.999998		1.000000	1.000000	0.999112	1.000000	1.000000	1.000000
9	9	0.037191	0.265695	0.557414	0.999212	0.962643	0.999988	0.999254	1.000000		1.000000	0.999998	1.000000	0.999999	0.999999
10	10	0.071345	0.398217	0.710034	0.999938	0.989457	1.000000	0.999943	1.000000	1.000000		0.999926	1.000000	1.000000	1.000000
11	11	0.003926	0.053130	0.173808	0.939036	0.673001	0.989784	0.940522	0.999112	0.999998	0.999926		0.999533	0.996722	0.995807
12	12	0.108664	0.505281	0.804355	0.999994	0.996594	1.000000	0.999995	1.000000	1.000000	1.000000	0.999533		1.000000	1.000000
13	13	0.181786	0.654303	0.901593	1.000000	0.999509	1.000000	1.000000	1.000000	0.999999	1.000000	0.996722	1.000000		1.000000
14	14	0.195087	0.675650	0.912653	1.000000	0.999649	1.000000	1.000000	1.000000	0.999999	1.000000	0.995807	1.000000	1.000000	

S) One-way analysis of variance (ANOVA) of the vastus medialis of the less-skilled players during the **deceptive trial** (14 shuttle sprints)

Sprints Effects

Tukey HSD test; variable DV_1 (Spreadsheet1)
Approximate Probabilities for Post Hoc Tests
Error: Within MSE = 50.954, df = 143.00

Cell No.	SPRINTS	{1} 45.984	{2} 45.393	{3} 43.852	{4} 42.744	{5} 39.143	{6} 39.962	{7} 38.756	{8} 39.973	{9} 38.386	{10} 37.041	{11} 36.362	{12} 37.059	{13} 36.772	{14} 38.469
1	1		1.000000	0.999980	0.998000	0.519251	0.724518	0.421652	0.727223	0.335340	0.114951	0.058680	0.116919	0.088948	0.353994
2	2	1.000000		1.000000	0.999765	0.669944	0.846079	0.571679	0.848115	0.476671	0.192358	0.105828	0.195242	0.153417	0.497879
3	3	0.999980	1.000000		1.000000	0.942491	0.988321	0.898384	0.988635	0.840026	0.526970	0.359687	0.531692	0.458393	0.854556
4	4	0.998000	0.999765	1.000000		0.994319	0.999598	0.985384	0.999616	0.968750	0.794433	0.636875	0.798163	0.736041	0.973375
5	5	0.519251	0.669944	0.942491	0.994319		1.000000	1.000000	1.000000	1.000000	0.999983	0.999599	0.999985	0.999932	1.000000
6	6	0.724518	0.846079	0.988321	0.999598	1.000000		1.000000	1.000000	0.999999	0.999322	0.994332	0.999366	0.998293	1.000000
7	7	0.421652	0.571679	0.898384	0.985384	1.000000	1.000000		1.000000	1.000000	0.999999	0.999925	0.999999	0.999992	1.000000
8	8	0.727223	0.848115	0.988635	0.999616	1.000000	1.000000	1.000000		0.999999	0.999292	0.994153	0.999338	0.998228	1.000000
9	9	0.335340	0.476671	0.840026	0.968750	1.000000	0.999999	1.000000	0.999999		1.000000	0.999989	1.000000	0.999999	1.000000
10	10	0.114951	0.192358	0.526970	0.794433	0.999983	0.999322	0.999999	0.999292	1.000000		1.000000	1.000000	1.000000	1.000000
11	11	0.058680	0.105828	0.359687	0.636875	0.999599	0.994332	0.999925	0.994153	0.999989	1.000000		1.000000	1.000000	0.999983
12	12	0.116919	0.195242	0.531692	0.798163	0.999985	0.999366	0.999999	0.999338	1.000000	1.000000	1.000000		1.000000	1.000000
13	13	0.088948	0.153417	0.458393	0.736041	0.999932	0.998293	0.999992	0.998228	0.999999	1.000000	1.000000	1.000000		0.999999
14	14	0.353994	0.497879	0.854556	0.973375	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.999983	1.000000	0.999999	

T) One-way analysis of variance (ANOVA) of the vastus medialis of the less-skilled players during the **unknown trial** (14 shuttle sprints)

Sprints Effect

	Tukey HSD test; variable DV_1 (Spreadsheet1) Approximate Probabilities for Post Hoc Tests Error: Within MSE = 34.592, df = 143.00														
Cell No.	SPRINTS	{1} 54.016	{2} 52.258	{3} 53.226	{4} 52.646	{5} 51.965	{6} 50.338	{7} 48.320	{8} 46.761	{9} 46.616	{10} 46.562	{11} 46.548	{12} 48.539	{13} 47.315	{14} 46.697
1	1		0.999980	1.000000	0.999999	0.999883	0.962089	0.500778	0.130430	0.110997	0.104359	0.102710	0.569089	0.228871	0.121616
2	2	0.999980		1.000000	1.000000	1.000000	0.999945	0.935717	0.562983	0.517694	0.500881	0.496589	0.958546	0.729971	0.543121
3	3	1.000000	1.000000		1.000000	1.000000	0.995629	0.740247	0.282945	0.248940	0.236942	0.233930	0.797403	0.434953	0.267720
4	4	0.999999	1.000000	1.000000		1.000000	0.999569	0.875994	0.442790	0.399915	0.384351	0.380406	0.912768	0.614611	0.423815
5	5	0.999883	1.000000	1.000000	1.000000		0.999992	0.964707	0.653513	0.609085	0.592290	0.587975	0.978937	0.806393	0.634178
6	6	0.962089	0.999945	0.995629	0.999569	0.999992		0.999902	0.969702	0.958244	0.953238	0.951889	0.999974	0.993196	0.965019
7	7	0.500778	0.935717	0.740247	0.875994	0.964707	0.999902		0.999995	0.999986	0.999980	0.999978	1.000000	1.000000	0.999992
8	8	0.130430	0.562983	0.282945	0.442790	0.653513	0.969702	0.999995		1.000000	1.000000	1.000000	0.999977	1.000000	1.000000
9	9	0.110997	0.517694	0.248940	0.399915	0.609085	0.958244	0.999986	1.000000		1.000000	1.000000	0.999944	1.000000	1.000000
10	10	0.104359	0.500881	0.236942	0.384351	0.592290	0.953238	0.999980	1.000000	1.000000		1.000000	0.999923	1.000000	1.000000
11	11	0.102710	0.496589	0.233930	0.380406	0.587975	0.951889	0.999978	1.000000	1.000000	1.000000		0.999917	1.000000	1.000000
12	12	0.569089	0.958546	0.797403	0.912768	0.978937	0.999974	1.000000	0.999977	0.999944	0.999923	0.999917		1.000000	0.999966
13	13	0.228871	0.729971	0.434953	0.614611	0.806393	0.993196	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000
14	14	0.121616	0.543121	0.267720	0.423815	0.634178	0.965019	0.999992	1.000000	1.000000	1.000000	1.000000	0.999966	1.000000	

U) One-way analysis of variance (ANOVA) of the vastus lateralis of the skilled players during the **unknown trial** (14 shuttle sprints)

Sprints Effect

Tukey HSD test; variable DV_1 (Spreadsheet1)
Approximate Probabilities for Post Hoc Tests
Error: Within MSE = 54.639, df = 143.00

Cell No.	SPRINTS	{1} 50.041	{2} 49.592	{3} 44.996	{4} 43.813	{5} 39.468	{6} 41.115	{7} 39.466	{8} 38.985	{9} 39.666	{10} 40.509	{11} 37.626	{12} 38.975	{13} 37.924	{14 38.9
1	1		1.000000	0.925939	0.726532	0.030744	0.153696	0.030661	0.017658	0.038169	0.089636	0.003121	0.017450	0.004657	0.01
2	2	1.000000		0.963772	0.818849	0.049836	0.219688	0.049711	0.029600	0.061015	0.134522	0.005679	0.029271	0.008340	0.02
3	3	0.925939	0.963772		1.000000	0.862002	0.991711	0.861618	0.773239	0.891252	0.970232	0.449110	0.771167	0.522289	0.75
4	4	0.726532	0.818849	1.000000		0.977257	0.999805	0.977149	0.946600	0.984826	0.998289	0.735425	0.945749	0.797739	0.93
5	5	0.030744	0.049836	0.862002	0.977257		0.999999	1.000000	1.000000	1.000000	1.000000	0.999998	1.000000	1.000000	1.00
6	6	0.153696	0.219688	0.991711	0.999805	0.999999		0.999999	0.999987	1.000000	1.000000	0.997032	0.999986	0.998807	0.99
7	7	0.030661	0.049711	0.861618	0.977149	1.000000	0.999999		1.000000	1.000000	1.000000	0.999998	1.000000	1.000000	1.00
8	8	0.017658	0.029600	0.773239	0.946600	1.000000	0.999987	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.00
9	9	0.038169	0.061015	0.891252	0.984826	1.000000	1.000000	1.000000	1.000000		1.000000	0.999992	1.000000	0.999999	1.00
10	10	0.089636	0.134522	0.970232	0.998289	1.000000	1.000000	1.000000	1.000000	1.000000		0.999595	1.000000	0.999879	1.00
11	11	0.003121	0.005679	0.449110	0.735425	0.999998	0.997032	0.999998	1.000000	0.999992	0.999595		1.000000	1.000000	1.00
12	12	0.017450	0.029271	0.771167	0.945749	1.000000	0.999986	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.00
13	13	0.004657	0.008340	0.522289	0.797739	1.000000	0.998807	1.000000	1.000000	0.999999	0.999879	1.000000	1.000000		1.00
14	14	0.016056	0.027060	0.756425	0.939521	1.000000	0.999980	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	

V) One-way analysis of variance (ANOVA) of the vastus lateralis of the less-skilled players during the **control trial** (14 shuttle sprints)

Sprints Effect

Tukey HSD test; variable DV_1 (Spreadsheet1)
Approximate Probabilities for Post Hoc Tests
Error: Within MSE = 29.958, df = 143.00

Cell No.	SPRINTS	{1} 48.701	{2} 46.126	{3} 43.375	{4} 41.932	{5} 42.314	{6} 43.306	{7} 42.742	{8} 43.892	{9} 41.897	{10} 42.049	{11} 42.033	{12} 42.590	{13} 39.493	{14} 40.565
1	1		0.997129	0.492352	0.127754	0.196009	0.469459	0.298188	0.664510	0.122553	0.146456	0.143685	0.258828	0.003033	0.019137
2	2	0.997129		0.994517	0.839293	0.914449	0.993054	0.965365	0.999339	0.830982	0.865468	0.861920	0.950960	0.149551	0.415814
3	3	0.492352	0.994517		0.999996	1.000000	1.000000	1.000000	1.000000	0.999994	0.999998	0.999998	1.000000	0.902728	0.993283
4	4	0.127754	0.839293	0.999996		1.000000	0.999998	1.000000	0.999842	1.000000	1.000000	1.000000	1.000000	0.998342	0.999998
5	5	0.196009	0.914449	1.000000	1.000000		1.000000	1.000000	0.999987	1.000000	1.000000	1.000000	1.000000	0.993015	0.999957
6	6	0.469459	0.993054	1.000000	0.999998	1.000000		1.000000	1.000000	0.999997	0.999999	0.999999	1.000000	0.914185	0.994705
7	7	0.298188	0.965365	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	0.975277	0.999500
8	8	0.664510	0.999339	1.000000	0.999842	0.999987	1.000000	1.000000		0.999808	0.999922	0.999913	0.999999	0.787438	0.969899
9	9	0.122553	0.830982	0.999994	1.000000	1.000000	0.999997	1.000000	0.999808		1.000000	1.000000	1.000000	0.998571	0.999998
10	10	0.146456	0.865468	0.999998	1.000000	1.000000	0.999999	1.000000	0.999922	1.000000		1.000000	1.000000	0.997327	0.999994
11	11	0.143685	0.861920	0.999998	1.000000	1.000000	0.999999	1.000000	0.999913	1.000000	1.000000		1.000000	0.997497	0.999995
12	12	0.258828	0.950960	1.000000	1.000000	1.000000	1.000000	1.000000	0.999999	1.000000	1.000000	1.000000		0.983631	0.999773
13	13	0.003033	0.149551	0.902728	0.998342	0.993015	0.914185	0.975277	0.787438	0.998571	0.997327	0.997497	0.983631		1.000000
14	14	0.019137	0.415814	0.993283	0.999998	0.999957	0.994705	0.999500	0.969899	0.999998	0.999994	0.999995	0.999773	1.000000	