

STRENGTH AND CONDITIONING OF ADOLESCENT MALE CRICKET PLAYERS

By

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ABSTRACT

Background: Modern day cricketers are faced with longer, more strenuous seasons which are more physically demanding than the traditional forms of the game. Due to these increased physical demands, players are more prone to both overuse injuries, particularly of the lower back (bowlers) and lower limbs (batsmen), as well as acute, impact injuries (fielders/wicket keepers). The increase in injury risk is of particular concern at younger levels as research has shown that adolescents are at a higher risk for injury than their adult counterparts. Therefore, there is a need for strength and conditioning programs that reduce the risk of injury and improve performance at this level. However, of the programs that are available, most are not multi-factorial in nature and are aimed at elite cricketers. This is of concern in low-to-middle income countries such as South Africa, where players often do not have access to facilities or equipment and thus need to be exposed to low-cost, no-cost training programs. Furthermore, most information is anecdotal and there is a distinct lack of injury prevention programs at an adolescent level.

Objective: The purpose of this thesis was to investigate the strength and conditioning practices of adolescent cricket players, particularly from a South African context, where there is a distinct lack of resources. This was through the completion of three phases; firstly, a literature review was completed to determine the information currently available on injury prevention strategies in cricket. The review also examined the injury statistics of five major playing cricket nations. Secondly, a survey was conducted to determine the current strength and conditioning practices of schoolboy and university coaches in South Africa. Lastly, a novel intervention program (CricFit) was designed and implemented within an adolescent population. The main purpose of the intervention was to determine whether players' physical fitness parameters improved over time and whether the risk of injury was reduced.

Methods: For phase one of the thesis (review paper), a search of the different scientific databases was undertaken to determine the nature and incidence of injuries in cricket activity as well as well as current strength and conditioning practices in place to reduce these injuries. These injury statistics and prevention programs were then reviewed. For the survey based research, an online questionnaire, adapted from previous strength and conditioning studies, was sent to 38 school boy and 12 university teams that participated in the top competitions in South Africa. In addition to the previous questionnaires, cricket specific practices and injury statistic questions were added to the survey. The survey consisted of three sections: a

general, cricket specific and injury and injury prevention section. The survey also allowed coaches at both university and school levels to describe their practices and ideas in order to understand their basic knowledge of scientifically-based principles of strength and conditioning. Thus coaches were encouraged to explain what conditioning practices they implemented through a number of open ended questions which were then analysed for minor and major themes. The focus of the intervention program was to improve general physical fitness for cricket players. The study was a pre- and post-test design where twenty eight schoolboy cricketers (aged 15-19 years) were allocated to a control (n=14) or experimental (n=14) group during the cricket pre-season period. Both groups performed traditional net and field based training over a four week period (one net and one field based session), with the experimental group performing an additional two, 35-45 minute, conditioning sessions per week ("CricFit" intervention program). The intervention consisted of exercises that centred on the movement demands associated with the sport of cricket as well as injury prevention exercises (specifically Nordic lowers and core strength). Prior to and post the four week intervention period, responses were measured using a test battery that was designed to replicate the demands of cricket activity.

Results: The results indicate on overall thesis summary. The literature view showed that there is a limited amount of injury prevention programs available for adolescent cricket players. It was also confirmed that for both adolescent and adult players, fast bowlers (lower back), followed by batsmen (lower limbs) and then fielders (impact) are the most prone to injuries. The survey showed that schools and universities in South Africa do conduct some form of conditioning, workload monitoring and injury prevention exercises; however the incorrect practices are being administered when considering the movement demands and most common injuries in cricket. It was also shown that most coaches did not have the adequate qualifications and experience to implement acceptable strength and conditioning programs. For the intervention study, both the control and experimental groups showed significant ($p < 0.05$) improvements in most responses, but the changes for the experimental group were greater than those shown in the control group. Furthermore, significant ($p < 0.05$) changes were shown between the two groups (control vs. experimental) for percentage body fat (12 vs. 11%), sit and reach flexibility (40.79 vs. 80.50mm), plank time (105.36 vs. 185.29s), 20 m sprint time (3.27 vs. 2.84s), push ups (34 vs. 41) and 25 m shuttle distance (699.18 vs. 746.79m).

Conclusion: Coaches need to be educated and trained to implement the correct strength and conditioning practices at an adolescent level as well as to better understand the link between the movement demands and principles of testing and training. An improved education process may be needed to improve the quality as well as the qualifications of strength and conditioning coaches. If coaches and trainers are educated properly, then the “CricFit” intervention program may be used to improve cricket specific fitness throughout the pre-season period. The “CricFit” programme is useful in countries such as South Africa, where often players do not have access to coaches and facilities and thus can be implemented easily with minimal cost.

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PUBLICATIONS

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CONTRIBUTIONS OF INDIVIDUALS TO THE PROJECT

As part of the affirmation of this thesis, I recognise contributions by various persons to this work as detailed below:

The experimental design, data collection and analysis for all work were devised by myself^a in conjunction with my supervisor, Prof Candice Christie^b.

Drafting of written work, including the literature review and manuscripts (papers one, two and three) were compiled and written by myself. All authors had input and reviewed the drafts before they were submitted for final publication.

Although the development and design of the “CricFit” intervention program and the test battery was done by myself, input was also provided by Greg King^c (Proteas Strength and Conditioning coach), however he did not contribute to the extent where authorship can be awarded.

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OUTLINE OF THE THESIS

Chapter 1: This comprises a short synopsis of the thesis focusing on background information to the study. It will also focus on the statement of the problem for the current investigation, including a short summary on the nature and incidence of injuries in cricket and strength and conditioning practices of cricket coaches within a South African context.

Chapter 2: This chapter includes a narrative review of literature focusing on a brief overview of the game of cricket and the different formats, the South African education systems, the history of strength and conditioning and current strength and conditioning practices in cricket. Furthermore, the general adaptation syndrome will be discussed as well as periodisation, testing for physical training and the different types of training (resistance, plyometric, speed, agility as well as aerobic and anaerobic training). This chapter will not focus on injuries and injury prevention strategies for cricket activity, as this will be discussed within Chapter 4 as a publication currently in press.

Chapter 3: This chapter is currently in press in the *Strength and Conditioning Journal*, and looks at injury prevention strategies in cricket. It investigates the nature and incidence of the injuries in the top cricket playing nations in the world as well as ways to prevent injuries from occurring. This is through factors such as physical training and work load monitoring of cricket players as well as coaching and technical observations to reduce injury risk.

Chapter 4: This chapter has been published in the *Journal of Strength and Conditioning Research* and looks at the strength and conditioning practices of university and high school level cricket coaches within a South African context. Chapter four is a survey based study focusing on aspects such as physical testing being implemented at schools and universities, training practices and equipment, cricket specific conditioning, workload monitoring as well as injury monitoring and prevention strategies.

Chapter 5: This chapter is published in *Human Movement* and looks at a novel intervention program for the strength and conditioning of adolescent cricket players. The intervention program was developed based on the findings of the previous two chapters (phase one and two) and was established on the basis of a low-cost no-cost program that could improve the physical fitness of a cricket player and reduce the risk of injury at minimal to no cost.

Chapter 6: This concludes the full thesis and provides practical applications, limitations and recommendations for future research.

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CHAPTER 1

BACKGROUND TO THE STUDY

INTRODUCTION

Cricketers are constantly under pressure to perform and as a result are faced with increasing demands both physically and psychologically (Stretch, 2003, Orchard *et al.*, 2016). This is mainly due to the longer seasons that modern day players are faced with as well as the introduction of new forms of the game (Patel *et al.*, 2002; Orchard *et al.*, 2010). However, when compared to other international sports, cricket has received very little research attention, especially with respect to the physical and cognitive demands of the game (Duffield and Drinkwater, 2008; Goble and Christie, 2017). This could be due to the fact that cricket is intermittent in nature and it is therefore difficult to study (Christie *et al.*, 2008). Furthermore, in order to perform, players need to remain injury free for the majority of the season; research has shown that increases in volume and intensity of cricket activity can lead to an increase in the risk of injury (Mansingh *et al.*, 2006). In order to prevent or reduce the likelihood of injury, scientifically based training programs that keep cricketers playing, despite heavy workloads are needed (Finamore, 1992), particularly in the pre-season period.

Although there have been a number of studies that have examined the nature and incidence of injuries in cricket players (Forrest *et al.*, 2017; Gamage *et al.*, 2017; Bayne *et al.*, 2016; Olivier *et al.*, 2016; Orchard *et al.*, 2016; Morton *et al.*, 2014), very few studies have looked at the design and implementation of injury prevention strategies and strength and conditioning programs. Of the information that is available, most is anecdotal in nature and has been passed down from coach to coach or player (Pearson, 2004; Woolmer *et al.*, 2008; Pyke and Davis, 2010) and it is questionable whether these programs are reliable and valid. Therefore, to date and to the author's knowledge, there have only been a handful of studies that have looked at certain aspects of cricket conditioning and injury prevention (Mukandi *et al.*, 2014; Stronach *et al.*, 2014; Cronin *et al.*, 2016; Soomro *et al.*, 2017). Two of the studies (Mukandi *et al.*, 2014; Stronach *et al.*, 2014) examined the strength and conditioning of fast bowlers (more specifically the mechanical and anthropometrical demands and their impact on strength and conditioning). One other looked at strength and conditioning for throwing in cricket (Cronin *et al.*, 2016) and the latest study developed a cricket injury prevention program (CIPP), although this was only a protocol based study (Soomro *et al.*, 2017). It was concluded by all studies that firstly, coaches need to be aware of the specific demands of the game when designing programs and, secondly, that players need to perform a progressive overload program that suits the individual player in terms of their anthropometry, training age and competitive level. This is to prepare the body for the workload experienced during

training and competition (Cronin *et al.*, 2016). It was also concluded that more research is needed in the area of strength and conditioning for cricket players. These studies were delimited to practices used by specialists in a high performance setting, and to date no study has examined the training practices of adolescents and young adults at a schoolboy and university level. Adolescents are at a greater risk of injury compared to adults mainly as a result of changes in their physiology during puberty when they are not yet fully developed while, at the same time, being exposed to high sporting workloads (Stretch, 1995; Abernethy and Bleakley, 2007). Some schools in South Africa require scholars to participate in numerous sports increasing their overall workloads. Research has shown that specifically spikes in acute workload can lead to an increased injury risk (Bourdon *et al.*, 2017; Gabbett and Whiteley, 2017; Williams *et al.*, 2017). During school and university holidays activity levels may drop increasing their risk of spikes in workload on return.

In South Africa, cricket is considered one of our major sports and attracts a lot of interest. Most affluent schools and universities offer cricket as a main sport. However, the availability to play the game is not equal across populations which is largely attributed to the fact that South Africa is considered a low-to-middle income country with extremes of wealth and poverty (Fiske and Ladd, 2003) and has unique secondary and tertiary education systems. The fact that the country is high up on the worlds poverty rankings plus has extreme areas of wealth means that schools and universities range from non-fee paying public schools to fee paying public schools and to private schools (Fiske and Ladd, 2003; Wilmot and Dube, 2015). As a result of this, many individuals do not have access to any sport regardless of facilities, equipment or coaches (non-fee paying schools). These schools sometimes don't have teachers or books and so sports are not prioritized. At the other end of the spectrum, the minority in more affluent schools and universities, have access to facilities and coaching which creates a large disparity and unequal opportunity. This is across all sports within South Africa. In order to overcome this inequality in South African sport, the quota system was introduced by the South African government, in 1999. This looked to play a central and interventionist role to transform sports and recreation in the country through the building of a non-racial democratic sporting industry and to achieve social transformation, by selecting players of colour for the different sporting codes, including athletics, cricket, football, netball and rugby, although this occurred more at a provincial and national level (Brink and Nortje, 2015). Although these quota systems were only introduced at provincial and national level, for all ages, there is still pressure on school and university coaches to implement the system.

Even within the cricket playing schools and universities, cricket and cricket strength and conditioning coaches lack experience, possess the incorrect qualifications and have insufficient educational training in injury prevention and training (Pote and Christie, 2016). Bearing this in mind, when designing any strength and conditioning or injury prevention program, consideration should be given to the practicality and ease of implementation of such programmes. They should be low-cost-no-cost programmes that can be implemented by coaches without qualifications and/or by coaches and players that do not have access to specific facilities or equipment.

STATEMENT OF THE PROBLEM

There is limited literature available in terms of the injury prevention strategies and strength and conditioning practices for the game of cricket. Furthermore, of those that are available, most have focused on players at the elite level and little attention has been given to the adolescent population. This is particularly pertinent within the South African context where there is inequality in terms of facilities, equipment, education and coaches, to name a few. Thus, by understanding the current programs and strategies, as well as the nature and incidence of injuries that adolescent players are exposed, scientifically based training programs may be implemented that improve physical fitness and reduce the risk of injury. The purpose of this study was therefore threefold:

To examine the injury prevention and strength and conditioning programs that are currently being implemented by the top cricket playing nations as well as the main injuries that occur during cricket activity.

To determine what strength and conditioning practices are being used by schools and universities in South Africa.

Based on the first two studies, and with the South African context in mind, to design a scientifically based, low-cost, no-cost strength and conditioning program for adolescent cricket players which can be implemented by themselves or through their coaches, to improve their physical fitness parameters and reduce the risk of injury.

CHAPTER 2

NARRATIVE REVIEW OF LITERATURE

Note: This chapter does not consider injuries and injury prevention strategies for cricket. These aspects have been published in Chapter 4 (*Injury prevention strategies in cricket*) and will be discussed there.

NATURE OF THE GAME OF CRICKET

Traditionally there has been the ideology that cricket is a physically less demanding sport compared to other intermittent sports, but this has been criticized to a large extent as cricketers nowadays have much longer seasons consisting of five day test matches, one day internationals (ODIs) and twenty/20 matches (Fletcher, 1955; Noakes and Durandt, 2000; Orchard *et al.*, 2010). Furthermore, the fact that the modern day cricketer is playing multiple formats throughout the year means that the risk of becoming injured is much higher (Orchard *et al.*, 2010).

Test match cricket was the first form of the game and is played over five days, with three sessions consisting of two hours each. The sessions are divided by a 40 minute lunch break and a 20 minute break for tea in the afternoon. There is also a 5 minute drinks interval during each two hour session. The bowling team is required to bowl 90 overs per day but this depends to a large extent on the weather. During a test match no fielding restrictions are implemented.

One day internationals (ODI), unlike test matches, always end with a result in a single day (or very rarely a tie). They consist of two sessions of 50 overs each (3.5 hours per session) with a 40 minute break in between the two sessions for lunch or dinner (depending on whether the game is a day/night or not). There are also drinks intervals within each session of 50 overs. Fielding restrictions are required during an ODI during certain phases of the game.

The introduction of Twenty/20 (T20) cricket has had an enormous effect on the modern day game. Tournaments such as the Indian Premier League (IPL), Caribbean Premier League (CPL) and the Big Bash League (BBL) have attracted a large amount of spectators not normally associated with the game and the focus is slowly shifting from test matches and ODIs to Twenty/20 cricket. Many believe that Twenty/20 cricket is a much more entertaining form of the game due to the number of boundaries hit and the fielding restrictions that need to be adhered to. Twenty/20 cricket is the most modern form of the game and consists of two sessions of 20 overs each. The change over from batting to bowling in this form of the game is much shorter than an ODI and in some forms of Twenty/20 games a 10 minute strategic timeout is allowed by both the batting and bowling side during certain overs of the match. It is thought that this form of the game requires much higher levels of fitness.

The fact that the game of cricket has evolved to such a large extent means that the demands that are placed on the players nowadays are significantly greater than when the game of cricket was first introduced (Noakes and Durandt, 2000; Orchard *et al.*, 2010). Furthermore, due to the increased physical demand of the game, players are at an increased risk for injury (Orchard *et al.*, 2010). Even at school level where the amount of cricket played is not as much, research has shown that adolescent cricketers are at a greater risk of injury compared to older players (Stretch, 2014). Ensuring that these young players can feed into the higher levels of play following school is therefore important and targeting this group is essential for the long term development of the sport. However, from a South African, low-to-middle income country perspective, this is difficult as coaches and players face a number of challenges not present in developed countries including, but not limited to, lack of equipment, facilities and specialised training (Steyn and Schneider, 2001; Pote and Christie, 2016). This is besides the fact that most South African schools do not even have access to proper health care and are not educated on the benefits of physical activity (McVeigh *et al.*, 2004). Furthermore, the fact that the South African education system differs at both a school and university level compared to the rest of the world, means that it is important that cricket activity as well as injury prevention strategies are examined within the context of this.

THE SOUTH AFRICAN CONTEXT

Background

The population of South Africa is approximately 46 million people (with 11 official languages) made up of 77-79% black Africans, 9% coloureds (mixed ancestry), 2.5% Asians/Indians and 10-11% white Africans (Faber and Kruger, 2005; Steyn *et al.*, 2006). The country is thus comprised of a vast mix of people and cultures ranging from those at the top-end of the socio-economic scale, to those that live below the poverty line (who make up the majority of the population) (Steyn *et al.*, 2006).

Furthermore, a large amount of the South African population live in rural areas or “townships” (urban slums); these areas are characterised by poor living conditions, inadequate access to sanitation and clean water, violence and lack of education (limited access to resources) (Schneider *et al.*, 2009). Thus the access to sporting facilities, coaches and sport itself is often a luxury only afforded to those that can afford it or attend schools that offer a sporting program.

As a result of these factors, adolescents in developing countries such as South Africa are inactive and often do not meet the daily recommendations for health and exercise (McVeigh *et al.*, 2004). Besides this however, there has been little research on physical activity patterns of children and adolescents in developing countries, which is in contrast to Western developed countries that promote the health benefits of physical activity and exercise (McVeigh *et al.*, 2004).

Physical activity and the education system

Schools are the perfect setting for promoting physical activity and exercise due to the fact that they reach a large population of children and adolescents (Cooper *et al.*, 2016; Coovadia *et al.*, 2016). However, there are a number of common barriers in low-to-middle income countries (such as South Africa) to physical activity in adolescent school children, such as lack of physical education classes, no access to facilities and equipment, lack of physical education specialists and trainers, inadequate financial resources, crowded school curriculum and nutritional habits (Armstrong *et al.*, 2017; Uys *et al.*, 2016). Research has shown that physical fitness is important during the adolescent years with cardio-respiratory fitness associated with a decrease in adiposity and muscular fitness associated with a lower risk of cardiovascular disease (Armstrong *et al.*, 2017). However, lack of physical activity together with poor nutritional habits can lead to increased obesity levels, particularly in developing countries such as South Africa, thus it is important to consider both these factors to ensure a health related improvement in adolescents (Armstrong *et al.*, 2017).

There is also the issue of safety as levels of violence are high in South Africa, and thus participation in physical activity is often low due to the unsafe area of many residences (Einarsson *et al.*, 2016). Furthermore, physical education is almost non-existent in South African schools with less than two thirds of children partaking in weekly physical education classes (physical education has only been allocated two out of the six hours of life skills lessons in foundation phases and one hour in the intermediate phase) (Draper *et al.*, 2014). This is worrying considering that schools should be providing at least 50% of the 60 minute recommendation of moderate-to-vigorous physical activity daily (Sit *et al.*, 2017).

In South Africa, the higher an individual's socio-economic status the greater the access to facilities, organised sporting events and finances, the opposite to that of those in the lower socio-economic bracket (Stalsberg and Pedersen, 2010). Furthermore, the South African private schooling system (which consists mainly of individuals in the higher socio-economic

bracket) offers internationally recognised education and sporting activities (DoBE, 2014). This is in total contrast to most rural, public schools where sporting activities may not even be offered at all, and if they are there is a lack of fields, equipment or coaches (Naidoo, 2007). Therefore it is important to look at physical activity, sport and training in the context of the South African educational system, particularly when designing intervention programs.

South African schooling and university systems

Education in South Africa is shaped not only by an environmental context, but also a broader political and socio-economical framework (Wilmot and Dube, 2015). A major issue that the South African education system has faced since 1994 has been to determine the appropriate balance between the reliance on public or private funds, despite pressure on the South African Constitution to provide free basic education at school and university level (Fiske and Ladd, 2003). However this is difficult for a low-to-middle income country that has between 20 000 and 30 000 schools and 23 tertiary institutions (11 universities, six universities of technology and 6 comprehensive institutions). This is further validated by the poverty rankings of South African schools which are categorised into groups known as quintiles (quintile one= most poor; quintile five= least poor) (Wilmot and Dube, 2015). Quintiles one, two and three are further categorised as no fee paying schools, whereas quintiles four and five are considered fee paying schools (Wilmot and Dube, 2015).

Furthermore, quintiles four and five can be divided into two main types of ordinary (excluding special needs) institutions, namely private independent schools and fee paying public schools. Although both are considered fee-paying schools private school education is considerably more expensive and exclusive plus the private and public schools differ in the number of terms per year. Public schools tend to be characterised by a four term school year whereas most private schools (there are some exceptions) use a three term schooling year. Regardless of type of school, however, sport plays an integral role in the development and education of individual learners, particularly in a South African context where sport is played mainly at schools/universities and not clubs. Furthermore, the Department of Basic Education recognises the importance of school sports to provide the foundations that are necessary for the holistic development of students in conjunction with the academic curriculum (DoBE, 2014). Thus, learners are encouraged to participate in a variety of sporting activities due to the many benefits that can occur. Despite this, the challenges highlighted earlier suggest that even though this is a recommendation, in practice it is not happening in most schools.

Most public (quintiles four and five) and private schools require their students to participate in one major summer sport (for example, cricket, aquatics or rowing) and one major winter sport (for example, rugby, hockey or netball), while students can choose to play sports at the tertiary level. This means that at a tertiary level, individuals are not forced to participate in any sport or physical activity and as a result the numbers of sporting teams and players are often reduced compared to school teams. Again there are contrasts in that while sport is a school requirement, not all schools are in a position to offer any sport. At the other end of the spectrum, we have more affluent schools that offer a very rich sporting programme and so pupils at schools that have reduced numbers often have to participate in more than one summer and winter sport. For example in the summer terms individuals often play cricket and water polo, whereas in the winter terms, rugby and hockey are often played together. This cross training can have a slight influence on individuals with moderate levels of general fitness (such as many adolescents) and can also be used as an injury prevention and rehabilitation tool (Loy *et al.*, 1995). However, for schools within the first, second and third quintiles sport is often not even offered and there is a distinct lack of coaches, practice/playing environments and facilities (Pote and Christie, 2016). It is therefore important that pupils are firstly exposed to sport throughout all quintiles and secondly, to some form of physical training to prepare them for the demands placed on them by their respective sports.

Cricket in South African Schools and universities

Universities, public and private schools in South Africa are usually broken down into three of four term years. In terms of cricket activity, most fee paying public and private schools as well as universities, offer cricket as a summer sport in the first (January-March) and third/fourth term (October-November) (approximately three months of cricket is played in the first term compared to two months of cricket in the third/fourth term). Generally individuals play between 20 and 40 cricket games per year depending on the type of matches as well as tournaments and tours participated in. The format of the game also differs between each term. In the first term declaration or time cricket is usually played, whereas in the third/fourth term limited overs cricket, more specifically 50 over matches are played. Twenty/20 cricket is played throughout the year depending on the different knockout competitions and tournaments. For those schools where cricket (or sport in general is not offered) an initiative by Cricket South Africa, Sport and Recreation in South Africa and the Department of Basic Education has been developed to achieve meaningful growth in the

quality and number of schools playing cricket in township and rural areas (quintiles one, two and three); particularly where opportunities to play the game is limited. This is through linking school and university cricket in these regions with Cricket South Africa's (CSA) regional performance centres and hubs- specifically black African players progressing through CSA's talent development pathways from grass roots to the elite level, and overcoming cultural and socio-economic barriers (Dove *et al.*, 2016)

In terms of training, the longest cricket pre-season period for both schools and universities is approximately one month, which is not long to implement cricket specific training programs and injury prevention programs. This together with the fact that some players participate in multiple sports and don't have access to coaches, equipment and facilities means that training programs and strength and conditioning is a luxury at most schools in South Africa. Thus a low-cost, no-cost, scientifically based strength and conditioning program (that can be implemented by coaches with minimal qualifications and education) would be beneficial to all schools and universities, particularly for those that cannot afford coaching, equipment and facilities. This is in order to specifically improve a player's physical and physiological characteristics to advance athletic performance in addition to the skills based training used by coaches during cricket activity.

A BRIEF HISTORY OF STRENGTH AND CONDITIONING

Although the Egyptians, Chinese and Indians all practiced resistance exercise and training, it was the ancient Greeks (mainly Hippocrates and Galen in 776 B.C.) that developed our modern understanding of athletic training (Todd, 1995; Hemingway *et al.*, 2002). After the initial introduction of athletic training, the Roman Empire copied the Greeks, but the Romans used these principles to train for military purposes instead of athletic ability. With the decline of the Roman Empire however, systematic exercise decreased although there are still accounts of athletic training during the renaissance era (14th-17th century) which was considered to be the link between the middle ages and modern history (Todd, 1995).

Sport began to re-emerge in the late 19th century, but few recognized the need for athletic training and early trainers were responsible for carrying water jugs, acting as team managers and providing occasional massages (Peterson, 2007). It was only in 1938 that the need for athletic training was once again acknowledged, but before any associations could take shape,

the II World war commenced, and as with the Romans, individuals were prepared for armed service instead of athletic competition (Peterson, 2007).

After the war it was quickly identified that if athletic training and conditioning was to develop into a profession, an association needed to be established to enforce respectable standards of care. This led to the development of the National Athletic Trainers Association (NATA), in the United States of America, which was founded in 1950 (Delforge and Behnke, 1999; Peterson, 2007). NATA was established to build and strengthen the profession of athletic instruction by exchanging ideas, knowledge and different methods of athletic training (Delforge and Behnke, 1999). Thus, in 1956, the NATA committee studied avenues to enhance the professionalism of training and developed a model curriculum for the professional preparation of athletic trainers (Delforge and Behnke, 1999). This was the start of modern day strength and conditioning practices as well as athletic training and although NATA disbanded in June 1998, it provided leadership in training throughout the world for nearly 50 years (Delforge and Behnke, 1999). The development of associations, post NATA, such as the National Strength and Conditioning Association (NSCA), the United Kingdom Strength and Conditioning Association (UKSCA), the Australian Strength and Conditioning Association (ASCA) and the Health and Fitness Professionals Association (HFPA) in South Africa is highly important in ensuring improvements in sporting performance, as well as reducing the risk of injuries.

MODERN DAY STRENGTH AND CONDITIONING RESEARCH

A number of studies have examined the strength and conditioning practices of different sports and activities. These investigations have mostly looked at high school, college and national sports teams in North America and focused on sports such as ice hockey, basketball and American football (Finamore, 1992; Durrel *et al.*, 2003; Ebben *et al.*, 2004; Simenz *et al.*, 2005; Duehring *et al.*, 2009; Wade *et al.*, 2014). These studies formed the basis of modern day strength and conditioning exploration and all used similar survey based research focusing on the specific demands of each sport. Detailed categories included background information, physical testing, flexibility, speed and agility development, plyometrics as well as strength and power development. There were also sections that examined miscellaneous or unique aspects of training, which focused on questions such as when athletes performed their workouts, whether high school coaches were exposed to physical education or health courses,

whether coaches promoted good nutritional practices and supplements, the frequency of injuries during strength and conditioning activities and the role that team coaches played in strength and conditioning practices (Ebben *et al.*, 2004; Simenz *et al.*, 2005; Duehring *et al.*, 2009). Additional studies have also been completed on the strength and conditioning practices of other intermittent sports such as tennis and soccer, however these have mostly focused on the physiological and biomechanical demands of the game rather than the implementation of programs to reduce injury and improve performance (Reid and Schneiker, 2008; Turner and Stewart, 2014).

CRICKET SPECIFIC CONDITIONING RESEARCH

Although there have been a number of studies that have looked at the risk factors, perceived injury risk and the nature and incidence of injuries in both senior and adolescent cricket players (Forrest *et al.*, 2017; Gamage *et al.*, 2017; Bayne *et al.*, 2016; Olivier *et al.*, 2016; Orchard *et al.*, 2016; Morton *et al.*, 2014), very few strength and conditioning or injury prevention programs have been developed. Of those programs that have been developed and implemented, most have focused on bowlers with little research examining batsmen and fielders (Mukandi *et al.*, 2014; Stronach *et al.*, 2014; Cronin *et al.*, 2016).

Mukandi *et al.* (2014) looked at strength and conditioning of fast bowlers and showed that in-season maintenance programs are important to maintain player fitness levels, specifically due to the shorter pre-season periods because of the growing popularity of Twenty/20 cricket. Thus conditioning should consist of high intensity and low volume sessions mainly using intermittent protocols (that are higher than the demands of the game) to develop anaerobic capacity (Mukandi *et al.*, 2014). Protocols such as the 30:15 intermittent fitness test or the 25m shuttle test should be used to train players as these can also help with acceleration and deceleration at increased heart rates. The main conclusion however was that trainers need to be aware of the demands of the game so that a progressive training program can be designed and implemented for each individual player (Mukandi *et al.*, 2014). Furthermore, it was concluded that a good pre-habilitation program is also needed for fast bowlers to correct muscle imbalances and thus reduce the risk of injury (Mukandi *et al.*, 2014).

Also in 2014, Stronach *et al.* examined the mechanical and anthropometric factors of fast bowling for cricket and the implications for strength and conditioning. It was established that fast bowlers need to be evaluated using a test battery that covers the general conditioning principles of strength, power, speed, aerobic and anaerobic, anthropometric and flexibility

aspects before completing a fitness program. Furthermore, once players have completed a base fitness program (that focuses on power and eccentric training) trainers should focus on the development of lower body speed and upper body power. In addition to this it is also important to improve flexibility in the lumbar region of the spine and the hamstring musculature to help cope with the technical movements associated with bowling. In terms of anthropometry, fast bowlers need to be as lean as possible, particularly to reduce the ground reaction forces at front foot impact. Lastly, Stronach *et al.* (2014) acknowledges that it is important to manage player's workloads. This is particularly significant for determining whether athletes are adapting to their training programs, understanding individual responses to training, assessing fatigue and the need for recovery as well as minimizing the risk of overtraining which may result in illness and injury (Bourdon *et al.*, 2017; Gabbett *et al.*, 2017). This is done through measuring either internal (for example blood lactate, ratings of perceived exertion) and/or external (for example speed, acceleration, metabolic power) training loads of individual players which are then analysed to determine if a player is optimally loaded or over or under loaded (Bourdon *et al.*, 2017). A common method of analysing these loads is through the acute:chronic workload ratio, which uses rolling averages to compare training loads completed in a recent period (usually one-two weeks), with the chronic training load completed over a longer period of time (usually four-six weeks). To date, to the authors knowledge and in terms of cricket activity, only one study has looked at throwing workload and injury risk (Saw *et al.*, 2009), whereas two investigations have monitored the workloads of fast bowlers at the elite level (Hulin *et al.*, 2014; McNamara *et al.*, 2016). All studies concluded that greater increases in acute workload relative to chronic workload lead to a greater risk of injury. Furthermore, 'spikes' in acute workload place players at an increased risk of injury (Gabbett and Witeley, 2017).

Cronin *et al.* (2016) examined strength and conditioning for throwing in cricket. It was shown that throwing related pain for all cricket disciplines was due to an acute spike in workload, specifically if the player had not previously followed a preparation program. They concluded that it is important for players to follow a progressive workload training program, at least four times a week, with a progressive increase in both intensity and volume to better prepare the athlete for workloads associated with training and matches. Additionally the program should consist of strength, endurance, hypertrophy, maximum strength and high velocity training.

In 2017, Soomro *et al.* developed a cricket injury prevention program (CIPP) to reduce injury rates in junior and community based cricket players. This study required participants between the ages of 14 and 40 years to perform the CIPP either as a pre-training warm-up or as a cool down post-training. However, this was a protocol based study (only the protocol was published) and besides for pilot testing, where qualitative information was collected, no quantitative data was gathered. The program was piloted on 50 club cricketers and adjusted according to each individual's subjective reflection of the injury prevention strategy. Thus on field pilot testing was used to validate the exercises in the program, gather implementation issues, determine time limits, and improve the structure of the program through feedback from players and coaches. There is however no evidence to suggest that this cricket injury prevention program reduces the risk of injury in junior or community based players as injury data is yet to be collected.

Therefore, there is a need to investigate the efficacy of a pre-season strength and conditioning program using a multi-factorial, scientifically based injury prevention and strength and conditioning program for adolescent cricket players that can reduce the risk of injury and improve physical fitness. In designing such a program it is important to consider the different training and testing principles as well as the diverse periodisation models that originated from the General Adaptation Syndrome.

GENERAL ADAPTATION SYNDROME

The General Adaptation Syndrome was initially described by Selye in 1956, which states that the body has a three-stage response to stress, which have been adapted to describe the developmental processes associated with physical training and sport involvement (Baker *et al.*, 2005). The three stages include (Figure 1):

1. The alarm stage: this occurs when the body reacts to a stimulus which could lead to a drop in performance due to stiffness and soreness during the days following the stimulus (Stone *et al.*, 1982).
2. The resistance stage: This is when positive adaptations occur and the body returns to homeostasis. During this phase a number of biomechanical and neuromuscular adaptations occur which lead to an improvement in performance (Stone *et al.*, 1982; Chiu and Barnes, 2003).

3. The exhaustion stage: this occurs when the magnitude of the stress on the body is too large, which leads to exhaustion and overtraining. This can also occur due to psychological stress placed on the body (Stone *et al.*, 1982; Chiu and Barnes, 2003).

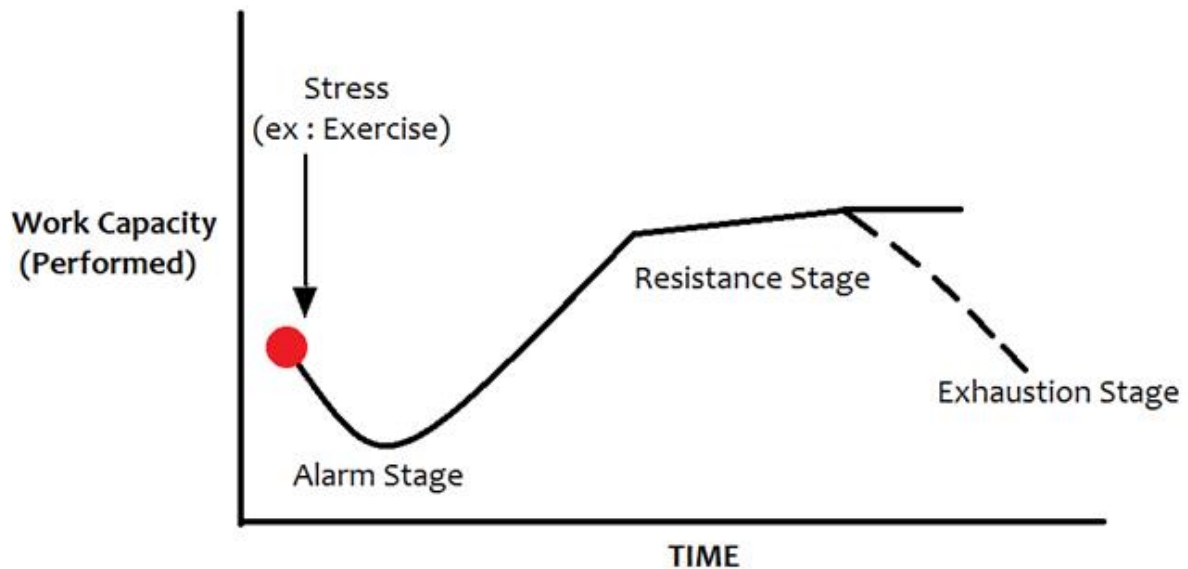


Figure 1: The General Adaptation Syndrome as described by Selye in 1956 (Accessed online at: <http://advancestrength.com/strength/how-does-the-body-adapt-to-exercise>)

There are two main training principles that the General Adaptation Syndrome is based on namely progressive overload and recovery (to avoid overtraining). In order to improve training status, players or teams need to be subjected to training loads beyond which they are normally accustomed, as physical conditioning is improved by putting the body through demands that cause strain or fatigue (Budgett, 1998; Pyke and Davis, 2010; Pook, 2012). This is known as the progressive overload principle and involves providing a proper stimulus for eliciting a desired physical, physiological or performance adaptation (Stone *et al.*, 2000; McArdle *et al.*, 2001; Stone *et al.*, 2002). Without some form of progressive overload, even a well-designed program limits an athlete's ability to make any type of improvement (Budgett, 1998; Pichot *et al.*, 2002; Baechle and Earle, 2008). Overload can occur through a number of factors such as increasing the volume of training and the intensity of the load, as well as changing exercise selection and correct resting periods; intensity refers to the rate of performing work and the rate at which energy is expended (Stone *et al.*, 2002). Volume on

the other hand is a product of exercise frequency and duration, and is an estimate of how much total work is performed, as well as the total amount of energy expended (Stone *et al.*, 2000). For example, during resistance training volume refers to: the number of repetitions and sets per exercise, whether large or small muscle groups are trained and the number of times per day, week and month these exercises are repeated (Stone *et al.*, 2000; Stone *et al.*, 2002).

In terms of overload and recovery, adaptations and improvements take place during rest (after exercise), highlighting the importance of rest in overload training (Pichot *et al.*, 2002; Pook, 2012). It is important to overload players in such a way as to avoid chronic fatigue, so training should begin slowly and progress gradually, based on the individuals training status (Pyke and Davis, 2010; Pook, 2012; Hulin *et al.*, 2014; Bourdon *et al.*, 2017). Players with a low level of conditioning and a less strenuous exercise history need a slower rate of progression compared to those with a strong conditioning background to avoid overtraining (Pichot *et al.*, 2002; Pook, 2012). Furthermore, recovery is important if an athlete is to derive maximum benefits from subsequent training sessions. Thus, the principle of recovery refers to the part of training where the benefits of the work undertaken are maximised through practices which reduce residual fatigue and enable a player to cope with workloads more effectively (Rushall and Pyke, 1990; Bishop *et al.*, 2008). This is particularly important in a school or university setting where individuals often have to play multiple sports and have to focus on other factors such as academics and cultural commitments. Therefore, the players ability and capacity to undertake more work, as well as work more efficiently, is enhanced which in turn encourages better adaptation to training (Rushall and Pyke, 1990; Bishop *et al.*, 2008). For recovery to play a significant role in a player's training regime, coaches need to obtain subjective feedback from individuals to gauge their response to training so that the load can be adjusted if necessary (Pyke and Davis, 2010; Gabbett and Whiteley, 2017). Recovery can be assisted by light exercise and stretching, relaxation techniques, massage, good sleeping habits and cold water therapy, the literature of these techniques is however controversial (Knapik *et al.*, 1992; Kokkonen *et al.*, 1998; Pyke and Davis 2010; Minett *et al.*, 2012). The relaxation and avoidance of strenuous physical activity are particularly important following days of high intensity or long duration training (Budgett, 1998; Baechle and Earl, 2008). Furthermore, it has been suggested that post exercise ingestion of adequate fluids and carbohydrates is important for replacing fluid lost and replacing muscle and liver glycogen stores that were likely depleted during training (Burke *et al.*, 2004; Baechle and

Earle, 2008). However, more recently it has suggested that this is not the case, and that the presence of thirst and not of water loss is the biological signal that we need to drink (Noakes, 2010).

In addition to overload and recovery there are additional training principles that also need to be considered. These include specificity, individuality and reversibility. Specificity states that the most appropriate training regime is one that closely simulates the movements and energy systems used for a particular sport (Pyke and Davis, 2010). For example, in cricket players it is important to focus on intermittent training practices such as the 25m shuttle test (repeat sprint ability) as this mimics the energy systems and movement demands associated with the game (Mukandi *et al.*, 2014; Stronach *et al.*, 2014). The principle of individuality implies that individuals react and adapt to training in unique ways and hence training programs, warm-ups and cool down/recovery sessions should reflect these differences (Pook, 2012; Pyke and Davis, 2010). For cricket this is particularly important for players that play all three formats of the game compared to a player who just plays test matches; training regimes will differ significantly between the two (Mukandi *et al.*, 2014). This is also an important consideration to take into account at the school and university level, where individuals are often limited in terms of time, facilities, equipment, nutritional factors and other commitments (this can also impact on an individual's psychological state). The last training principle is reversibility, which states that when physical training is stopped, the body re-adjusts in accordance with the diminished physiological demand and any beneficial adaptations may be lost (Romer and McConnell, 2003). This is of specific importance when a player is injured and cannot play for a long period of time, and needs to be taken into account when an individual is re-introduced into training. Furthermore, this is the case when players return from school or university holidays; individuals often come back untrained in many instances.

As a result of the General Adaptation Syndrome and these training principles, the concept of periodisation was developed to maximise an individual's adaptations through training by optimising performance and recovery and reducing the chances of overtraining (Buckner *et al.*, 2017).

PERIODISATION

For decades, a primary focus for conditioning and sports coaches has been to determine the most efficient and effective method of strength development for athletes (Rhea *et al.*, 2002). Therefore it is important that professionals are able to prescribe the most appropriate program for these athletes; preferably a program that has been tested in a research setting (Rhea *et al.*, 2002). However, while there is not an optimal program design that is agreed upon, there is a general consensus that some form of periodisation must be a major part of any plan (Rhea *et al.*, 2002).

Traditionally, periodisation has been used by athletes and coaches in an attempt to maximise fitness gains and physical performance and nowadays it has become a foundation of athletic training (Fleck, 1999). Thus, it can be simply defined as a process to logically and sequentially manipulate training variables to optimise performance (Kirby *et al.*, 2010). These training variables include volume, intensity, frequency, type of exercise, recovery and type of muscle action or contraction performed (Fleck, 1999; Fleck, 2011; Naclerio *et al.*, 2013). Periodised programs have shown greater strength increases in males and females as well as trained and untrained individuals compared to non-varied (non-periodised) training programs (Jimenez, 2009; Fleck, 2011). However, it needs to be considered that individuals play multiple sports throughout different seasons at a school and university level and thus traditional periodisation models are not often feasible at these types of establishments. This together with the fact that there are other academic and cultural commitments means that periodisation cycles and periods need to be adapted to suit the individual and the different sports they play, particularly to ensure that they are being optimally loaded. In terms of elite athletes (specifically for periodisation) managing and preparing athletes is arguably easier as there are not as many external factors and pressures that need to be considered when designing training programs. Therefore, periodisation models need to be re-evaluated for cricket activity both at the elite and non-elite levels, particularly at a school and university level, where other factors need to be considered.

However, in order to understand periodisation fully, there are a number of factors that need to be taken into account, including: the periodisation cycles, periods and models as well as the part of the sports season that is in progress (for example, off-season vs. in-season training).

Periodisation for cricket activity

The periodisation of team sports (such as cricket) is difficult because of the variety of training goals as well as the volumes and intensities of concurrent training sessions and competitions (Mukandi *et al.*, 2014). Thus, cricket strength and conditioning coaches need to consider the complexity of the session, the experience of the player, the volume and intensity of the session (conditioning, net and field based sessions), the fixture list and other sports that are being played at the school and university level. The fixture list is an important component when designing a periodisation model for cricket players due to the different formats and competitions that are played around the world throughout the year (Mukandi *et al.*, 2014). This depends on each individual player and thus the training principle of individuality is also an important component. As a result of these factors, it has been established that the undulating model of periodisation is more beneficial for team sports such as cricket, rugby and hockey (Hoffman, 2012; Lambert, 2009). The non-linear or undulating model caters for a variation in training focus and is more dramatic during the individual microcycles compared to the traditional linear model (Baker *et al.*, 1994; Lambert, 2009; Fleck, 2011; Issurin, 2010). This model therefore enables variation in intensity and volume within each 7-10 day cycle (by rotating different protocols) to train different components of the neuromuscular system such as strength, power and local muscular endurance (Jimenez, 2009; Fleck, 2011; Simao *et al.*, 2012). A major benefit of the non-linear periodisation model is that it may be utilised for sports that have a long competitive season without requiring a concentrated build up to one specific event (Hoffman, 2012; Lambert, 2009). Furthermore, it has been shown that non-linear programs have also been developed where a particular training zone is used for a one or two week period before changing training volume and intensity; known as a bi-weekly non-linear periodisation plan (Fleck, 2011).

In terms of the South African schooling and university systems, the undulating periodisation model is the ideal approach to allow for the correct adaptations to take place. The fact that coaches and trainers are only allowed short pre-season periods (the longest of which is normally one month), packed fixture lists that often require long periods of travel and other academic and cultural commitments, means that strength and conditioning sessions need to be characterised by high intensity and low volume sessions (depending on the individual) which is indicative of the non-linear model of periodisation. There are however problems that can arise through the use of periodisation at schools and universities. For instance, not all schools can afford strength and conditioning coaches and as a result coaches may not

know what is happening in terms of fitness training at other sessions outside of cricket sessions. At the bigger schools and universities, it may be possible to implement a periodised program, as the strength and conditioning specialist oversees training for all sports and can focus on individual loads. At the lower quintile schools though this is often not the case and coaches run their own conditioning sessions for their specific sport and team and as a result the focus is shifted from the individual. Furthermore, the periodisation process is also difficult to implement for talented, individual players that may be required to play up to three sports in the summer and winter terms and thus placing them at risk for under or overtraining.

However, before a training program is implemented (no matter the periodisation model that is adopted), it is important to physically test an individual in order to determine the player's strengths and weaknesses. This will give the strength and conditioning coach an idea of what areas the player needs to 'work on' to improve performance and at the same time reduce the risk of injury.

TESTING FOR PHYSICAL TRAINING

There are a number of different components that need to be considered when testing an individual's athletic performance. Therefore, Fitness testing is part of an inclusive conditioning programme, with results from these tests showing conditioning professionals and trainers the weaknesses that need to be addressed to improve performance and reduce the risk of injury (Pook, 2012). Furthermore, it can provide information that can help to assess the ability to perform a required job or sports task, track conditioning or de-conditioning over time, evaluate the effectiveness of strength and conditioning interventions as well as increase participation motivation (Burnstein *et al.*, 2011). However, before any evaluation can take place it is important to know what tests can be used to assess athletic performance.

Test selection

The evaluation of event or sporting requirements precedes both training preparation and implementation (Spencer and Gatin, 2000). However, in order to ensure validity and reliability, there are a number of elements that conditioning professionals need to consider, including: the energy requirements of the sport, movement pattern specificity, experience and training status, age and sex as well as environmental factors. It is also important to note that while these are important factors to consider, other aspects such as medical history, nutritional profile, somatotype and mental toughness also need to be taken into account.

The metabolic energy requirements of the sport

The test being administered should simulate the energy requirements of the sport that is being assessed. Therefore, an understanding of the three energy systems (phosphagen, glycolytic and oxidative systems) is highly important as well as the processes that operate together to satisfy the energy requirements of muscle (Gastin, 2001; Baechle and Earle, 2008). For example, when testing a batsman in cricket, the test should mimic the phosphagen and fast glycolysis energy systems, such as the repeat sprint ability/5m shuttle run test. However, when testing long distances runners, the test should imitate the oxidative system, such as a 5 km time trial.

Movement pattern specificity/functional assessments

This deals with the specific movements that a sport requires. In other words, each sport requires different movement patterns and the test administered should mimic these patterns. For example, a test suitable for a high jumper would be the vertical jump or the standing broad jump test whereas a cricket player would be at an advantage performing sprint and agility analyses. Furthermore, this is important as inefficient movement patterns of certain activities may result in poor test results or reinforce poor biomechanical movement patterns which could result in injury (Chorba *et al.*, 2010). Particularly important to note is that cricket is intermittent in nature and thus tests should reflect this (for example, repeat sprint ability tests)

Experience and training status

An athlete that is well trained and experienced will be able to perform a test that is complex and intensive in nature, whereas an individual who is less trained needs to start off with a more basic testing program (Baechle and Earle, 2008; Pook, 2012). Furthermore, the type of training that an athlete has been exposed to also needs to be taken into account. For example, an athlete who has been performing interval training should not be tested using a 3 km time trial, or an athlete who has been training with machines cannot be expected to perform a strength test with free weights. In terms of schoolboy cricketers, testing should focus on the basics early on and then progress throughout the individual's career.

Age and sex

The reliability and the validity of a test are dependent on the age and sex of the athlete (Baechle and Earle, 2008). This is particularly important when comparing adult athletes to adolescents. Adolescents may lack the strength and experience compared to adults when

performing a specific test. For example, when performing a repetition maximum bench press it is often advised that adolescents do not perform a one repetition maximum, but rather a 10 repetition maximum test. Research has shown that it is also important to consider the relative age effects of school children and adolescents, particularly in terms of time of birth during the year, as older individuals tend to outperform younger individuals (Veldhuizen *et al.*, 2015).

In terms of sex, males may be able to perform a number of pull ups, whereas many women may lack the upper body strength to complete a chin up (Baechle and Earle, 2008). Furthermore, there are certain physiological characteristics that differ according to sex and age such as heart rate or oxygen consumption responses (Ogawa *et al.*, 1992). Thus these factors need to be taken into account when testing adolescent school boy cricketers for conditioning purposes.

Environmental factors

Before administering an athletic test of any sort, it is important to consider the environmental conditions. High temperatures, together with humidity can have an impact on endurance exercise performance, pose a certain number of health risks such as heat stroke, as well as lower the validity of aerobic endurance tests (Baechle and Earle, 2008). This is of particular importance for cricket testing as often this takes place in the summer where players are subjected to high temperatures. Temperature may also have an effect on tests that are administered at different times of the year. For example an athlete that is tested in winter may not represent with the same results if tested in the summer. This may be negated by testing athletes indoors in a controlled environment setting. Another environmental factor that may impact test results is altitude. Studies have shown that while tests of strength and power are not affected by altitude, aerobic endurance tests are, and should be controlled by allowing athletes to acclimatize before performing any aerobic endurance tests (Grover *et al.*, 1986; Baechle and Earle, 2008).

Testing sequence

The sequence of testing is important in determining the implementation of a conditioning program (Reiman and Manske, 2009). So, while test selection is key, it is also important from an administrative point of view to ensure that the testing battery is performed in the correct order (Hoffman, 2012).

Thus, exercise science is imperative as it can help determine the proper order of tests as well as the duration of rest periods between tests to ensure reliability (Baechle and Earle, 2008).

There are a number of factors that need to be considered when determining the order of testing including the number of athletes being tested, the length of the testing period (for example 2 hours compared to one day) and the number of strength and conditioning professionals that are available to assist with the testing (Hoffman, 2012). Ideally though, despite these factors, testing should be performed in a sequence (Hoffman, 2012). According to general guidelines the least fatiguing and highly skilled (agility and explosive ability) tests should be performed first (Baechle and Earle, 2008; Reiman and Manske, 2009).

Table 1 shows an example of the correct sequence that the tests should be administered in. However, testing many athletes at one time may require the use of several different testing stations, thus the ideal testing sequence may not always be possible or realistic (Reiman and Manske, 2009; Hoffman, 2012).

Table 1: Example of testing order involving non-fatiguing and fatiguing tests (adapted from Baechle and Earle, 2008).

Type of test	Example
Non-fatiguing	Stature, mass, flexibility, skinfolds, vertical jump
Agility	Pro-agility, T-test, Illinois
Maximum power	1RM bench press, 1RM power clean
Sprint	10 m sprint, 40 m sprint
Local muscular endurance	maximum sit-ups/push-ups in a minute
Fatiguing anaerobic capacity	400 m run, repeat sprint ability/25m shuttle run
Aerobic capacity	3 km time trial, 12 minute run

For example, one athlete may perform a sprint test prior to a strength test, whereas another individual may perform a strength test before an agility assessment (Hoffman, 2012).

Aerobic tests may also be administered on different days to other tests (Baechle and Earle, 2008). If this is the case though, it is important to note that when the athletes are re-tested, the testing sequence must remain the same for each individual athlete.

TYPES OF TRAINING

Little research has examined the effects of types of training and training principles on adolescent school children, particularly within a South African context. This is worrying considering young individuals are at a high risk of injury compared to adults and thus different training practices should be considered for each group (Abernethy and Bleakley, 2007). However, besides the limited amount of literature, it has been shown that children and adolescents that follow age-appropriate training guidelines are at a low risk of injury and can improve performance (Faigenbaum *et al.*, 2009). This needs to be considered when training adolescent school children.

There are four main types of exercise prescription that need to be considered:

1. Resistance training
2. Plyometric/explosive power training
3. Speed and agility training
4. Aerobic and anaerobic training

Resistance training

Resistance training has grown in popularity and has a positive impact on athletic ability through an increase in muscle strength, power, speed, hypertrophy, local muscular endurance, motor performance, balance and co-ordination (Kraemer and Ratamess, 2004; Baechle and Earle, 2008). An important component of any form of resistance training is appropriate program design (Kraemer and Ratamess, 2004). This involves a number of factors such as exercise instruction, goal setting, a method of evaluation of training, progress towards a training goal, correct prescription of acute program variables and specific methods of progression (Kraemer and Ratamess, 2004). In terms of cricket activity, resistance training in fast bowlers can cause adaptive alterations in nervous system function as well as changes in

muscle structure (Mukandi *et al.*, 2014). This is particularly important as the bowling action is an explosive intra- and inter-muscular activity (Mukandi *et al.*, 2014). Positive correlations have also been shown between ball release speed and upper and lower body strength (Mukandi *et al.*, 2014). For batting, it has been shown that upper body strength is a good predictor of maximum hitting distance (Taliep *et al.*, 2010). Thus strength training is important for all cricket disciplines.

Before a player performs any form of resistance training however, stability and mobility exercises should be completed (Pook, 2012). This allows for anatomical adaptation, which provides a base of strength and stability to those new to resistance training or following a long rest period (for example, off-season) (Pook, 2012). Once a base of strength has been provided, players may perform more advanced resistance training exercises which consist of core and assistance exercises, structural and power exercises and sport-specific (functional) exercises (Baechle and Earle, 2008). The specific order that these exercises are performed in is also important to allow for sufficient recovery time and reduce the risk of injury. Usually power exercises are performed first, followed by non-power core exercises, and lastly assistance exercises (Baechle and Earle, 2008). To assist further with player recovery, lower and upper body exercises as well as push and pull exercises can be alternated (Baechle and Earle, 2008). Lastly, resistance training should incorporate both eccentric and concentric muscle actions (Kraemer *et al.*, 2002).

There are also a number of training systems that can be implemented during resistance training, which are based on a player's sport specific goals, technique and training experience (Pook, 2012). These systems include:

- Single sets: one set of each exercise is performed.
- Pyramids: lifting from a light to a heavy load or vice versa.
- Supersets: incorporate versatility into resistance training. Sets of two or more exercises are used, for example a pulling exercise, followed immediately by a pushing exercise.
- Split routines: this method of training deals with hypertrophy, where different drills are performed for the same body part and the routines are split. For example, on day 1, exercise the back, biceps and legs and on day 2 the chest, shoulders and triceps.

- Complex training: this is an advanced system, where heavy and light loads are used in the same set. Once a heavy load has been lifted, there are high levels of muscle recruitment as well as nervous system excitation and thus performance during lighter load sets is enhanced.

Furthermore, during resistance training it is important to consider the number of repetitions, the load and the frequency of training. According to Kraemer *et al.* (2002) a novice player should initially perform 8-12 of their one repetition max (RM), while an advanced player should start between 1-12 RM, with 3 minute rest breaks between sets. Eventual emphasis should be on heavy loading (1-6 RM) at moderate contraction velocities (1-2 s for the concentric and the eccentric phase of the lift) (Kraemer *et al.*, 2002). If a player performs a workload 1-2 repetitions over the desired number, then the load may be increased by 2-10% of 1RM. The recommendation for training frequency 2-3 days per week for novice players and 4-5 days per week for advanced training (Kraemer *et al.*, 2002). However, it needs to be remembered that these are just guidelines. Other factors such as the part of the season, injury status and periodisation cycles, periods and models also need to be considered.


Plyometric training

Plyometric training has become an important part of any conditioning program and has evolved into a widely accepted and effective tool to improve explosive power and agility (Kutz, 2003). According to the American College of Sports Medicine, plyometric training conditions the body through dynamic and functional resistance exercises and improves abilities such as speed, explosive jumping, running and agility. It has been shown that for cricket players lower limb plyometric training in the pre-season can improve shuttle run performance which is important for batsmen running between the wickets (Houghton *et al.*, 2013). Furthermore, this type of training also improves vertical jump height which is essential for fielders jumping to catch a ball (Houghton *et al.*, 2013). Upper body plyometric training has also been shown to increase bowling velocity and improve performance in medium pace bowlers (Singh *et al.*, 2014).

There are two ways to increase a muscles force producing capabilities. Firstly, by increasing the rate at which a motor unit is stimulated and secondly, by increasing the number of motor units that are activated (Kutz, 2003). Training an athlete using plyometrics, affects these factors and as a result the neuromuscular system is trained to respond effectively and efficiently (Kutz, 2003). Therefore, essentially plyometric training is related to the stretch

shortening cycle. The stretch shortening cycle of muscle function eludes to the fact that body segments are periodically subjected to impact or stretch forces (particularly during movements such as hopping and jumping) (Komi, 2000). During plyometric training, external forces lengthen the muscles so that eccentric actions are taking place (Komi, 2000). This is known as the eccentric phase of the stretch shortening cycle (Kutz, 2003). Following this the amortization phase takes place (Kutz, 2003). This phase refers to the short time period between the eccentric action and the concentric contraction. For example, during a box jump, this phase is the time that elapses between landing and jumping again. The amortization phase must be kept short to ensure a minimal loss in stored elastic energy (Kutz, 2003). After this brief time period the last phase takes place which is known as the concentric phase, where the active muscles contract concentrically (Komi, 2000; Kutz, 2003). Therefore, the combination of eccentric and concentric actions, together with the amortization phase, results in a natural type of muscle function called the stretch shortening cycle (Komi, 2000).

Table 2: Progression representing the lowest to the highest intensity plyometric exercises (adapted from Ebben, 2007).

Start	Sub-maximal jumps in place (Example: short cone hops, ankle hops)	
	Sub-maximal jumps in place (Example: tall cone hops)	
	Squat jumps	
	Weighted jumps	
	Low box and depth jumps	
	Maximum jump and reach without overhead goals	
	Maximum jump and reach to overhead goals	
	Tuck and pike jumps	
	Depth jumps: heights similar to the players vertical jump height	
	End	Single leg jumps

As with resistance training, progression is a key component that needs to be considered during plyometrics, particularly to ensure the safety of the players and athletes (Kutz, 2003; Ebben, 2007; Baechle and Earle, 2008). Furthermore, if a player is not able to squat between 1.5 and 2.5 of their body weight, no plyometric training should be implemented (Kutz, 2003).

Table 2 represents the correct progression that players should follow when using plyometric training.

Unlike resistance training that focuses on specific sets and repetitions, plyometrics uses exercise intensity as an indicator of the work performed. Each exercise is performed at maximum intensity, which is usually determined by amount of foot strikes or touches (Kutz, 2003). Elite athletes usually work at an intensity of 200-400 touches, whereas beginners typically train at an intensity of 60-150 contacts (Kutz, 2003; Ebben, 2007). In terms of rest periods, athletes usually rest between 30s-3mins depending on the individual however it is important to allow for sufficient recovery time before performing the remaining exercises (Kutz, 2003). Rest periods should account for 5-10 times more than the time taken to complete the exercise. For example, if a vertical jump exercise takes 4s then the rest period should last approximately 20-40s (Ebben, 2007).

Lastly, it is important that resistance training and plyometrics are integrated wherever possible. This allows for maximal efficiency and physical improvement (Baechle and Earle, 2008). An example of how this integration can be applied is shown in Table 3.

Table 3: The integration of resistance training and plyometrics (from Baechle and Earle, 2008).

Day	Resistance training	Plyometrics
Monday	High intensity upper body	Low intensity lower body
Tuesday	Low intensity lower body	High intensity upper body
Thursday	Low intensity upper body	High intensity lower body
Friday	High intensity lower body	Low intensity upper body

Speed and agility training

Speed and agility have always been considered important for the development of athletic training programs and both are crucial qualities for most sports (Young *et al.*, 2001; Craig, 2004). Furthermore, speed and agility are key components for cricket activity, specifically for batsmen running between the wickets or fielders having to dive/run to stop a ball (Lockie

et al., 2013; Herridge *et al.*, 2017). Particularly with the new formats of the game that have been introduced, there are often ‘game changing’ moments that require speed and agility; this may be the difference between a win or a loss (Herridge *et al.*, 2017).

In terms of speed, it is key that a player covers ground efficiently and economically over the first few meters and then increases stride length and stride frequency over the next 50 m (Pearson, 2004; Craig, 2004). Therefore, training for speed requires focus on factors such as running mechanics, stride length and frequency, the leg cycle and hip/height position (Pearson, 2004). Examples of exercises include high knee kicks, resisted or assisted running, high speed sprints and hill sprints or sled training (Craig, 2004; Baechle and Earle, 2008). In terms of agility, there are four elements that need to be considered (Pearson, 2004):

1. Balance: refers to the ability to stand, stop and walk using the centre of gravity. For example, walking on a balance beam or standing on one leg. Usually, balance does not take too long to train.
2. Co-ordination: deals with mastering simple skills under more complex situations, which often takes time. This can be achieved by dividing a skill into its separate components and then gradually bringing them together. Training co-ordination would include, for example, footwork drills or walking on a balance beam while playing catch.
3. Programmed agility: this deals with a player that has experienced a stress already and is aware of the demands that will be placed on them. Examples of programmed agility drills are the zig-zag marker drill or T-marker drills. These drills can eventually be conducted at high speeds, but should be learnt at low speeds.
4. Random agility: this is the last element that needs to be considered and deals with the player performing tasks with unknown patterns and demands. This can be achieved through incorporating visual and audible signals into the drill being performed, so that the skill is closely mimicking the game situation.

Thus, there are a number of benefits that can be gained from performing the correct speed and agility training exercises. These include injury prevention, faster sprint times and improved running economy through the control of small movements in the knee, hip, back, shoulder and neck for optimum body alignment (Pearson, 2004; Craig, 2004). However,

perhaps one of the biggest benefits is the impact of speed and agility training on the central nervous system. By repeating certain exercises over and over again, the central nervous system can adjust the length of an individual's muscle spindles (through motor neuron activation), which eventually translates to faster times and improved agility (Craig, 2004).

As with resistance training and plyometrics, speed and agility training should mimic the sport being played and exercises should be completed from simple to complex, low to high intensity and general to sports specific (Brown and Ferrigno, 2014). Furthermore, it is also important to consider the training frequency, intensity and volume:

- Frequency: should be altered according to the individual. Athletes should begin with one or two exercises to obtain basic mechanics and technique. As the individual becomes more advanced, frequency can be increased to three times per week.
- Intensity: should be altered depending on velocity of movement, whether the movement is planned or unplanned and the degree of the angle of the movement. Low intensity is between 40-50% of maximum, moderate between 50-80% maximum and high between 80-100% maximum.
- Volume: there is an inverse relationship between exercise intensity and volume, therefore as intensity increases, volume should decrease. This is important for assessing progression and should be based on the athlete's level of fitness.

Aerobic and anaerobic training

Anaerobic training refers to all out efforts of 2 minutes or less, while efforts lasting longer than several minutes are aerobic in nature (Payne *et al.*, 1986; Glassman, 2003). In other words, aerobic exercise is sustainable for long periods of time, whereas anaerobic exercise is not (Glassman, 2003). Furthermore, anaerobic training uses exercises that require an element of explosive power, such as plyometrics and high speed interval instruction, whereas aerobic training constitutes long distance events (Baechle and Earle, 2008). Benefits of anaerobic exercise includes an increase in speed power and strength, improvements in cardiovascular health, a greater ability to burn fats and a development of both anaerobic and aerobic capacity (Glassman, 2003). Therefore, anaerobic training can also benefit endurance athletes who are more aerobically efficient (Glassman, 2003; Baechle and Earle, 2008). For cricket, aerobic and anaerobic qualities are both important qualities for all disciplines, but particularly for fast bowlers that can cover a large amount of distance (especially in multi-day games) (Herridge

et al., 2017). Furthermore, it is also important that players of all disciplines have some sort of base aerobic fitness level. However, once a base fitness level has been achieved, it is important for trainers to develop anaerobic qualities that mimic the demands of the game through speed and repeat sprint ability training (Mukandi *et al.*, 2014; Herridge *et al.*, 2017).

Essentially then, it is important to understand the different energy systems when a player is training to determine whether they are performing aerobic or anaerobic exercise (Table 4). For example, in cricket, when running between the wickets or sprinting to field a ball, an immediate and rapid supply of energy is required (Payne *et al.*, 1986). Thus, energy is derived anaerobically (phosphagen energy system) within the specific muscles activated during that exercise.

Table 4: The effect of duration and intensity of exercise on the phosphagen, glycolytic and oxidative energy systems (from Baechle and Earle, 2008).

Duration of event	Intensity of event	Primary energy system(s)
0-6 seconds	Extremely high	Phosphagen
6-30 seconds	Very high	Phosphagen and fast glycolysis
30 seconds-2 minutes	High	Fast glycolysis
2-3 minutes	Moderate	Fast glycolysis and oxidative system
greater than 3 minutes	Low	Oxidative system

This also mimics actual match-play and is important in strengthening the lower limb musculature and as a result muscle contractibility and power (Woolmer *et al.*, 2008). Endurance fitness for cricketers on the other hand is best achieved by running for up to 30 minutes at a time (Woolmer *et al.*, 2008). This not only adapts the body to weight bearing exercise, but also means that energy is derived aerobically (oxidative energy system) by the active muscles (Payne *et al.*, 1986; Woolmer *et al.*, 2008). It is important to note though, that

each separate energy system does not switch ‘on or off’, but are integrated with one another and overlap from one process to the next (Payne *et al.*, 1986).

SUMMARY

The game of cricket is changing and is a lot more physically demanding than originally thought, compared to the traditional format of the game. This, coupled with the different formats of the game (test matches and limited overs cricket) and longer seasons means that players of the modern era are subjected to heavier workloads throughout the season and are thus at an increased risk of injury.

However, limited literature is available in terms of injuries to adolescent cricketers as well as injury prevention strategies and strength and conditioning programs to reduce the risk of injury and improve performance. Furthermore, in the context of the South African educational system, many individuals do not even have the opportunity to play the game of cricket, and if they do are often hampered by a lack of coaches, equipment or facilities.

Therefore the development of a low-cost, no-cost, scientifically based strength and conditioning program (that can be implemented by coaches or players without specialised qualifications) is important to improve the physical fitness attributes of individuals as well as reduce the risk of injury.

The current study will therefore be divided into three main phases. The first phase will focus on injuries and current injury prevention strategies in cricket activity. The second phase will be a survey based study, looking at the current strength and conditioning practices and injury prevention programs that are being implemented at schools and universities in South Africa. In the last phase, information from the first two phases will be used to develop a cricket intervention program looking to improve physical fitness and reduce injury risk.

NOTE: To avoid repetition throughout this thesis the methods and statistical analyses for each investigation will be discussed within their respective chapters.

CHAPTER 3

INJURY PREVENTION STRATEGIES IN CRICKET

Paper 1: Pote L & Christie CJ (in press). Injury prevention strategies in cricket. *Strength and Conditioning Journal*.

At the time of thesis submission paper 1 is currently undergoing a second round of review following minor revisions in the *Strength and Conditioning Journal*, as an original manuscript. Revisions were required by the reviewers and implemented by the first author. For the purposes of this thesis, the format has been converted to the format of the thesis and not aligned with the requirements of the specific journal.

INTRODUCTION

The demands placed on cricket players are often substantial specifically due to longer seasons, the introduction of new forms of the game and competitions occurring outside of the regular season (off-season) (Stretch, 2003; Orchard *et al.*, 2016). As a result, players are susceptible to a wide range of injuries that may occur any time during the season (Stretch, 2003). While cricket has traditionally been associated with a low to moderate injury risk, there has been an increase in the incidence of injuries over the years and the ‘average’ injury is becoming more severe (Orchard *et al.*, 2006; Milsom *et al.*, 2007).

There is a lack of injury prevention research, specifically at an adolescent and schoolboy cricket level, besides the known potential for injury risk (Finch *et al.*, 2010). To date and to the authors’ knowledge, there are limited scientifically based cricket injury prevention programs that have been developed. There are a number of programs that have been designed and published by well-renowned cricket coaches and academics (Pearson, 2004; Pyke and Davis, 2010; Saw *et al.*, 2011; Herridge *et al.*, 2017), but these are anecdotal or focus on specifically elite athletes. Furthermore, when observing the different injury-prevention programmes, it would seem as if the incorrect practices are being focused on, particularly in terms of injury prevention, mainly due to lack of experience, inadequate qualifications (non-sport science or conditioning related qualifications) and due to a lack of education of cricket coaches (Pote and Christie, 2016). It has been shown that coaches (in South Africa) focus mainly on core work and general fitness (rowing, cycling and long distance running) for batsmen and strength training for bowlers, when conditioning adolescent players (Pote and Christie, 2016). This is interesting considering that the main injuries for batsmen and bowlers are hamstring and lower back injuries respectively (Stretch, 2003; Stretch and Venter, 2005). These insufficient practices may lead to potential injuries and thus there is a need for sound, scientifically based injury-prevention programs for cricketers across the age span (Pote and Christie, 2016).

Therefore, the main purpose of this review was to determine what scientifically based, cricket-specific injury prevention programs are currently available to assist coaches, strength and conditioning specialists and players to reduce the risk of injury. This was then linked to injury data to make recommendations for future research with respect to cricket player preparedness for training and competition.

OVERVIEW OF THE NATURE AND INCIDENCE OF INJURIES IN CRICKET

There are only five major cricket playing nations that have collected long term injury data. These nations include South Africa, Australia, New Zealand, West Indies and England. Of these nations, only South Africa and Australia have published more than one paper with regards to injury statistics and causation with the Australian data being more comprehensive. A summary of these findings is shown in Table 5.

South Africa has the most literature available (see Table 5) in terms of injury surveillance and data collection (1993-2014). Furthermore, it is the only cricket playing nation that has investigated the nature and incidence of injuries at an adolescent level (Stretch and Venter, 2005; Stretch and Trella, 2012; Stretch, 2014). However, these are largely retrospective questionnaire studies that have been conducted over a period of time; between 1993 and 2014. While other cricket playing nations have only looked at national, county and state players, who are professional in nature (Leary and White, 2000; Mansingh *et al.*, 2006; Orchard *et al.*, 2010; Frost and Chalmers, 2014), the Australian database specifically is more extensive as it has looked at injury data and statistics continuously over a ten year period. However, comparisons between the nations are difficult as each have used different methods and definitions of injury surveillance (Orchard *et al.*, 2010). This is mainly due to factors such as the exclusion of time loss injuries from the main definition (the original definition only includes 'match time loss'), new definitions in response to the introduction of twenty/20 cricket and flaws in how data is collected (Orchard *et al.*, 2010). Thus it is important to take this into account when reviewing the injury statistics of each country. This is besides that fact that a recent publication has studied the incidence and prevalence of cricket injuries in elite males using updated consensus definitions (Orchard *et al.*, 2016). Furthermore, limited research has been done on players/disciplines other than fast bowlers and thus a true understanding of the injury risks associated with batting, fielding and wicket keeping is lacking; this is important when designing training programs. Thus there is perhaps a need to focus on the movement demands of these disciplines (positional differences) to adequately address injury prevention.

Table 5: Injury statistics for the different countries and competitions.

Country/ Competition	Author	Year	Sample Size	Age/level	Most injured region	Most injured discipline	Match or practice injury
<i>South Africa</i>	Stretch	1993	308	26*, club/provincial	Lower limbs	Fast bowlers	Match
	Stretch and Venter	2005	594	12 and up, provincial/national	Lower limbs	Fast bowlers	Match
	Milsom et al.	2007	196	u/19, provincial	Lower back	Fast bowlers	Match
	Stretch and Raffin	2011	36	N/A, national	Lower limbs	Fast bowlers	Match
	Stretch and Trella	2012	1292	u/15/17/18, provincial	Lower limbs	Fast bowlers	Match
	Stretch	2014	2081	u/15/17/18, provincial	Lower limbs	Fast bowlers	Match
<i>Australia</i>	Orchard et al.	2002	N/A	N/A, state/national	Lower back	Fast bowlers	N/A
	Orchard et al.	2006	±175	N/A, state/national	Lower limbs	Fast bowlers	Match
	Finch et al.	2010	88	u/12, amateur (juniors)	Lower limbs	Batting/Fielding	Match
	Orchard et al.	2010	±243	±21-33, state/national	Lower limbs	Fast bowlers	Match
	Orchard et al.	2016	N/A (2006-2016 season)	N/A/national	Lower limbs/ lower back	Fast bowlers	N/A
<i>New Zealand</i>	Frost and Chalmers	2014	248	N/A, national	Lower limbs	Fast bowlers	Match
<i>West Indies</i>	Mansingh et al.	2006	323	18-37, domestic/national	Lower back	Fast bowlers	Match
<i>England</i>	Leary and White	2000	54	27*/county	Lower limbs	Fast bowlers	N/A
<i>Asian Cricket Council U/19 Elite Cup)</i>	Das et al.	2014	112	U19/national	Lower limbs	Batsmen	Match
<i>Cricket World Cup, 2011</i>	Ranson et al.	2011	76	N/A, national	Lower limbs (time loss injuries) Lower back (non-time loss injuries)	Fast bowlers (time loss injuries) Batsmen (non-time loss injuries)	N/A

Where: *=mean age; N/A= no data; ±=estimated sample size based on information in paper.

Lastly, Table 5 shows that the majority of injuries occur during match play, despite the fact that most studies have looked at injuries during both training and matches. This is most likely due to acute spikes in workload, which gives credence to the fact that the monitoring of player workload to prevent injuries is important at an elite and non-elite level.

In spite of this, there are a number of important and common trends that can be seen. Across nations, fast bowlers are most prone to injuries, followed by batsmen and then fielders. Most common sites and type of injury are similar between all studies, including the discipline (bowler, batsmen or fielder) and whether the injury is acute or chronic (Table 6). These trends are evident in both adolescents and adults.

Table 6: Injuries in cricket players.

Site	Discipline	Acute or chronic?
Upper limbs	Fielders and wicket keepers	Acute
Lower limbs	Batsmen	Acute and chronic
Lower back	Fast bowlers	Chronic
Abdominal region	Fast bowlers	Chronic

Note: Acute injuries occur as a result of a sudden trauma, for example an impact injury such (15,38). Chronic injuries occur over time, through overuse, such as stress fractures (spondylolysis) (14,16)..

With respect to the proposed risk factors associated with the game, there are a number of similarities between the different investigations (Table 7). These studies show that pace bowlers are the most prone to injuries, specifically in the lumbar spine and lower limb regions. This is mainly due to inadequate physical attributes, poor posture and bowling technique (mixed action technique), high physical demands and excess workload (overload or spikes in acute workload). Batsmen were the second most injured players, with lower limb injuries (hamstring and quadriceps strains) occurring most often. These were as a result of sprinting between the wickets and high workload.

Table 7: Injury risk factors for different cricket disciplines.

Potential risk factors for fast bowlers
<ul style="list-style-type: none"> • Inadequate physical attributes • Poor bowling technique (mixed action technique) • High physical demands • Lack of flexibility (hamstrings and lower back) • Trunk lateral flexion postures during bowling and reduced lateral slide of the anterior abdominal fascia • Increase in shoulder counter-rotation (the alignment of the shoulders between back foot and front foot contact) • Knee angle at ball release (a flexed front leg means reduced risk of injury) • Overuse (high number of deliveries bowled, back to back matches, enforcing the follow on in a test match, spikes in acute workloads) • Increased stride length to height ratio as well as high ball release (114% of standing height) • Inadequate warm-up and return to match-play too soon after experiencing an injury • Overload in the run-up, delivery stride and follow through as well as incorrect foot placement during delivery • Repetitive trunk rotation in a mixed bowling action causing abnormalities to the spine (biomechanical technique) • An increase in the amount of cricket being played as well as an increase in the risk of injury associated with T/20 cricket
Potential risk factors for batsmen
<ul style="list-style-type: none"> • Lower limb injuries due to running between the wickets • Overuse injuries due to the introduction of T/20 cricket • Lack of stretching (flexibility), strength and cricket specific training • Impact injuries (direct contact with a ball, bat or other player and lack of protective equipment) • Poor hamstring to quadriceps ratio
Potential risk factors for fielders
<ul style="list-style-type: none"> • Muscle strains (quadriceps and hamstring strains) in the lower limbs due to explosive movements in the field • Impact injuries (contact with a ball or player, direct impact with the ground or boundary, unanticipated bounce or poor visual/spatial awareness)

References: Stretch, 1993; Bartlett *et al.*, 1996; Finch *et al.*, 1999; Mansingh *et al.*, 2006; Stretch, 2003; Stretch and Venter, 2005; Milsom *et al.*, 2007; Shaw and Finch, 2008; Finch *et al.*, 2010; Opar *et al.*, 2012; Orchard *et al.*, 2006; Orchard *et al.*, 2010; Orchard *et al.*, 2016; Hullin *et al.*, 2014; Morton *et al.*, 2014; Mukandi *et al.*, 2014; Bayne *et al.*, 2016; Gabbett and Whiteley, 2017.

Impact injuries were also common in batsmen. Lastly, it was shown that fielders and wicket keepers were least likely to become injured, the main injury being through impact of the ball.

Due to the loss in playing time that occurs as a result of these injuries, it is important that trainers address these issues through scientifically based training programs and techniques.

Injuries are however multi-factorial in nature; a point that strength and conditioning coaches need to take into account when training individual players. What is noteworthy is that a lot of the injuries can be mitigated with adequate physical preparedness in the form of conditioning.

INJURY PREVENTION STRATEGIES FOR CRICKET

While there are existing data on the nature and incidence of cricket related injuries, limited literature is available in terms of injury prevention programs and strategies. The injury prevention strategies that are available are not multi factorial in nature and only focus on distinct or separable aspects (for example, only core strength or repeat sprint ability) (Morton *et al.*, 2014; Sanctuary, 2014). A progressive training program needs to be developed that suits each individual player so that certain weaknesses can be corrected (Mukandi *et al.*, 2014). Further, it is also important that conditioning and injury prevention programs take into account the demands of the game through the specificity of replicating actual match play (Christie *et al.*, 2017).

Physical training for cricketers

The importance of intermittent training has been highlighted as a significant training tool for preventing injuries in cricket players (Noakes and Durandt, 2000). This is not only for the development of greater anaerobic capacity, but also owing to the eccentric loading of lower limb musculature (Mukandi *et al.*, 2014; Pote and Christie, 2016). It has been shown that traditional in-season training programs, combined with the demands of match play are not sufficient to maintain player fitness throughout the competition period, and thus players should be exposed to more high intensity, low volume sessions (Mukandi *et al.*, 2014). Furthermore, these sessions need be manipulated throughout the competition period, for each individual, depending on when matches are played (Cronin *et al.*, 2016). This is of particular importance to determine whether a player is being exposed to the optimal workload or is being under or over trained (Cronin *et al.*, 2016).

Repeat sprint ability protocols, such as the 25 meter shuttle, 30:15 interval fitness and intermittent yo-yo test are probably important training tools for all cricketers. Additionally, this type of training may improve the ability of the lower limb musculature to handle the high eccentric loads (Noakes and Durandt, 2000). Cricketers are exposed to repeated eccentric muscle strain as a result of the need for repeated, high intensity effort requiring numerous decelerations and accelerations when playing cricket. This has been show to contribute to

muscle strain injuries, particularly in the quadriceps and hamstrings (Noakes and Durandt, 2000). Thus training for cricketers should also focus on the eccentric loading of the musculature through exercises such as Nordic hamstring lowers and repeat sprint training, which has been shown to reduce the risk of injuries in other intermittent sports (Mjolsnes *et al.*, 2004; Pote and Christie, 2016). These exercises reduce the risk of hamstring strains through increased eccentric torque and the shifting of the torque-joint angle curves of the hamstrings to longer muscle lengths (Opar *et al.*, 2012). This is further confirmed by the fact that a decrease in eccentric peak torque of the knee extensors and flexors has been shown during running between the wickets in cricket, thus possibly increasing the risk of hamstring strains (Christie *et al.*, 2017)

Core muscle strength and flexibility have also been highlighted as important factors to consider for injury prevention in cricket players (Morton *et al.*, 2014; Bayne *et al.*, 2016). This is particularly for fast bowlers who are the most prone to lower back injuries (Orchard *et al.*, 2006). Stabilisation of the core musculature can improve the lateral slide of the fascia in the anterior abdominals (transverse abdominis is more stable) and as a result decrease the risk of injury in fast bowlers (anterior abdominal slide occurs during the concentric contraction of the transverse abdominis muscle bilaterally during a normal cricket delivery) (Morton *et al.*, 2014). Additionally, training core muscle strength is especially important in young cricketers where abnormalities of the spine, especially with a mixed bowling technique, can predispose these players to stress fractures later in their career (Finch *et al.*, 1999; Stretch and Trella, 2012; Mukandi *et al.*, 2014). The rotational emphasis of bowling actions means that programs should focus on core muscle training, which allows strength to spread peripherally to the more distant regions of the body (Mukandi *et al.*, 2014). Furthermore, core training has also been shown to improve trunk mobility, stability, rotational strength and flexibility of cricket players (Cronin *et al.*, 2016). The relationship between the pelvis and the lumbar area of the spine (lumbo-pelvic-hip complex) is important in ensuring players remain injury free. Studies have shown that bowlers who are more laterally flexed during the delivery stride experience greater lumbo-pelvic lateral flexion and as a result are more prone to lower back pain (Bayne *et al.*, 2016; Olivier *et al.*, 2016). Injuries can be reduced by controlling the lumbo-pelvic-hip complex in three ways. Firstly, through the stabilization of the core muscles and joint ligaments to ensure intra-pelvic stability, secondly to improve lumbo-pelvic stability and lastly through strengthening the hip abductors and external rotators to help with pelvic-femoral (hip) stability (Bayne *et al.*, 2016). Therefore, strength and conditioning

coaches may consider addressing trunk position as well as dynamic control of the trunk and pelvis.

Lastly, strength and power training has been shown to be important from an injury prevention perspective, specifically in terms of fast bowling (Mukandi *et al.*, 2014). Research has shown that the implementation of a suitable strength and power program can cause adaptive alterations in nervous system function and alter architecture and structure of muscles (Mukandi *et al.*, 2014). Additionally, strength and power training of the lower and upper limbs can also improve batting and bowling performance through an increase in ball release velocity as well as acceleration and deceleration when running (Mukandi *et al.*, 2014).

Workload monitoring for cricketers

Perhaps one of the most important factors to consider in terms of injury prevention is to manipulate an individual's workload in both training and competition (Mukandi *et al.*, 2014; Orchard *et al.*, 2016). Workload monitoring has been shown to be effective in identifying players at risk for injury through the measurements of both internal and external workloads (Bourdon *et al.*, 2017; Williams *et al.*, 2017). This has been shown to be particularly important in fast bowlers who are most likely to become injured if not monitored properly (Finch *et al.*, 1999). A number of cricketing studies have shown that injuries can be reduced if the number of balls bowled, days of rest and frequency of bowling are monitored and controlled (Finch *et al.*, 1999; Dennis *et al.*, 2005; Mukandi *et al.*, 2014; Saw *et al.*, 2011). Besides bowling, workload monitoring has also been shown to be effective in identifying injury thresholds in certain throwing dominated sports such as cricket, baseball, water polo and hand ball (Black *et al.*, 2016). However, due to factors such as chronological and training age, different injury definitions and time frames used for monitoring, injury thresholds remain unclear in these types of sports (Black *et al.*, 2016). Furthermore, there is a limited amount of literature available that examines the workload of cricket players and the injury thresholds of individuals. Thus it is important to monitor cricket match-play and training by using more than one workload monitoring technique so that coaches may understand the factors that contribute to injury and influence performance (Black *et al.*, 2016).

There is a significant correlation between injury occurrence and exposure to high acute workloads (both internal and external) relative to chronic workloads, regardless of whether the individual is a batsman, bowler or fielder (Saw *et al.*, 2011; Hullin *et al.*, 2014; Mukandi

et al., 2014; McNamara *et al.*, 2017). Thus, by monitoring the acute:chronic workload ratio, it may be possible to identify injury risk (Bourdon *et al.*, 2017; Gabbett and Whiteley, 2017; Williams *et al.*, 2017). This ratio uses rolling averages to compare acute training loads completed in a recent period (approximately 7-10 days) with an individual's chronic training load completed over a longer period of time (approximately 4-6 weeks) (Bourdon *et al.*, 2017; Williams *et al.*, 2017). Studies have shown that when the acute:chronic workload ratio is between 0.8-1.3 (the acute load is approximately equal to the chronic load) the risk of a player becoming injured is relatively low (Bourdon *et al.*, 2017; Gabbett and Whiteley, 2017; Williams *et al.*, 2017). This is because exposure to a load allows the body to tolerate load, and training develops the physical qualities that are associated with reduced injury risk (Bourdon *et al.*, 2017). However, a workload ratio below 0.3 (undertraining) or above 1.5 (overtraining) leaves the individual at a high risk of injury. Thus, when monitoring any athlete it is important to look at the association between both the acute and chronic workload rather than each in isolation. (Bourdon *et al.*, 2017).

There are however, a number of problems associated with manipulating player workload to reduce the risk of injury. The schedule of cricket fixtures may cause problems specifically when multi-day matches are scheduled in close proximity to T/20 matches (for example test matches followed closely by T/20 matches) (Orchard *et al.*, 2016). If players are required to play all matches (which contractually they may be obligated to) then spikes or rapid changes in acute workloads are often unavoidable (Orchard *et al.*, 2016). The fact that substitutions are not allowed in cricket is also a problem (specifically in multi-day matches); if a bowler becomes injured or a team cannot be bowled out, bowlers may be exposed to particularly high workloads, thus putting them at risk of injury. Other problems include, the accuracy of self-reported data for workload monitoring, the neglecting of training loads compared to game loads and the lack of techniques to monitor all the training completed by the players (Black *et al.*, 2016).

Coaching and technical observations to reduce injury risk

Injuries can also be prevented through coaching and technical interventions, particularly important for bowlers with mixed action techniques (Bartlett *et al.*, 1996). Coaches and trainers should prevent fast bowlers, specifically those at an adolescent level, from acquiring this technique through encouraging the front on or side on actions (Bartlett *et al.*, 1996). Furthermore, changing the technique of fast bowlers can also result in more side on shoulder alignment at back foot contact and decreased shoulder counter rotation, thus reducing the risk

of injury (Ranson *et al.*, 2009). However, changing a bowler's technique (to reduce the risk of injury) may take long periods of time and can also impact on bowling performance in terms of accuracy, consistency and ball release speed (Noakes and Durandt, 2000; Mjolsnes *et al.*, 2004). An alternative to changing bowling technique may be to include exercises involving neuromuscular control such as balance and proprioception drills, which may prevent injury in bowlers faced with an action leading to inherently high loads (Olivier *et al.*, 2016).

The prevention of impact injuries is another important factor that needs to be considered, particularly in batsmen and fielders, who are most prone to these types of injury. It has been shown impact injuries can be avoided in batsmen by training them to react (reaction time) to the line and length of a delivery within a short period of time to avoid contact with the ball (Finch *et al.*, 1999). This is however difficult due to the unpredictable bounce of the ball on different surfaces (Finch *et al.*, 1999). Furthermore, studies have shown that the use of protective head gear (helmets) can significantly reduce the frequency of head, neck and facial injuries in cricket batsmen (Finch *et al.*, 1999; Saw *et al.*, 2011), however these offer insufficient protection for high velocity impacts, over 27m/s (McIntosh and Janda, 2003). Other specialised equipment that can be used to protect batsmen against impact injuries includes chest guards as well as thigh and arm guards, which are not used as often as other common equipment such as pads, gloves and helmets (Finch *et al.*, 2010). In terms of fielders and impact injuries, skill development programs can be used to train players. Coaches need to train fielders to focus on becoming more skilled in catching and throwing, as traditional training mainly focuses on batting and bowling (Finch *et al.*, 2010). This can be performed through specific fielding drills that fine tune ball handling skills (Finch *et al.*, 2010).

Therefore, while appropriate coaching is essential for the success of a team, it is important to determine the intrinsic and extrinsic injury risk factors associated with the sport so that appropriate preventative measures can be implemented (Bayne *et al.*, 2016; Olivier *et al.*, 2016). If a player is injured, skill has no influence and so ensuring an injury-free season is seen as imperative.

CONCLUSION

Only five major cricket playing nations have collected injury statistics. There is therefore a need for the minor playing nations to start a database as the needs of different nations are diverse. Furthermore, most of the data only takes into consideration players at a domestic and international level. This is problematic though as injury prevention should be implemented as soon as possible at all levels to ensure the longevity of players from non-professional to professional cricket. A positive however, is that the research examines players of all ages, more importantly adolescents who are most likely to become injured. Lastly, it is important that a standard definition for injury and injury surveillance techniques be developed so that data can be compared across levels and countries. Furthermore, fast bowlers have received the most research attention (as they are the most prone to injury), but as a result there is most likely a lack of understanding in terms of the injury risk for batsmen, fielders and wicket keepers.

Most of the conditioning and injury prevention practices are implemented by coaches who are experienced in the field of cricket. While they may be considered 'experts' in the area, most of their knowledge and experience has been passed down from coach to coach and thus the evidence is anecdotal, with no scientific background. Furthermore, some of the practices executed are out of date and no longer valid. Thus, there is a need to educate coaches in the correct manner so that scientifically based training and programs may be implemented to prevent injuries.

Monitoring of player workload is important. This is so that thresholds can be developed to determine whether a player is under or over loaded. Furthermore, there are other external considerations that also have to be taken into account such as environmental factors, the level of coaching, facilities and medical staff available. The acute:chronic-workload ratio however may be the best tool available at the moment to overcome these issues.

Further research is needed by countries to determine the best cricket injury prevention strategies relative to their individual players.

PRACTICAL APPLICATIONS

The following section seeks to provide workouts that can be implemented by practitioners and trainers to improve strength, reduce the risk of injury and improve the physical fitness attributes of players both at an adolescent and adult level (Avery and Faigenbaum, 2009). Table 8 represents some forms of field based conditioning that can be used by coaches to improve player fitness. Workouts A, B and C (Table 9, 10 and 11) focus on aspects such as resistance training (including super-setting), plyometrics and core work, which are important components to consider for injury risk. It is important to remember however, that this is a blanket program and that it may be necessary for trainers to design and implement individual programs depending on the needs of the player as well as their injury history. Furthermore, they require some specialised equipment so need to be implanted at the correct facilities and through supervised coaches. Thus these programs could be used to improve the base fitness levels of players, who have not previously followed a specific program, particularly in the pre-season period

Table 8: Field based conditioning to improve cricket fitness.

Conditioning work	Exercise	Sets	Reps
Day 1	25m shuttle (RSA)	2-3	30s on 35s off (max)
Day 2	3km time trial	N/A	N/A
Day 3	Rowing	25-30mins	30s on 35s off (max)
Day 4	Cycling	25-30mins	30s on 35s off (max)

Note: adjust sets and repetitions according to training status. max= maximum effort; RSA= repeat sprint ability; Reps= repetitions.

Table 9: Workout A

Workout A	Week 1-2		Week 3-4		Week 4-6	
	Sets	Reps	Sets	Reps	Sets	Reps
Rowing*	1	2000m	1	2000m	1	2000m
Bench press	3	15	3	12	3	10
Incline flies	3	15	3	12	3	10
Tricep push down	3	15	3	12	3	10
Battle rope [#]	3	30s	3	45s	3	1min
Box Jumps [#]	3	30s	3	45s	3	1min
Med ball slams ⁺	3	30s	3	45s	3	1min
Clap push ups ⁺	3	30s	3	45s	3	1min
Core:						
Plank	3	45s	3	1min	3	1min30s
Mountain climbers	3	45s	3	1min	3	1min30s

Table 10: Workout B

Workout B	Week 1-2		Week 3-4		Week 4-6	
Exercise	Sets	Reps	Sets	Reps	Sets	Reps
Cycling*	1	15mins (60% max)	1	15mins	1	15mins
Overhand pull ups/lateral pull downs	3	15	3	12	3	10
Seated row	3	15	3	12	3	10
Dumbbell curls	3	15	3	12	3	10
Split squats [#]	3	30s	3	45s	3	1min
One arm barbell push press [#]	3	30s	3	45s	3	1min
Medicine ball passes ⁺	3	30s	3	45s	3	1min
Underhand pull ups ⁺	3	30s	3	45s	3	1min
Core:						
Side plank	3	45s	3	1min	3	1min30s
Bicycle crunches	3	30s	3	45s	4	45s

Table 11: Workout C

Workout C	Week 1-2		Week 3-4		Week 4-6	
Exercise	Sets	Reps	Sets	Reps	Sets	Reps
Steps*	3	1min	3	1min	3	1min
Squats	3	15	3	12	3	10
Leg press	3	15	3	12	3	10
Face pulls	3	15	3	12	3	10
Hamstring curls	3	15	3	12	3	10
Skipping [#]	3	30s	3	45s	3	1min
Dumbbell push press [#]	3	30s	3	45s	3	1min
Dumbbell step ups ⁺	3	30s	3	45s	3	1min
Dips ⁺	3	30s	3	45s	3	1min
Core:						
Russian twists	3	45s	3	1min	3	1min30s
Mountain climbers	3	45s	3	1min	3	1min30s

Where: *= warm-up; [#]= super set 1; ⁺= super set 2. Break between supersets= 30s; Break between strength work= 2mins; break between sets= 2mins. Reps= repetitions.

Linking notes between Chapters 2, 3 and 4

The findings of Chapter 2 and 3 suggest that not much is known about the nature and incidence of injuries in the adolescent population (more research has been done on elite players). It was however identified that the most common injuries were to the lower back (fast bowlers), lower limb musculature (batsmen) and impact injuries (fielders and wicket keepers). Furthermore, there are no strength and conditioning programs that have been developed or implemented to improve physical fitness and reduce the risk of injury. This is specifically worrying from a South African perspective, where players not only lack access to coaches, equipment and facilities, but are also deprived of general physical activity for health and fitness. Based on these chapters, the purpose of Chapter 4 was therefore to conduct a survey that looked to examine the current strength and conditioning practices that are being implemented at South African schools and universities.

CHAPTER 4

STRENGTH AND CONDITIONING PRACTICES OF UNIVERSITY AND HIGH SCHOOL LEVEL CRICKET COACHES: A SOUTH AFRICAN CONTEXT

Paper 2: Pote, L and Christie, CJ (2016). Strength and conditioning practices of university and high school level cricket coaches: a South African context. *Journal of Strength and Conditioning Research*, 30: 3464-3470.

INTRODUCTION

Cricket is one of the world's major team sports and yet it has received very little research attention particularly with regards to the physical demands of the game (Duffield and Drinkwater, 2008; Mansingh *et al.*, 2006; Orchard *et al.*, 2010). This is surprising considering that performance can be improved by gaining a deeper understanding of these requirements (Noakes and Durandt, 2000; Rudkin and O'Donoghue, 2008). The rapid transformation to the game including the introduction of Twenty/20 cricket has added to player workload, resulting in an increased risk of injury (Milsom *et al.*, 2007; Noakes and Durandt, 2000; Rudkin and O'Donoghue, 2008). According to Stretch (2014), 19-24 year old cricket players are at a greater risk of injury compared to their more adult counterparts (Stretch, 2014). Furthermore, the seasonal incidence of injury of South African schoolboy and club cricketers is between 34.2 and 49%, which is relatively high considering that 28% of players cannot return to play for at least 21 days after injury (Stretch, 1993; Stretch, 1995; Stretch and Trella, 2012). Thus there is a need to implement an educational process of injury prevention and management, specifically for schoolboy and young club cricketers whose injury patterns differ compared to adults (Milsom *et al.*, 2007; Stretch and Trella, 2012; Stretch, 2014). An effective strategy is properly designed strength and conditioning programs which may not only reduce the risk of soft tissue injuries, but further benefit player performance (Finamore, 1992). This has also been shown in previous studies that have focused on football players (Steffen *et al.*, 2008). However, it needs to be acknowledged that certain injuries, such as impact injuries cannot be negated through strength and conditioning practices (Woolmer *et al.*, 2008).

The conditioning practices of schoolboy and university cricket players in South Africa are not known (Opar *et al.*, 2012). The training practices of sports such as American football, basketball and ice hockey have been studied but these sports do not mimic the movement patterns and physiological demands of cricket match play (Duehring *et al.*, 2009; Ebben *et al.*, 2004; Petersen *et al.*, 2010; Simenz *et al.*, 2005). As the demands of cricket are different to these sports, training principles and practices should differ. Therefore, a first line of approach would be to assess current strength and conditioning practices within the sport of cricket. As cricket coaching typically starts at school and extends into university, it is important to understand the practices of coaches at this level. As players reach elite level, many strength and conditioning practices have already been imparted. Therefore, research

targeting a non-elite and junior cricket athlete population may have greater impact on the physical development of cricket players.

Furthermore, current strength and conditioning practices are not based on scientific research, but rather on anecdotal evidence through coaches and players experiences (Pyke and Davis, 2010; Woolmer *et al.*, 2008). There is thus a need to link the physical demands of the game to practices of strength and conditioning. This is to allow players to cope with the physical demands of cricket and as a result reduce the risk of injury and optimise performance. Therefore, the purpose of this study was to examine the strength and conditioning practices of schoolboy and University level cricket coaches in South Africa, which will differ according to age group.

METHODS

Experimental approach to the problem

This study was an online, survey based examination of the strength and conditioning practices of university and high school level cricket coaches in South Africa. As a result, coaches at both levels would describe their practices and ideas in order to understand their basic knowledge of scientifically based principles of strength and conditioning. Furthermore, the survey was designed in such a way as to avoid any biased interpretation of the questions by the responding coaches. In other words, coaches were encouraged to explain what conditioning practices they implemented through open-ended questions, instead of being given a number of choices, which may have influenced their responses (Simenz *et al.*, 2005).

Participants

The participants recruited were the head strength and conditioning specialists or coaches (in the case of no strength and conditioning specialist), at 12 university and 38 high school teams (n=50). The university teams selected were based on their participation in the Varsity Cup Cricket and University Sport of South Africa (USSA) competitions, which includes the top university players in the country. The high school teams chosen were the top 38 in the country at the time (rankings as of 9th March 2015). Ethical clearance was granted by the Department of Human Kinetics and Ergonomics Ethical Standards Committee for research involving human participants (Rhodes University, Grahamstown, South Africa), and all participants were informed of the benefits and risks of the investigation.

Survey

The survey used was based, on and adapted from, previous questionnaires done on strength and conditioning practices and was made up of both qualitative and quantitative questions (Duehring *et al.*, 2009; Durell *et al.*, 2003; Ebben *et al.*, 2004; Simenz *et al.*, 2005; Wade *et al.*, 2014). In addition to these, cricket specific practices and injury statistic questions were added. The survey itself consisted of three main sections, made up of both qualitative and quantitative questions:

1. General questions which included background information on the coaches as well as their degrees, diplomas and qualifications. This section also focused on general conditioning practices such as physical testing, flexibility, speed and agility development as well as plyometric and resistance training.
2. Cricket specific questions focusing on conditioning practices and player workload monitoring for batsmen, bowlers, fielders and wicket keepers.
3. Injury and injury prevention questions, including injury monitoring, prevention exercises and common injury sites for batsmen, bowlers, fielders and wicket keepers.

The general questions were validated by previous studies (Duehring *et al.*, 2009; Durell *et al.*, 2003; Ebben *et al.*, 2004; Simenz *et al.*, 2005; Wade *et al.*, 2014). The cricket specific and injury prevention questions were validated through pilot testing. This was done by sending the survey to three coaches and six sports science experts/academics to determine if the questions were reliable and valid. Once feedback was received, certain questions were modified. This included changing the order of the questions so that the logical order of the survey would be improved, changing some qualitative questions to quantitative queries and re-wording questions to make them more comprehensible. After this the survey was re-assessed by sports scientists and only once this was completed was the survey sent to coaches.

Procedures

A letter describing the study was sent via email to the strength and conditioning specialists and coaches at the respective schools and universities. This was a letter of information that included a description of the broader study, an explanation of what the survey would entail and an electronic link that the coaches needed to access in order to complete the survey. It was emphasised that by accessing the link, consent was provided. Coaches were informed that they could exit the survey at any time without any implication. It was also stated that

feedback would be provided if requested, but no names of coaches or institutions would be included in the feedback response.

The coaches were given 30 days from the time of receiving the email to complete the survey. If no responses were received after one week, a reminder was sent. After 30 days, the questionnaires that were completed were collated for statistical analyses.

Statistical analyses

The survey was made up of both fixed response (quantitative) questions and open-ended (qualitative) questions. The quantitative questions were analysed using the data analysis tool supplied by the 'kwik surveys' website. Results were collated in real time and analyses (including individual analyses) were performed as each response was completed. Furthermore, data were limited to certain segments through filtering and cross analyses were performed to simplify the data for each question. The proportions of the responding coaches were also calculated for each question. For the qualitative questions, data were collated and analyzed for specific major or minor themes. This was performed by analyzing data according to methods that were used in previous strength and conditioning surveys, as well as through experienced scientific researchers (Ebben *et al.*, 2004). These themes were then used to determine the results of the survey.

RESULTS

Background information

Twenty four out of fifty coaches replied to the survey. This response rate of 48% was deemed acceptable as it was higher than previous survey based research on conditioning practices. However, it needs to be noted that not all coaches answered every question, which was a limitation of the study. Furthermore, absolute values as well as rounded percentages were used to present the results, as a single response may have influenced percentage values to a large extent. Lastly data were pooled for each sub-group as responses of the two groups were similar. The basic demographic data of the respondents are shown in Table 12.

Table 12: Basic demographic data of the participants.

	n (%)
Gender (n=18)	
Male	17 (94)
Female	1 (6)
Experience (n=18)	
>15 years	3 (17)
5-15 years	6 (33)
<5 years	9 (50)
Education (n=18)	
Postgraduate degree	5 (28)
Undergraduate degree	5 (28)
Other*	8 (44)
Institution (n=18)	
University	6 (33)
High school	12 (67)

***Note:** Other refers to additional qualifications, such as diplomas or certificates

Physical testing

Fourteen out of eighteen respondents (78%) indicated that their players did some form of physical testing (Figure 2). Of these, all signified that these tests were applied in the pre-season with ten (72%) and eight respondents (64%) indicating a re-test during the in-season and off-season respectively.

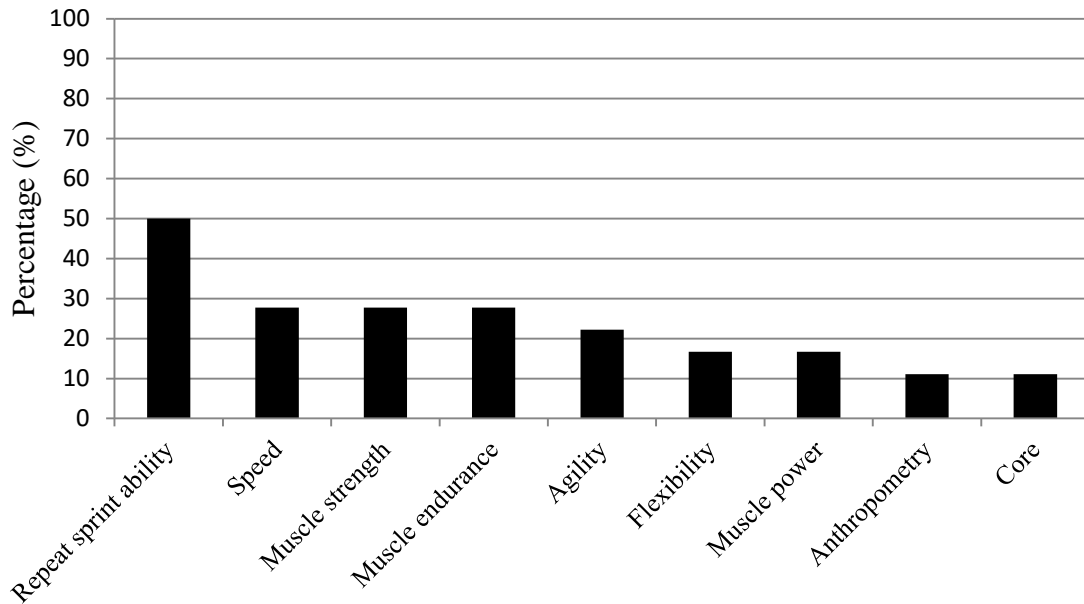


Figure 2: Percentage of the physical testing exercises implemented by coaches (n=14).

Training practices and equipment

Figure 3 and figure represent the different training practices that coaches focused on and how many sessions were implemented per week. It is important to note that flexibility training included static and dynamic stretches, implemented both before and after a match/practice session. Furthermore, resistance training was mainly applied in the pre-season.

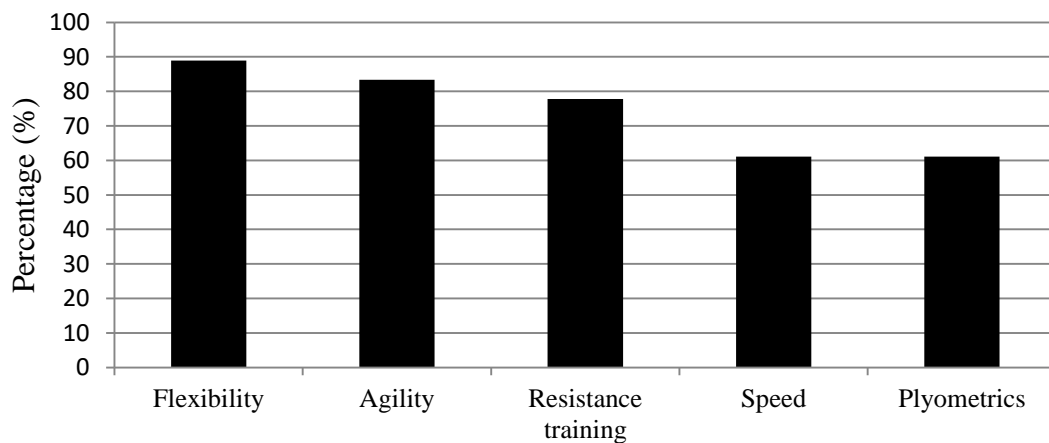


Figure 3: Percentage of the different training practices implemented by coaches (n=18).

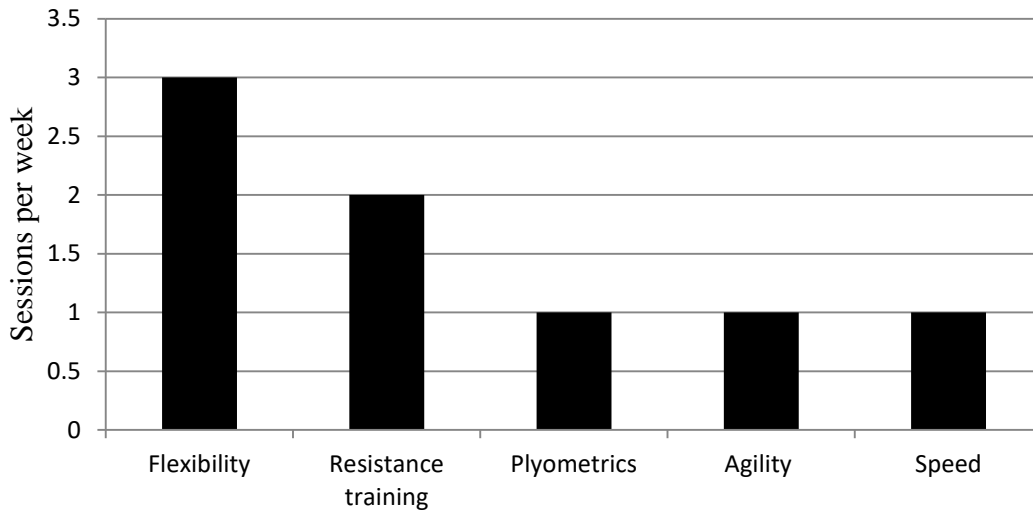


Figure 4: Number of sessions completed each week for the different training practices.

The most common types of equipment used by coaches to improve the different training practices are shown in Table 13. Other equipment that coaches used included: parachutes, sleds, cones, boxes and medicine balls.

Table 13: Most common equipment used for each type of training as a percentage of the respondents (n=14,6,14,7,12 for flexibility, speed, agility, plyometrics and resistance training respectively).

Type of training	Equipment
Flexibility	Resistance bands (71%)
Speed	Hurdles (50%)
Agility	Ladders (57%)
Plyometrics	Hurdles (57%)
Resistance training	Weights (50%)

Cricket specific conditioning

Overall, thirteen out of seventeen respondents (76%) indicated that different conditioning practices were implemented for batsmen, bowlers, fielders and wicket keepers (Table 14).

Table 14: The different conditioning practices implemented for the specialist positions.

	n (%)
Batsmen (n=20)	
Core	4 (36)
General fitness*	4 (36)
Sprints	3 (27)
Strength*	3 (27)
Match specific exercises*	2 (18)
Balance	1 (9)
Explosive power	1 (9)
Agility	1 (9)
Visual training	1 (9)
Bowlers (n=21)	
Strength*	5 (24)
General fitness*	4 (19)
Core	4 (19)
Match specific exercises*	2 (10)
Agility	2 (9)
Flexibility	1 (5)
Visual training	1 (5)
Explosive power	1 (5)
Running technique	1 (5)
Wicket keepers (n=21)	
Strength*	6 (29)
Agility	5 (24)
Visual training	3 (14)
General fitness*	2 (10)
Flexibility	2 (10)
Core	2 (10)
Match specific exercises*	1 (5)
Fielders (n=21)	
General fitness*	5 (24)
Strength*	4 (19)
Agility	4 (19)
Match specific exercises*	2 (10)
Core	2 (10)
Sprints	2 (10)
Flexibility	1 (5)
Reaction training	1 (5)
Visual training	1 (5)

***Note:** Strength training takes into account body weight exercises. General fitness includes rowing, cycling and long distance running. Match specific exercises refers to simulating game play such as running between the wickets, catching and hitting specific target areas.

Workload monitoring

Eleven out of sixteen (69%) coaches indicated that player workload was monitored. The number of deliveries bowled was the primary method used to monitor bowler workload (78%) and the amount of time spent at the crease was the main technique used to monitor batter workload (44%). This occurred during practices and matches. It was also indicated by 44% of these coaches that they did not think it was necessary to monitor batting workload. Furthermore, 56% of these coaches responded that there was no reason to monitor wicketkeeper and fielder workload as these positions were monitored through batting and bowling.

Injury monitoring and prevention

Twelve out of fifteen (80%) responding coaches indicated that they kept a record of injured players. Of those, all indicated bowlers were the most likely to sustain an injury. The most common types of injuries for each position are represented in Table 15. It should however be noted that these were the perceptions of the coaches as no actual injury surveillance was conducted in this study.

Table 15: Most common injury types for each specialist position.

	Batsmen n=11 (%)	Bowlers n=12 (%)	Fielders n=10 (%)	Wicket keepers n=8 (%)
Shoulder	0 (0)	1 (8)	3 (30)	0 (0)
Hamstrings	4 (36)	2 (17)	0 (0)	2 (25)
Quadriceps	0 (0)	0 (0)	0 (0)	0 (0)
Lower back	3 (27)	8 (67)	1 (10)	2 (25)
Knee	1 (9)	1 (8)	0 (0)	0 (0)
Ankle	0 (0)	0 (0)	2 (20)	0 (0)
Impact injury	3 (27)	0 (0)	4 (40)	4 (50)

In terms of injury prevention twelve out of fifteen (80%) coaches stated that they implemented injury prevention exercises. These were mainly implemented in the pre-season and in-season. The most common practices used to prevent injuries were stretching exercises

and strengthening high risk injury areas. Only one out of fifteen (7%) respondents indicated using some form of eccentric training to reduce the risk of injury.

DISCUSSION

The most important finding of this study was that the majority of the coaches implemented some form of cricket specific conditioning, workload monitoring and injury prevention; this is important in terms of performance and injury risk. However it would seem as if not appropriate conditioning practices are being focused on.

Looking specifically at batsmen and bowlers, respondents indicated that core work, general fitness (for batsmen) and strength training (for bowlers) were the focus of most training programs, although areas of strength training were not specified (Table 11). This is interesting considering the fact that the most common injuries are hamstring and lower back injuries for batsmen and bowlers respectively. This would suggest that training for batsmen should focus mainly on the eccentric loading of the lower limb musculature through exercises such as Nordic hamstring lowers and repeat sprint training, which has been shown to work in other sports such as rugby, soccer and football (Arnason *et al.*, 2007; Brooks *et al.*, 2006; Gabbe *et al.*, 2006). These exercises reduce the risk of hamstring strains through increased eccentric torque and the shifting of the torque-joint angle curves of the hamstrings to longer muscle lengths (Opar *et al.*, 2012). This is further validated by the fact that a decrease in eccentric peak torque of the knee extensors and flexors has been shown during running between the wickets in cricket, thus potentially increasing the risk of hamstring strains (Christie *et al.*, 2017). However, only three out of seventeen (18%) respondents indicated that eccentric training and repeat sprint exercise is used for injury prevention and conditioning in batsmen. In terms of bowlers, the majority of respondents indicated a focus on strength training, with only a few focusing on core and flexibility training. This is unusual as these types of training are important in reducing lower back injuries, such as stress fractures, which are the most common in fast bowlers (Stretch and Orchard, 2003). According to Woolmer *et al.*, (2008), a specific routine needs to be developed that includes a full range of movements that strengthen the core, specifically for those players recovering from lower back injuries (Woolmer *et al.*, 2008). Furthermore, a stretching program to improve flexibility is crucial not only for lower back injuries, but also for hamstring strains (Woolmer *et al.*, 2008). This is of particular importance in adolescents, who are at the

greatest risk of injury (Stretch and Trella, 2012). These injuries are often underpinned by multiple factors and as a result interventions are needed to protect the young athlete. Furthermore, although impact injuries were the most common for fielders and wicket keepers (Table 12), the type of training that these positions are exposed to do not mimic actual match play (Table 11). For example, both specialities need to be as agile and fast as possible, with good reactions and visual awareness, but these factors are not being trained sufficiently, as shown in Table 11. Thus, although coaches and specialists that responded to the survey were aware of the main injury types and causes, the concept of specificity is missing and no replication of actual match play is being implemented. This may lead to a low work intensity that will not show significant training effects, which in turn may lead to injury and a decrease in performance (Pyke and Davis, 2010).

There may be a number of reasons why the appropriate conditioning practices are not being implemented. These include, but are not limited to, lack of experience, incorrect qualifications and insufficient educational training. Only ten of the eighteen (56%) respondents indicated that an undergraduate or postgraduate degree had been obtained. Of these, only 22% had a degree relating to sports, exercise or human movement sciences, the remainder being made up of degrees in management or economics. Furthermore, of the 44 % of coaches that indicated other forms of education (diplomas, certificates or coaching courses), only 25 % were related with sports or conditioning practices. Thus it would seem, in this case, that there is a lack of sufficient educational training in terms of conditioning techniques. In other words, coaches and even ‘conditioning specialists’ do not use scientifically based training programs or interventions, but rather knowledge that is passed down from coach to coach. Thus the evidence for the coaching strategies used is not based on research, but rather a coach’s perception of what is correct or not. Coaches and specialists however were not provided with a definition of ‘injury’, which is a limitation to the study.

Another finding was that eleven out of sixteen respondents (69%) monitor player workload, specifically through time spent at the crease for batsmen and number of deliveries bowled for bowlers. This is important, particularly for bowlers where research has shown that there is a certain threshold above which the risk of injury increases exponentially (Dennis *et al.*, 2003). Furthermore, high workloads may lead to overuse injuries which are exceedingly prevalent in the developing musculoskeletal systems of adolescents (Dennis *et al.*, 2005). Thus coaches and specialists need to combine workload monitoring with the correct conditioning practices if an overall decrease in injuries is to be seen. However, the available literature on player

monitoring is contradictory (in terms of frequency and deliveries per session/match) and further research into this area is required (Dennis *et al.*, 2003; Dennis *et al.*, 2005). Additionally, although it was indicated that batsmen workload was monitored, no scientific research has been conducted on the optimal workload required to reduce the risk of injury in adolescent cricketers. In terms of fielders, respondents indicated that workload monitoring was not required; though research has shown that a high frequency of throwing may lead to injury (Rudkin and O'Donoghue, 2008). It has however been shown that questionnaire based well-being measures can be used to monitor overall workload and fatigue in cricket and reduce the risk of injury (McNamara *et al.*, 2013).

Lastly, fourteen out of eighteen (78%) coaches indicated that their players were subjected to some form of physical testing at least twice a season, which is important to observe in order to identify any training adaptations that may have occurred. However, although it was shown that repeat sprint ability was the most tested variable, there was no indication of this type of training being implemented. Thus it would seem that coaches are monitoring physical fitness out of necessity and are not committed to improving specific weaknesses that may be exposed through testing practices. This is most likely again due to lack of experience and educational knowledge.

PRACTICAL APPLICATIONS

Firstly, and most importantly, the findings of this study can be used as an educational tool to inform coaches of the correct conditioning practices that need to be implemented. This is imperative as most schoolboy and university South African coaches at present are implementing training programs based on anecdotal evidence instead of scientific findings. Secondly, it provides coaches and specialists with a source of data that describes the strength and conditioning practices that are currently being implemented in schoolboys and University cricket players. These data can be used to design and administer scientifically based training programs to decrease the risk of injury and improve performance, specifically in the adolescent population. Furthermore, these findings may be used by future researchers as a mode of comparison to improve and diversify current practices. Lastly, the fact that most coaches did not have specialised certifications in strength and conditioning indicates the need for a more improved educational process.

Linking notes between Chapters 4 and 5

The study undertaken in Chapter 4 identified that most coaches and trainers in South Africa lack the qualifications to implement the correct strength and conditioning/injury prevention programs at an adolescent level. Thus, the findings of both Chapter 3 and 4 were used (in Chapter 5) to design a low-cost, no-cost, scientifically based intervention program that can be used by trainers with minimal qualifications and limited equipment/facilities to improve the physical fitness attributes of their players. Furthermore, based on the movement demands of the game a test battery was also developed that was used to assess whether or not the intervention was successful or not.

CHAPTER 5

A NOVEL INTERVENTION PROGRAM (CRICFIT) FOR THE STRENGTH AND CONDITIONING OF ADOLESCENT CRICKET PLAYERS

Paper 3: Pote, L and Christie, CJ (2018). A novel intervention program (“CricFit”) for the strength and conditioning of adolescent cricket players. *Human Movement*, 19: 13-20.

INTRODUCTION

The game of cricket is played in over 100 countries worldwide and is constantly growing in popularity (Mukandi *et al.*, 2014). The first form of the game, the five-day test match, has evolved into the one day game and more recently into the 20 over format (Mukandi *et al.*, 2014; Pote and Christie, 2016a) and the game is a lot more physically demanding than it used to be (Noakes and Durandt, 2000). Furthermore, with the introduction of different match formats, players are subjected to longer seasons and increased workloads. This means that players need to remain physically fit for extended time periods, specifically to reduce injury risk (Milsom *et al.*, 2007; Pote and Christie, 2016b; Stretch and Trella, 2016).

The increase in injury risk is of particular concern at younger levels as research has shown that adolescent cricket injury risk is higher than in adult cricketers (Stretch, 2014). Seasonal incidence of injury of schoolboy and club cricketers in South Africa, between the age of 19 and 24 years old, is between 34.2 and 49%, with the main injuries occurring in the lower back and hamstrings for bowlers and batsmen respectively (Dennis *et al.*, 2003; Stretch, 1995; Stretch, 2014). This is of particular concern, especially since the return-to-play time for most injuries is approximately 21 days in this age group (Stretch, 1995; Stretch, 2014).

While there are a number of conditioning programs that have been developed, most are used by specialists in high-performance settings (Cronin *et al.*, 2016; Mukandi *et al.*, 2014). There is therefore a disparity between programs implemented at an elite versus an amateur level. To date, only one research paper has looked at the strength and conditioning practices of amateur level cricket coaches and strength and conditioning specialists (Pote and Christie, 2016b). The research found that there is a distinct lack of strength and conditioning programs for adolescent cricket players. Furthermore, workloads are not normally monitored and seasons of different sporting codes overlap, thus resulting in school children playing multiple sports at a time. This is problematic in terms of the time period that pupils are exposed to for their pre-season training block, the maximum duration which is typically four weeks. Furthermore, it is not known whether players at a school or club level are being under, over or optimally trained. Most coaches indicated a lack of knowledge and time as factors affecting their ability to prevent injury and ensure that players are adequately conditioned. A low-cost or no-cost intervention program that is easily implementable at all schools and clubs, regardless of resources, funding and qualifications would therefore be ideal (Pote and Christie, 2016b) and would go a long way to improve physical fitness (Faigenbaum *et al.*, 2016). Furthermore, physical attributes that players develop through training and competition help with their

success as a cricketer (Sanctuary, 2014). To the authors' knowledge, no targeted and easily implementable strength and conditioning programme has been established that can be administered by coaches with little to no strength and conditioning experience. It is thus important to expand the understanding of strength and conditioning practices at an adolescent level, not only to improve physical fitness, but also to reduce the risk of injury.

Therefore the purpose of this study was to examine the effects of a four-week, pre-season, field-based intervention (CricFit intervention) on general fitness measures, designed to reflect the demands of the game, in an adolescent population. This was in addition to their traditional net and field-based training. It was hypothesized that the intervention would significantly improve physical fitness parameters and would be an ideal adjunct to traditional net practices.

MATERIALS AND METHODS

Participants

Twenty-eight schoolboy cricket players (characteristics shown in Table 17) were recruited for the study. The required sample size was calculated using equations from Whitley and Ball (2002). The power of 0.8 with a medium to large effect size was calculated. The result was that the required sample was different for different dependent variables. These ranged from a sample of four for core strength to a sample of 1580 for sum of skinfolds. Based on sample size calculations the 25m shuttle (8), agility (6), plank (4) and medicine ball throw (7) responses showed that the sample size was sufficient. Flexibility (63), standing broad jump (437), 20m sprint (176) and push-up (31) responses showed that the sample size needed to be increased. This was taken into consideration in addition to the constraints of human-centred exercise intervention research which typically has low samples. Plus the constraints in terms of personnel, budget and access to school level players not involved in other sports means that the study was delimited to a sample of 28. Greater emphasis for all measures was placed on the clinical relevance as is the modern trend in exercise intervention and sports science research. Players were recruited from the Kingswood College Senior School in Grahamstown, Eastern Cape, South Africa, and all participants played for the top school team in their specific age groups. Ethical clearance was granted by the Department of Human Kinetics and Ergonomics Ethical Standards Committee for research involving human participants (Rhodes University, Grahamstown, South Africa), and all players were informed

of the benefits and risks of the investigation and signed informed consent. Prior to performing any testing or intervention sessions, players completed a physical activity screening questionnaire (Appendix A) to ensure that they were healthy and free of injury. Individuals were then either assigned to a control (n=14) or an experimental group (n=14). In order to ensure that changes were not as a result of between day reliability changes, players were matched according to baseline test and fitness levels. There were no significant differences between the groups besides for age and percent body fat (the control group were younger and had less percent body fat) and all played for their respective first teams. Thus the results must be seen within the context of this limitation. Participants had also just returned from a one month holiday where no exercise was prescribed or completed (this was prior to the intervention; the completion of the first test battery) and thus were of a similar level of fitness (participants were told to refrain from training in the holidays). Furthermore, all players were boarding scholars at the same school and thus were exposed to the same conditions and nutrition.

Study design

The current investigation study was a pre-, post-test design which included an experimental and control group. The experimental group participated in a strength and conditioning intervention while the control group did not. The intervention took place over a four-week pre-season period, prior to the first fixture being played and was designed based on previous literature of strength and conditioning practices for intermittent sports as well as the movement demands of cricket (Bloomfield *et al.*, 2007; Finch *et al.*, 1999; Mjolsnes *et al.*, 2004; Olivier *et al.*, 2013; Pote and Christie, 2016b; Woolmer *et al.*, 2008). Players in the experimental group were required to complete two sessions per week, with each session lasting between 35-45 minutes depending on the stage of the intervention (Table 16). The control group only participated in traditional net and field-based training. The fact that specialised equipment is not always available at a schoolboy level (for example, gym equipment), means that the intervention was designed to incorporate the minimal amount of apparatus necessary and focus more on body weight exercises. Thus, only a medicine ball, thera-bands and agility ladders were needed for training. Adherence to the program was controlled through a roll call at each session and participants were excluded if more than two sessions were missed.

The focus of the “CricFit” intervention was to improve general physical fitness for cricket players (Table 16).

Table 16: Week one, two, three and four of the "CricFit" intervention program.

Week 1			Week 2		
Session 1			Session 1		
	Sets	Reps		Sets	Reps
Sprints (20 m)	2	6	Sprints (20 m)	2	6
Plank	2	45s	Plank	3	45s
Ladder drills*	1	3	Ladder drills*	1	3
Skipping	2	1min	Skipping	3	1min
Lizzard crawls	2	10	Lizzard crawls	3	10
Nordic lowers	2	5	Nordic lowers	2	6
Session 2			Session 2		
25 m shuttle	2	2#	25 m shuttle	3	2#
Side plank	2	45s	Side plank	2	45s
W-sprint agility drill	2	1min	W-sprint agility drill	3	1min
Overhead med ball slams	2	45s	Overhead med ball slams	3	45s
Burpees	2	45s	Burpees	3	45s
			Nordic lowers	2	6
Week 3			Week 4		
Session 1			Session 1		
	Sets	Reps		Sets	Reps
Sprints	2	8	Sprints	2	8
Plank	2	1min	Plank	3	1 min
Ladder drills*	2	3	Ladder drills*	2	3
Squat jumps	2	45s	Squat jumps	3	45s
Lizzard crawls	3	12	Lizzard crawls (therabands)	3	12
Nordic lowers	3	6	Nordic lowers	3	8
Session 2			Session 2		
25 m shuttle	3	2#	25 m shuttle	4	2#
Side plank	3	45s	Side plank	3	1min
W-sprint agility drill	3	1min	W-sprint agility drill	3	1min
Overhead med ball slams	2	1min	Overhead med ball slams	3	1min
Burpees	2	1min	Burpees	3	1min
Nordic lowers	3	6	Nordic lowers	3	8

*Each set consists of single runs, in-and-outs, double runs and shuffles. # 1 repetition= 1x25 m shuttle run (maximum effort). **Notes:** Quality of movement is important for ladder drills and intensity and running form is essential when sprinting. Breaks between sets= 30 s; breaks between exercises= 1min. Ladder= 4 m long.

The intervention consisted of a number of exercises that centred on the movement demands associated with the sport of cricket as well injury prevention exercises (specifically Nordic lowers and core work). Thus the program focused on aspects such as agility, strength, power, endurance, speed, flexibility, repeat sprint ability and injury prevention exercises. These prevention exercises targeted specifically the lower back and hamstring musculature that are the most commonly injured areas in bowlers and batsmen respectively (Milsom *et al.*, 2007). Exercises throughout the intervention were varied to avoid repetition and monotony. Lastly, the intervention also incorporated a dynamic warm-up and a static cool down (approximately five minutes each). Both the warm-up and cool down focused specifically on the lower limb and back musculature.

Procedures

The control and experimental group were required to perform a battery of physical tests prior to, and after, completing a four-week, cricket-specific, intervention program (the control group did not perform the intervention program). One habituation and two testing sessions were required for the study. All sessions were carried out at the High Performance Centre at Kingswood College, Grahamstown, South Africa and all testing took place at the end of the winter break, in order to ensure similar baseline measures of fitness.

During the habituation session the intervention was explained to the players both verbally and in writing. The objectives of the research project were also explained, which included information regarding the test protocol and intervention procedures. After this, basic anthropometric and demographic data were collected for each player, which included age, stature, mass and sum of seven skinfolds (chest, triceps, subscapular, axilla, abdominal, suprailliac and thigh). Players were also instructed not to consume alcohol 24 hours prior to testing; to not perform any strenuous exercise before testing and to consume a light meal at least an hour before. Lastly, players from both groups were asked to refrain from any additional exercise during the intervention period (this was monitored by the researcher). Thus, players from both groups performed one net and one middle session (a session that mimics a match scenario) per week, but those in the experimental group performed an additional two conditioning sessions on alternate days. The duration of the net and middle sessions were approximately two hours each.

Testing session one required the players to complete the test battery prior to performing the intervention. The tests were performed in the following order:

Sit and reach flexibility

This occurred before the player was warmed up. Players were required to only stretch until the muscle was tight and not until any pain was felt. A sit and reach box was provided and the 'zero' point on the box was set to 260 mm. When performing the test the player sat on the floor with their knees extended, ankles flexed and bare feet against the edge of the box. The player then flexed at the hip and reached towards their toes with both hands, making sure that the knees were not flexed at any point during the test.

Lower limb power

The player stood with their feet comfortably apart, behind a demarcated line. The player was allowed to bend (flex) the knees and swing the arms prior to the jump, however a run-up or a shuffle step prior to the jump was not allowed. The player was allowed a maximum of two efforts. The maximum distance (cm) from the take-off line to the back of the heel closest to the take-off line was recorded.

Upper body power

The test involved throwing a 3 kg Medicine Ball forward over the head for maximum distance. The player stood with feet shoulder width apart and behind the start line and faced the direction in which they intended to throw. The ball was then drawn backwards over the head (elbow bend was permitted) and the trunk was permitted to extend back as the arms were taken behind the head. In one motion the ball was then thrown forward for maximum distance. Several practices were required to get the best trajectory for maximum distance. The player's feet were allowed to lift off the floor during the throw, however, they were not allowed to step or fall forward over the line after the ball was released. Three trials were allowed.

Agility

The players' speed and agility was assessed using the Illinois agility test. Each player started off in the prone position (lying down) with their chin touching the start line. When the whistle was blown the player completed the course in their quickest time possible. Times were recorded using a stopwatch. Players completed two tests each, separated by a recovery period.

Speed

The players' speed was assessed using a 20 m sprint. The test determined the players' maximum sprint speed as well as their ability to accelerate from a stationary position. Each player was required to produce an all-out effort, therefore a thorough warm-up consisting of sub-maximal running and stretching was performed prior to testing. A stopwatch was used to time each player and two maximal efforts were completed separated by a 1- minute recovery period.

Muscle endurance

For muscle endurance, players performed the maximum amount of push-ups possible in one minute. Each player started with their thumbs 0-5 cm wider than their shoulder width and the repetition was only counted if their back and body were straight, they touched the testers fist when descending and finished with their arms fully extended (straight).

Core strength

This assessment determined the maximum amount of time that an elevated plank position could be held by a player. The upper body of the player was supported off the ground by the elbows, forearms and toes with the legs and torso held straight. The stopwatch was started once the player was in this position and the test ended once the player was unable to maintain this posture.

Repeat Sprint Ability

Repeat sprint ability was assessed using the 25 m shuttle test. Six cones were set at 5m intervals. At the start of the test, each player was required to sprint to cone 1, touch the base of the cone with their hand and then sprint back to the starting position, where they touched the base of the cone with their hand and sprinted to cone 2. This process was repeated until all the cones were touched. After 30 s a whistle was blown and the distance that the player covered was measured. The player was then given a 35 s break after which the process was repeated again. This occurred six times and each time the 30 s was completed, the distance was recorded.

Prior to performing the test battery, players performed a dynamic warm-up and after testing, a static stretching cool down was completed. This testing session also took place at least three days prior to the start of the intervention to ensure players were fully recovered.

Testing session two occurred after the intervention was completed. Players performed the same test battery as in session two to determine whether there were any improvements. Tests were performed in the same order as well as the same time of the day.

Statistical Analyses

Statistics software (StatSoft, Inc. [2011] STATISTICA[®]. Version 13.0) was used to perform all statistical analyses. Participant numbers were calculated using equations from Whitley and Ball (2002) to meet a β power of 0.8 at an α value of $p < 0.05$ and a power analysis was also performed. The power analyses and sample size calculations were performed to determine whether non-significant results were due to lack of relationship between the groups or due to lack of statistical power. Descriptive statistics were calculated for all dependent variables (mean \pm SD). A T-test for dependent samples was used to calculate any significance within each group pre and post. A T-test for independent samples (using the change in absolute values) was used to calculate significance comparing the control and experimental groups. A mixed model ANOVA (general linear model) was used to analyse the interaction effect between the protocol and time, as well as to adjust the data through post-hoc analysis. A probability level of $p < 0.05$ was used to denote statistical significance for all tests. Furthermore, due to the small sample size of the study the Cohen's d was used as an effect size statistic to help determine the meaningfulness of the effects identified together with the p value. The criteria for interpreting effect sizes were: < 0.2 trivial, $0.2-0.5$ small, $0.5-0.8$ medium, > 0.8 large (Hopkins, 2004). The fact that studies have shown that effect sizes are calculated independent of sample size (Khan *et al.*, 2016) and that reporting significance through only the p value for analysis is not appropriate to fully understand the results (Sullivan and Feinn, 2012), meant that for the current investigation, effect sizes together with significance were used for the interpretation of the data.

RESULTS

Table 17: Basic demographic, morphological and anthropometric characteristics for the control and experimental groups (mean±SD).

		* Age	Stature (m)	Mass (kg)	Sum of 7* (mm)	* Body fat (%)
Control						
	Pre			67 (±13.27)	93 (±35.49)	12 (±4.84)
		15 (±0.49)	1.75 (±0.07)			
	Post			68 (±14.16)	94 (±33.21)	12 (±4.55)
Experimental						
	Pre			74 (±12.69)	109 (±35.73)	14 (±4.84)
		17 (±1.21)	1.78 (±0.09)			
	Post			74 (±12.47)	# 88 (±25.22)	# 11 (±3.61)

Where: *= significant difference between control and experimental groups (overall absolute change) and # = significant difference within groups ($p < 0.05$).

A significant difference ($p < 0.05$) was shown for age between groups, with the experimental group being two years older than the control group. The groups were matched for all other variables pre-intervention (Table 17). A significant decrease ($p < 0.05$) was shown for both the sum of seven skinfolds (ES=0.68) and body fat percentage (ES=0.66) measures within the experimental group only post-intervention (Table 17). The largest decrease occurred at the suprailiac skinfold site. Furthermore, significant decreases ($p < 0.05$) were shown between the control and experimental groups for, sum of seven skinfolds (ES=1.43) and percentage body fat (ES=1.42) post-intervention (overall absolute change).

Sit and reach flexibility

For flexibility, a significant increase ($p < 0.05$; ES=0.46 and 0.88) was observed within the experimental group as well as the absolute change between the two groups (Table 18). Effect size for the control group was trivial (ES= 0.04). An interaction effect was also observed between conditions over time ($p = 0.03$). Mean percentage change was 27.42 % and 7.01 % for the control and experimental groups respectively.

Standing Broad Jump

No significant differences were observed within or between the groups for the standing broad jump measure (Table 18), despite a large increase being observed within the experimental group (ES= 0.81). The control group (ES= 0.35) showed a percentage change of 2.70 % and the experimental group a 3.58 % change. No interaction effect was observed ($p= 0.72$).

Overhead Medicine Ball Throw (3 kg)

No significant changes were observed for the medicine ball throw, both within and between groups (Table 18). There was, however, a meaningful increase in the experimental and control group (ES= 0.75 and 1.19 respectively), with a percentage change of 1.05 % and 4.25 % for the control and experimental groups. No interaction effect was observed ($p= 0.08$).

Agility

A significant decrease ($p<0.05$) was observed within the control (ES=1.76) and experimental (ES= 3.95) groups for agility. There was no difference between groups (Table 18), although a mean percentage change of 8.57 % and 10.31 % was shown for the control and experimental groups respectively. No interaction effect was observed ($p=0.28$).

20 m Sprint

There were significant decreases ($p<0.05$) in 20 m sprint time for both the control (ES=1.34) and experimental (ES= 5.55) groups. A significant decrease ($p<0.05$; ES=4.30) was also observed overall (absolute change), between the two groups (Table 18). An interaction effect was shown between conditions over time ($p=0.001$). Overall mean percentage change was 8.41 % for the control group and 26.78 % for the experimental group.

Push-ups

A significant increase ($p<0.05$; ES=0.90) in push-ups was shown within the experimental group over time (improvement). An overall, significant difference ($p<0.05$; ES=1.04) was also observed between the control (percentage change= 4.35 %) and experimental (percentage change= 24.84 %) groups for the number of push-ups completed (Table 18). An interaction effect was observed between conditions over time ($p=0.02$).

Plank

There was a significant increase ($p<0.05$; ES=1.45) in plank time in the experimental group (Table 18). A significant increase ($p<0.05$; ES= 1.97) was also shown for the overall absolute change between the two groups (Percentage change= 1.88 % for the control group and 91.86

% for the experimental group). An effect size of 0.13 was shown in the control group. Furthermore, an interaction effect was observed over time between conditions ($p=0.001$).

25 m Shuttle Run

For the 25 m shuttle run, significant increases ($p<0.05$) were observed in both the control (ES=1.08; percentage change= 6.12 %) and experimental groups (ES=4.38; percentage change= 13.58 %). Furthermore a significant increase ($p<0.05$; ES=1.61) was also observed between the two groups overall (Table 18). An interaction effect was observed over time between the two conditions ($p=0.001$).

Table 18: Pre- and post-intervention responses for the control and experimental groups (mean \pm SD).

		Sit and reach flexibility (mm)	Standing broad jump (m)	Agility (s)	* Plank time (s)	20m sprint time (s)	Medicine ball throw (m)	* Push-ups	25m shuttle distance (m)
Control									
	Pre	44.43 (\pm 98.17)	2.19 (\pm 0.26)	17.34 (\pm 0.90)	101.83 (\pm 20.48)	3.52 (\pm 0.19)	6.77 (\pm 1.29)	32.42 (\pm 10.00)	654.00 (\pm 26.21)
	Post	40.79 (\pm 94.58)	2.27 (\pm 0.20)	& 15.93 (\pm 0.69)	105.36 (\pm 31.18)	& 3.27 (\pm 0.18)	6.53 (\pm 1.07)	33.86 (\pm 10.20)	& 699.18 (\pm 46.60)
Experimental									
	Pre	45.40 (\pm 87.59)	2.20 (\pm 0.14)	16.92 (\pm 0.52)	110.07 (58.73) \pm	3.65 (\pm 0.17)	7.40 (\pm 1.61)	32.62 (\pm 8.60)	654.67 (\pm 36.21)
	Post	# 80.50 (\pm 61.94)	2.30 (\pm 0.11)	# 14.93 (\pm 0.49)	# 185.29 (\pm 44.29)	# 2.84 (\pm 0.12)	7.85 (\pm 1.76)	# 40.83 (\pm 9.54)	# 746.79 (\pm 21.72)

Where: *= significant difference between control and experimental groups (overall absolute change); # = significant difference within experimental group; &= significant difference within control group ($p<0.05$).

Retrospective statistical power

Table 19 shows the sum of 7 skinfolds (13.40%), flexibility (37.90%) and standing broad jump (12.40%) measures represent with a relatively low statistical power (using an alpha level of 5%). There was a medium power for sum of 7 skinfolds and large power for all the other measures.

Table 19: Statistical power and effect sizes for the intervention group.

Measure	Statistical power (%)	Effect size (ES)	Size of ES
Sum of 7 skinfolds	13.40	0.68	Medium
Flexibility	37.90	0.88	Large
Standing broad jump	12.40	0.81	Large
Overhead medicine ball throw	77.40	1.19	Large
Agility	99.70	3.95	Large
20m sprint	100.00	5.55	Large
Push-ups	58.80	0.90	Large
Plank	100.00	1.45	Large
25m shuttle run	95.90	1.80	Large

DISCUSSION

The present study was the first to determine the impact of a low-cost, no-cost intervention program on adolescent cricket players. The most important finding of the investigation was that the “CricFit” intervention program had a positive impact on most of the experimental test scores post-intervention. Significant improvements as well as large and medium effect sizes were observed for agility, sprint time and repeat sprint ability scores post- intervention for the control group, showing that traditional net and field-based coaching techniques also have an impact on certain fitness parameters. However, the changes observed in the intervention group were greater than those seen in the control group (for most measures) thus showing that there are greater benefits to performing traditional training as well as two extra strength and conditioning sessions per week (the extra sessions were justifiable). Furthermore, although there was reduced power in the case of the sum of 7 skinfolds, for flexibility and standing broad jump (Table 19), medium and large effect sizes were observed.

Agility (ES=3.95 experimental; 1.76 control) and sprint times (ES=5.55 experimental; 1.34 control) decreased significantly ($p<0.05$) for both groups over the intervention period (greater decreases were shown in the intervention group), which is a similar observation to what has been shown in other intermittent sports interventions (Bloomfield *et al.*, 2007). This is an important finding to consider, particularly for the design of late stage rehabilitation programs, as well as pre-season training in the development plan of both adolescents and adults (Bloomfield *et al.*, 2007). Furthermore, increased speed and agility is a desirable trait in cricket as all cricketing activities (batting, bowling and fielding) can benefit from an improvement in these two aspects. For example, batsmen can sprint and turn quicker

between the wickets when running and fielders may reduce the amount of runs that the opposition score by moving quickly to the ball. This increase in speed and agility could be attributed to an improvement in an athlete's lower limb power, as shown in other cricket related studies (Foden *et al.*, 2015). Although the current study showed no significance for standing broad jump (lower limb power), a large effect size (ES= 0.81) was seen, which may explain the improvements in sprint and agility times. Furthermore, lower limb power measurements, such as the counter movement jump and the standing broad jump have been shown to best reflect the speed and change of direction demands of cricket players (Foden *et al.*, 2015).

Push-ups for the experimental group (ES=1.04) increased significantly ($p<0.05$) over the four-week period. This is imperative for batsmen, bowlers and fielders. Although push-ups over time are typically a measure of muscle endurance, upper body strength may also improve. In terms of batting, upper body strength has been associated with an increased hitting distance (Taliep *et al.*, 2010). Thus, the greater the force generated by the muscles in the upper body region during the bat swing, the greater the power output of the cricket stroke (Taliep *et al.*, 2010). This becomes particularly important on larger cricket grounds, where more force is required by the batsman to clear the boundary. Upper body strength is also key for bowlers and fielders; positive correlations have been shown between ball release speed and maximum upper body strength, which may increase the speed at which a ball is bowled or thrown (Cronin *et al.*, 2016). Additionally, although no significant differences were shown for overhead medicine ball throw responses, a large effect size was observed between groups, post-intervention (ES= 0.75). This type of training has also been shown to help with injury prevention for throwing when fielding and for fast bowling (Cronin *et al.*, 2016).

Maximum plank time increased significantly (ES= 1.45; $p<0.05$) for the experimental group. This is a similar finding to another study, where core strength training significantly impacted muscle and back strength in cricketers (Subramanian, 2014). Furthermore, equipment free, core conditioning routines have been shown to improve trunk and core muscle endurance in adolescents (Allen *et al.*, 2014). This may improve athletic performance and decrease the incidence of lower back injuries during dynamic, high impact physical activity by stabilising the spine (Woolmer *et al.*, 2008; Allen *et al.*, 2014); particularly important for fast bowlers who are most prone to lower back injuries and subjected to high ground reaction forces of the front foot when landing at the popping crease. Further, this is important to consider as

traditional coaching techniques do not take these ground reaction forces into account when training (coaches do not measure ground reaction forces).

Repeat sprint ability (25 m shuttle distance) improved significantly (ES= 4.38; $p<0.05$) throughout the intervention period for both the control and experimental groups, meaning that there was an improvement in cardiovascular fitness and/or muscle elastic return capacity. The fact that both groups improved shows that traditional practices do focus on the core needs of the game, such as sprinting between the wickets, however the benefits to the player may be greater if exposed to a strength and conditioning program as well as traditional training. Additionally, the nature of the sprint activity by bowlers, batsmen and fielders means that it is important that coaches are aware of the acute and chronic neuromuscular responses as a result of the constant accelerations and decelerations (Subramanian, 2014). Thus there is a need to implement repeat sprint ability training (such as 25 m shuttles) to focus on eccentric loading of the lower limbs to avoid injuries. Furthermore, studies on batsmen have shown a decrease in eccentric peak torque of the knee flexors and extensors when running between the wickets (during high intensity running over a seven over period), potentially increasing the risk of hamstring strains (Pote and Christie, 2016a), thus further showing the importance of eccentric work through repeat sprint training.

Flexibility increased significantly (ES= 0.88; $p<0.05$) for the experimental group. This increase in flexibility was most likely due to the dynamic warm-up that was performed prior to and the static stretching completed post-workouts. There is however conflicting evidence in terms of the relationship between increased flexibility and reduced risk of injury (Thacker *et al.*, 2004). Some studies have shown that an increased flexibility may in fact increase the risk of injury, but may be beneficial for sports that require a greater range of motion (Knapik *et al.*, 1992; Kokkonen *et al.*, 1998). Research has shown though that flexibility imbalances in athletes may be the main cause of injuries in specific sports due to elasticity of the muscle (Knapik *et al.*, 1991).

Limitations

There are a number of limitations acknowledged by the authors for the present study. Firstly, the fact that an additional two sessions per week were performed by the experimental group (and not the control group), may be seen as a limitation to the study, however the fact that these sessions only required an additional 90 minutes per week (an extra 37.5% compared to the control group) and benefited the players' physical fitness (for the experimental group),

showed that the intervention program was worthwhile. This is further justified by the fact that no additional exercises or gym work was performed by both groups during the intervention period. The intervention was also to expand the understanding of schoolboy strength and conditioning which is currently lacking.

Secondly, it may be seen as a limitation that the intervention period was as short as four weeks. This is however, the longest period of time that private schools in South Africa can utilise for pre-season cricket training. Furthermore, research and the results from this have shown that this is a sufficient amount of time for specific adaptations to occur.

Thirdly, no performance or injury data was collected for the current study. Further research should collect this data to determine whether the intervention program has an impact on a player's performance as well as risk of injury or re-occurrence of a previous injury.

CONCLUSIONS

The findings of this investigation indicate that the "CricFit" intervention may be used by coaches and conditioning specialists to improve general fitness throughout the pre-season period. While traditional coaching techniques did improve some measures, performing an additional two conditioning sessions per week was shown to be beneficial to the players. Further research should assess whether the program can be used to prevent injuries in players through the tracking of injury data. This is particularly important for adolescent players who are the most prone. Physical education teachers may also utilise the intervention to improve the general fitness of individuals in a school environment.

The program can also be implemented at any location without any specialised equipment. This is especially important for schools, teams and clubs that do not have access to particular equipment and facilities. Lastly, the intervention is not time consuming as it only lasts between 35 and 45 minutes per session (including the warm-up and cool down), twice a week for four weeks. This is essential for adherence to the program and is also important in a school environment where pupils have to focus on other aspects such as academics and cultural commitments.

CHAPTER 6

CONCLUSION, LIMITATIONS, RECOMMENDATIONS FOR FUTURE RESEARCH AND PRACTICAL APPLICATIONS

CONCLUSION

A review of injuries and injury prevention strategies in cricket, as well as a survey based analysis of current strength and conditioning practices at an adolescent level in South Africa led to the development of a unique (CricFit) strength and conditioning intervention program. No multi-factorial, low-cost, no-cost, scientifically based strength and conditioning or injury prevention programs (for adolescent players) have been developed to reduce the risk of injury or improve physical fitness, and performance. It was found that most of the strength and conditioning coaches in South Africa are inexperienced and lack the qualifications to apply the appropriate fitness or injury prevention programs, and as a result the wrong practices are being implemented. This is with particular reference to workload monitoring and injury prevention strategies. As a result, and based on this information as well as injury statistics and prevention programs, a novel four week intervention program was developed that required minimal equipment and could be performed in any environment. This was deemed important due to the fact that most adolescent players and individuals in South Africa lack access to physical activity opportunities let alone coaches, equipment and facilities. The findings from the intervention showed that performing an extra 30-45 minutes twice a week (in addition to traditional field and net based training) had a beneficial effect on an individual's physical fitness parameters. Future studies should investigate the effect of the intervention on performance and injury risk and, although challenging, try and recruit larger samples.

LIMITATIONS

Although every effort was made to control any extraneous variables that may have affected the investigation, there were a number of limitations. These should therefore be taken into account when examining the findings of the study:

1. Not all questions were answered by coaches and trainers in the survey based study, which must be seen as a limitation of the investigation.
2. The fact that coaches were not provided with a standard injury definition for the survey based research must be seen as a limitation of the study.

3. A limitation of the intervention study was that although the control group performed the same traditional net and field based training as the experimental group, no additional form of exercise or conditioning was performed while the experimental group did their 90 minute “CricFit” session. This may have impacted the results.
4. For the intervention based study the control and experimental groups were matched according to baseline characteristics. However, the fact that the players in the control group had a significantly lower body fat percentage and were younger than the individuals in the experimental group may be seen as a limitation of the study.
5. The fact that the control and experimental groups only had 14 participants each is a limitation of the intervention investigation; a greater sample size may have impacted the responses recorded. This was as a result of limited access to players and other school commitments, such as academics and cultural obligations.
6. The short intervention period (four weeks, eight sessions) may be seen as a limitation however findings would suggest that this period of time is long enough for adaptations to occur. Thus eight pre-season sessions over 4-weeks are sufficient to result in relevant training adaptations in these players.
7. The fact that no performance or injury data was collected may be seen as a limitation of the intervention study. This was due to the fact that a detailed injury history of each individual was not available from the different physiotherapists that each player attended. Furthermore, accurate performance data was also not available.

RECOMMENDATIONS FOR FUTURE RESEARCH

The following section seeks to provide recommendations and opportunities for future research:

1. Every attempt must be made to recruit the largest possible sample considering that human exercise intervention research is limited by its inability to obtain and retain adequate numbers. This is a broader challenge for the discipline where relying on

humans to participate in physical exertion is faced with numerous challenges. Some of these include that participants are required to devote time for 3 and 7 days per week for at least an hour at each session over weeks or months. These sessions have to be under supervision so that each individual receives the same treatment (in this case exercise). Unlike pharmacological clinical trials, exercise trials are inherently more complex from a recruitment and retention perspective. How this can be overcome remains a challenge for our field.

2. Future research should look at quantifying injuries and injury patterns in nations outside of the five major cricket playing countries (Chapter 3). This should include the analysis and causality of injuries at an adolescent level; to date the research at these age groups is lacking. Furthermore, a standardised injury definition needs to be developed so that injury statistics can be compared at different levels of play and between the different cricket playing nations. Perhaps the updated consensus on injury definitions developed by Orchard and colleagues (2016) should be used when observing the incidence and prevalence of cricket injuries.
3. While workload monitoring studies have been done on cricket fast bowlers and players of other intermittent sports, no studies have looked at the monitoring of adolescent cricket players. Workload monitoring was not in the scope of this investigation, but future research should examine the workloads (internal and external) placed on adolescent cricket players through methods such as the acute:chronic workload ratio or session ratings of perceived exertion. This is important as the demands placed on these young players are different to older, professional players. Furthermore, for school boy players, there are other important factors that need to be taken into consideration when designing a strength and conditioning program including, but not limited to: participation in multiple sports, short pre-season periods, exposure to different nutritional plans and diets (depending on whether they are day scholars or boarding pupils), academic and cultural pressures (stress), the onset of puberty, parental and household pressures, different socio-economic statuses as well as cultural beliefs and stand points.
4. Although the control group (for the intervention based study) did the same traditional net and field based cricket training as the experimental group, it is recommended that

future studies incorporate an extra 90 minutes of additional training during the pre-season and when just returning from school holidays. Many children are inactive during the holiday periods and this will get them to the level required for competition. Future research should use an alternative intervention in the control group so that the intervention periods are matched. As a result, any influences (negative or positive) on the responses can be attributed exclusively to the intervention program.

5. An additional investigation should examine the effects of the intervention program over a full season (pre-season as well as in-season) and compare this to a pre-season only intervention in order to determine whether the same, or more, benefits can occur over an extended period of time. This will allow teams to continue with the intervention throughout the season ensuring that players remain physically fit and match ready.
6. Future studies should test the efficacy, validity and reliability of the “CricFit” intervention program, specifically in different samples. Different schools, clubs, age groups and levels of professionalism may impact the effect that the intervention has on diverse population groups. Furthermore, the intervention program should also be tested on a female sample and look at coach implementation of the programme as if it is not implemented appropriately, it may not be effective and actually increase the risk of injury.
7. The test battery that was utilised in the intervention based study was the first to test the responses of adolescent cricket players. Future research should look at further refining this program to be even more cricket specific and implementable at all levels.
8. It is recommended that future research should take an in-depth look at the effect that the intervention program has on injuries and player performance.

PRACTICAL APPLICATIONS

The following section seeks to provide practical applications based on the current study:

1. The findings of the survey based study together with the intervention investigation should be used to educate and train coaches
2. The findings from the survey based study can be used by researchers as well as coaches to compare the different practices and thus improve on, and diversify, the current programs that are being implemented.
3. The “CricFit” intervention program can be used by coaches and trainers to improve the physical attributes of individuals, not only for cricket activity, but also other intermittent sports that have similar movement patterns to cricket.
4. The “CricFit” intervention program can be used by physical education teachers to improve general fitness as well as to promote exercise and physical activity at a school and university level.

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APPENDIX A: GENERAL INFORMATION

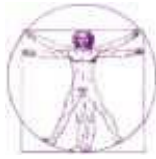
ETHICAL APPROVAL

INFORMATION TO PLAYERS

PLAYER CONSENT FORM

PHYSICAL ACTIVITY SCREENING QUESTIONNAIRE

ETHICAL APPROVAL: SURVEY BASED RESEARCH (PHASE 2)



Human Kinetics and Ergonomics Application for Ethical Approval



RHODES UNIVERSITY
Where leaders learn

Student Name: Lee Pote
Type of Research: PhD
Project Title: A survey of the current strength and conditioning practices in schoolboy and university level cricket players
Supervisor: Dr Candice Christie
Application received: 26 May 2015
Code: HKE-2015-7

Dear Lee

Following review of your ethics submission as well as the re-submission and consideration of feedback, your study is granted ethical clearance.

Approved ✓	Approved, on condition that suggestions have been effected	Request for rework and resubmission	Rejected
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Please note that any/all amendments to your protocol or methodology, including statistical analyses must be reported, via email, to the chair for the record.

A handwritten signature in black ink, appearing to read 'JE Viljoen', on a light yellow background.

Dr JE Viljoen

Chair: Human Kinetics and Ergonomics Ethics Committee

ETHICAL APPROVAL: INTERVENTION BASED RESEARCH (PHASE 3)



RHODES UNIVERSITY
Where leaders learn

Rhodes University Ethical Standards Committee, Rhodes University, P O Box 94, Grahamstown, 6140

Tel: +27 46 603 7366 • Fax: +27 46 603 8934 • Email: ethics-committee@ru.ac.za

06-Jun-2016

Dear Lee Pote,

Ethics Clearance: Strength and conditioning of schoolboy cricketers: a four week field based intervention study.

Principal Investigator: Lee Pote

This letter confirms that a research proposal with tracking number: RU-HSD-16-05-0011 and

Title: **Strength and conditioning of schoolboy cricketers: a four week field based intervention study** was given ethics clearance by the Rhodes University Ethical Standards Committee pending amendment to the following:

It is incumbent on the researcher to ensure that the physical tasks associated with this study are in fact "minimal" and that they are in fact similar to, or do not exceed, those encountered during a normal cricket practice or match.

Please contact the Ethics Committee for clarification of the stipulations, if deemed helpful.

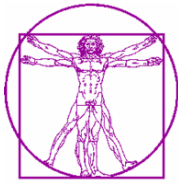
Please ensure that the ethical standards committee is notified should any substantial change(s) be made, for whatever reason, during the research process. This includes changes in investigators. Please also ensure that a brief report is submitted to the ethics committee on completion of the research. The purpose of this report is to indicate whether or not the research was conducted successfully, if any aspects could not be completed, or if any problems arose that the ethical standards committee should be aware of. If a thesis or dissertation arising from this research is submitted to the library's electronic theses and dissertations (ETD) repository, please notify the committee of the date of submission and/or any reference or cataloguing number allocated.

Yours Sincerely,

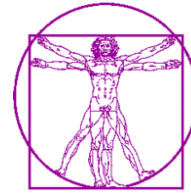
A handwritten signature in blue ink, appearing to read 'J. Marx'.

Dr J. Marx: Chairperson RUEESC.

INFORMATION TO PARTICIPANTS: SURVEY BASED RESEARCH (PHASE 2)



RHODES UNIVERSITY
Grahamstown • 6140 • South Africa



HUMAN KINETICS AND ERGONOMICS

Contact information:

Name: Lee Pote

Cell number: 072 11 700 41

E-mail: l.pote@kingswoodcollege.com

To whom it may concern

I have spoken to some of you already and I would be really grateful if you could take a few minutes to complete the following survey. The survey comprises the second phase of my PhD research that will be looking at the strength and conditioning practices of university/school cricket coaches. This will help to inform the rest of my research, which will involve the design of a unique conditioning program. The questions are short and concise and will not take long to answer.

If you wish to take part in this survey, please click on the link below and follow the instructions:

XXXXXXXXXX (online survey link)

By clicking on the link you are automatically consenting to participate in the survey.

Please note that you are in no way obligated to take part in this research and may exit the survey at any time, thereby terminating your consent to participate. Furthermore, the results obtained will be completely anonymous and there will be no mention of you, your team or your institution in any correspondence that may follow. Feedback will be provided if requested via email.

If there are any queries or questions please do not hesitate to contact me at any time.

Your help is greatly appreciated

A handwritten signature in black ink, appearing to read 'Lee Pote', positioned above a horizontal line.

Lee Pote

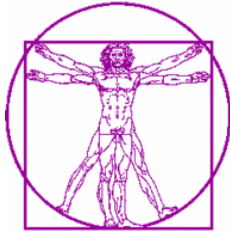
Head Strength and Conditioning coach

Kingswood College

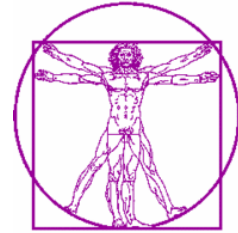
MSc HKE, Department of Human Kinetics and Ergonomics

Grahamstown, South Africa

**INFORMATION TO PARTICIPANTS: INTERVENTION BASED RESEARCH
(PHASE 3)**



RHODES UNIVERSITY
Grahamstown • 6140 • South Africa



HUMAN KINETICS AND ERGONOMICS

Contact information:

Name: Lee Pote

Cell number: 072 11 700 41

E-mail: l.pote@kingswoodcollege.com

Dear _____

Thank you for volunteering to participate in the PhD research that I am currently conducting. Your help and participation is greatly appreciated.

Title of thesis

Strength and conditioning of schoolboy cricketers: a four-week field-based intervention study (CricFit).

Aims of the study

Cricket has received very little research attention, particularly in terms of the physical demands of the game and the conditioning practices that are being implemented. To date, only one study has examined the strength and conditioning practices of schoolboy cricketers and it has shown that there is a mismatch between what is being applied by the coaches and the correct techniques that should be executed. In other words, while most coaches do implement some form of cricket specific conditioning, workload monitoring and injury prevention exercises, the wrong practices are being used which may be doing more harm than good. Thus the purpose of this study is to determine the impact of a scientifically based, 4 week conditioning intervention program on schoolboy cricketers and thus reduce the risk of injury and improve performance.

The intervention

The intervention will take place over a four week period between September and October. Before and after the intervention period a battery of tests will be performed to determine whether the intervention has been successful or not. Furthermore a 'to do' list will be given to each of you to complete before performing the tests. These tests include:

- Stature, mass, percentage body fat and flexibility

- Agility
- Power
- Speed
- Muscle endurance
- Repeat sprint ability

The four week intervention will consist of two, 45 minute sessions per week. Your normal practices will not be affected. Prior to each session a dynamic warm-up will be completed and at the end of the session a static cool down will take place. During these sessions conditioning activities that mimic the game of cricket will be performed as well as a number of injury prevention exercises. These conditioning activities will consist of skill based conditioning games as well as core, strength, speed, agility flexibility, power and repeat sprint ability work.

Risks

The risks of this study are fairly minimal and are similar to those you will encounter during a normal cricket practice or match. You are more than likely to experience delayed onset muscle soreness (stiffness) at first, but this is to be expected when performing any type of exercise and will subside over time and throughout the intervention. There is also the risk pulling a muscle during all out sprinting or cramp during the sessions, however this can be negated through a dynamic warm-up prior to exercise and a static cool down after the sessions.

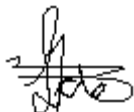
Benefits

The benefits of the study outweigh the risks. You will have a greater understanding of the physical demands of the game from both a training and match perspective. Furthermore, the process of education will be invaluable in terms of how to train for improved performance and understanding how to implement specific injury prevention exercises. Lastly, the intervention is expected to be successful and thus your in-season performances may be enhanced due to the training that occurred during the pre-season.

Other

If there are any queries or questions please do not hesitate to contact me at any time. Photographs may be taken for illustration purposes, but these will remain anonymous. If at any time players feel the need to withdraw from the study due to personal reasons, they may do so without any consequence or action.

Regards



Lee Pote

PLAYER CONSENT FORM: INTERVENTION BASED RESEARCH (PHASE 3)



RHODES UNIVERSITY
Grahamstown • 6140 • South Africa



Human Kinetics and Ergonomics Department INFORMED CONSENT AND INDEMNITY For research involving human participants

I, have been fully informed of the research project entitled:
“Strength and conditioning of schoolboy cricketers: a four week field based intervention study”.

I have read the information sheet and understand the testing procedure that will take place. All testing procedures, associated risks and the benefits from partaking in this study have been verbally explained to me as well as in writing [*letter of information appended to this document*]. I have had ample opportunity to ask questions and to clarify any concerns or misunderstandings. I am satisfied that these have been answered satisfactorily. I understand that all data collected for publication purposes will be kept anonymous and all information gained in this regard will be treated confidentially. Furthermore, I consent to photographs, knowing that these will be altered to ensure my anonymity. I understand that I am able to withdraw from the study at any point, irrespective of external influences placed on me by the researcher. In agreeing to participate in this research study I waive any legal recourse against the researchers from the Department of Human Kinetics and Ergonomics (HKE), Rhodes University, from claims resulting from personal injuries sustained whilst participating in the above mentioned research. I am aware and fully understand that the Department of Human Kinetics and ergonomics is not responsible for any injuries due to my personal negligence and non-compliance with instructions. This waiver shall be binding upon my heirs and personal representatives. I have read and understood the above information, as well as the information provided in the letter accompanying this form. I therefore consent to voluntarily participate in this research project.

PARTICIPANT PROVIDING CONSENT:

_____	_____	_____
(Print Name)	(Signed)	(Date)

WITNESS:

_____	_____	_____
(Print Name)	(Signed)	(Date)

PRINCIPAL RESEARCHER:

_____	_____	_____
(Print Name)	(Signed)	(Date)

PHYSICAL ACTIVITY SCREENING QUESTIONNAIRE

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.

- | | | |
|--|------------------------------------|--|
| <input type="checkbox"/> Heart problems | <input type="checkbox"/> Anaemia | <input type="checkbox"/> Eye problems |
| <input type="checkbox"/> Peripheral vascular disorders | <input type="checkbox"/> Asthma | <input type="checkbox"/> Hypoglycaemia |
| <input type="checkbox"/> High/low blood pressure | <input type="checkbox"/> Emphysema | <input type="checkbox"/> Diabetes |
| <input type="checkbox"/> Epilepsy | <input type="checkbox"/> Migraine | <input type="checkbox"/> Hyperthyroidism |
| <input type="checkbox"/> 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 _____

APPENDIX B: DATA COLLECTION

SURVEY

DATA COLLECTION SHEET

SURVEY

Section 1- General

Background information

1. Name? _____ Surname? _____
2. Age? _____ Gender? _____
3. What institution are you currently working at? _____
4. What is your position at this institution? _____
5. How long have you occupied this position? _____
6. What qualifications do you have (degrees, diplomas, strength and conditioning qualifications etc...)?

Physical testing

1. Do you test your players physical fitness? _____
2. If yes, what fitness parameters are tested and which tests are used for each (e.g. agility-Illinois agility test etc...)?

3. When are these tests implemented?
Pre-season
In-season
Off-season

Flexibility development

1. Do you require your players to partake in flexibility training? _____
2. If yes, what type of flexibility training?

3. What type of stretching practices do they perform? (static, dynamic etc...)

4. When do they perform these stretches?

Before a practice or a match

After a practice or a match

Other: specify _____

5. Is any specific equipment used to help with flexibility training?

Speed development

1. Do you require your players to partake in speed training? _____

2. If yes, what drills are used?

3. What equipment is used for speed training (if any)?

4. How often are your players subjected to speed training (per week e.g. 1,2 etc...)??

Agility development

1. Do you require your players to partake in agility training? _____

2. If yes, what drills are used?

3. What equipment is used for agility training?

4. On average, how often are your players subjected to agility training (per week e.g. 1,2 etc...)?

Plyometric training

1. Do you require your players to partake in plyometric training? _____

2. If yes, what drills are used?

3. What equipment is used for plyometric training?

4. On average, how often are your players subjected to plyometric training (per week e.g. 1,2 etc...)??

Strength/resistance training

1. Do you require your players to partake in resistance training _____

2. If yes, what type of training is implemented?

3. When is this training mainly implemented?

Pre-season

In-season

Off-season

4. What equipment is used for this type of training (if any)?

5. On average, how often are your players subjected to resistance training (per week e.g. 1,2 etc...)??

Section 2- Cricket specific

1. Do you implement different conditioning practices for batsmen, bowlers or fielders/keepers? _____

2. If yes, what is different for each specific position?

Batsmen:

Bowlers:

Fielders/keepers:

3. Do you monitor bowler, batsmen or fielder/keeper workload? _____

4. If yes, how?

Batsmen:

Bowlers:

Fielders/keepers:

Section 3- Injuries/injury prevention

1. Do you keep a record of injured players or specific injuries?

2. If yes, what is the most common injured position (batsmen, bowler, fielder/keeper)?

3. What is the most common area of injury for:

Batsmen?

Shoulder

Hamstrings

Quadriceps

Lower back

Other: Specify

Bowlers?

Shoulder

Hamstrings

Quadriceps

Lower back

Other:Specify

Fielders/keepers?

Shoulder

Hamstrings

Quadriceps

Lower back

Other:Specify

4. Do you implement any injury prevention exercises?

5. If yes, what exercises are implemented?

6. What part of the season are these exercises implemented?

Pre-season

In-season

Off-season

7. Are different exercises implemented for different playing position?

8. If yes, what is different for each specific position?

Batsmen:

Bowlers:

Fielders/keepers:

Section 4- Comments

If you feel that there are any areas of interest that should be taken into account or considered, please provide some information in the area below:

DATA COLLECTION SHEET: INTERVENTION BASED STUDY (PHASE 3)

Data collection sheet

Name and Surname: _____

Age: _____ Stature: _____ Mass: _____(kg) Flexibility: _____(mm)

Sum of seven skinfolds:

- Chest: _____
 - Triceps: _____
 - Subscapular: _____
 - Axilla: _____
 - Abdominal: _____
 - Suprailliac: _____
 - Thigh: _____
- %BF: _____ Sum of seven skinfolds: _____

Standing broad jump: 1. _____ 2. _____ (m)

Overhead medicine ball throw: 1. _____ 2. _____ (m)

20m sprint: 1. _____ 2. _____ (s)

Agility: 1. _____ 2. _____ (s)

Plank time: _____(s)

Maximum push-ups: _____

25m shuttle test:

- Trial 1: _____
- Trial 2: _____
- Trial 3: _____
- Trial 4: _____
- Trial 5: _____
- Trial 6: _____

APPENDIX C: INTERVENTION

“CRICKFIT” INTERVENTION PROGRAM

WARM-UP AND COOL DOWN

“CRICKFIT” INTERVENTION PROGRAM

20m sprint

Plank

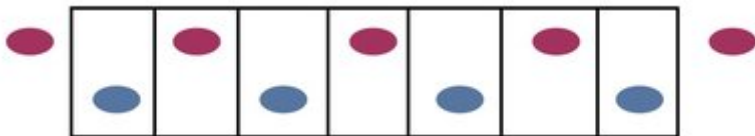


Side plank

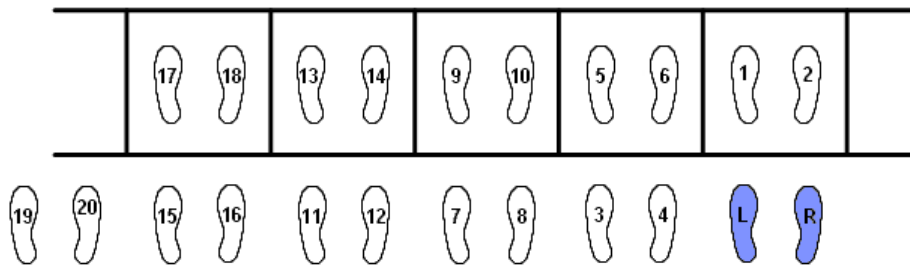


Ladder drills

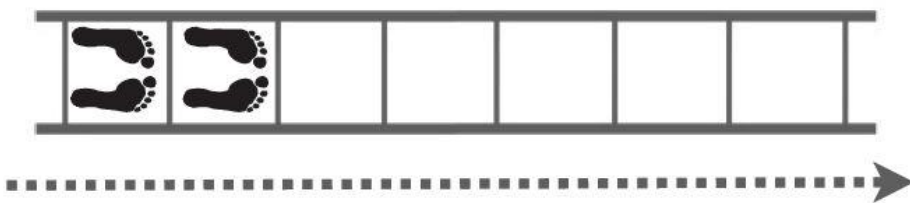
Single runs (Source: <https://ballersinstitute.com>)



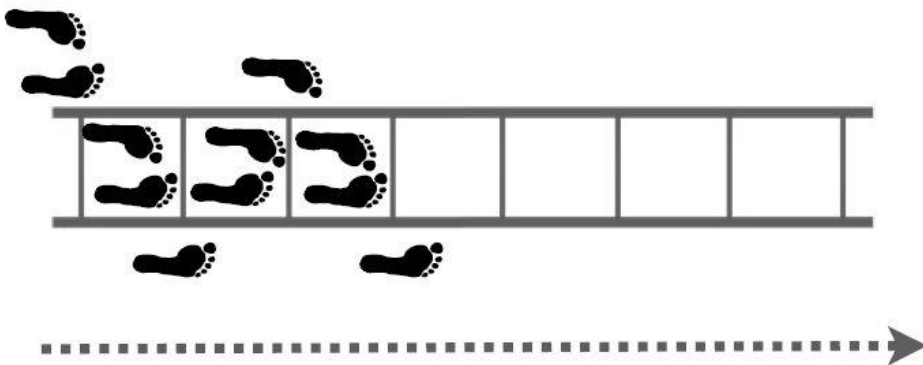
In-outs (Source: <http://www.tayha.org>)



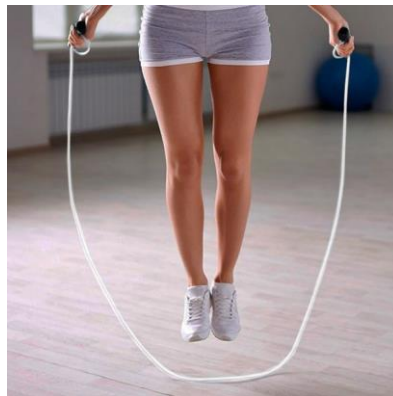
Double runs (Source: <https://ballersinstitute.com>)



Shuffles (Source: <https://ballersinstitute.com>)



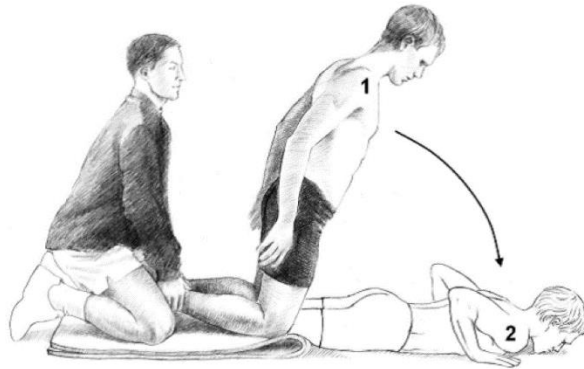
Skipping (Source: www.thetimes.co.uk)



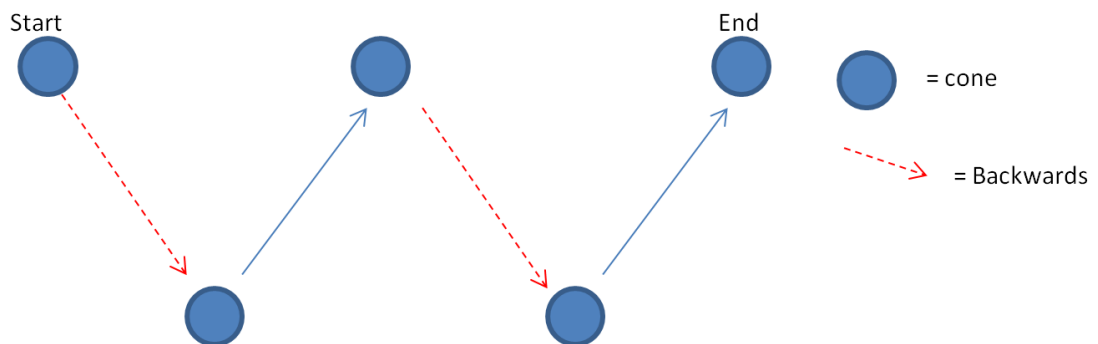
Lizard crawls



Nordic lowers (Source: <http://lermagazine.com>)



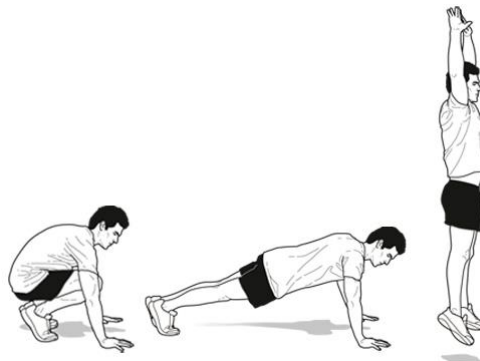
W-sprint agility drill



Overhead medicine ball slam (Source: www.menshealth.com)



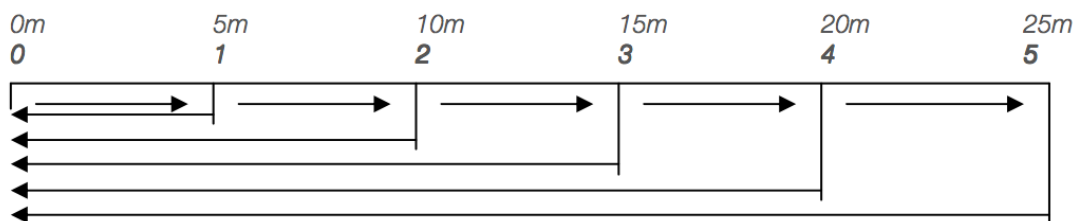
Burpees (Source: <https://workoutlabs.com>)



Squat jumps (Source: www.menshealth.com)



25m shuttles (Source: <https://www.prep4rugby.com>)



WARM-UP AND COOL DOWN

Jog at 60% of maximum for 120m (followed by dynamic stretching)

Lunges



Squats



Hamstring kicks



Hamstring shuffles



Leg swings



Calf walk-outs



Lumbar rolls



Turtle rolls and release



Iron cross stretch



Scorpion stretch



T-push ups



Three 20m sprints (60%, 80%, 100% of maximum)

Cool down

The cool down consisted of a static stretch of both the upper and lower body musculature (hamstrings, quadriceps, glute muscles, calves, groins, deltoids, pectoral muscles) with each stretch being held for 12 seconds.

APPENDIX D: STATISTICS (INTERVENTION BASED STUDY)

INITIAL STATISTICS

WITHING GROUP STATISTICS

BETWEEN GROUPS STATISTICS

INTERACTION EFFECT STATISTICS

INITIAL STATISTICS

Variable	T-tests; Grouping: Group (Initial stats)										
	Group 1: c Group 2: e										
	Mean c	Mean e	t-value	df	p	Valid N c	Valid N e	Std.Dev. c	Std.Dev. e	F-ratio Variances	p Variances
Mass	66,9286	73,8933	-1,44468	27	0,160055	14	15	13,27110	12,69029	1,093631	0,866461
Stature	1,7529	1,7767	-0,74590	27	0,462176	14	15	0,07010	0,09832	1,967054	0,231504
Flexibility	44,4286	45,4000	-0,02816	27	0,977742	14	15	98,16996	87,58653	1,256269	0,675881
Sum of 7	93,3714	109,2067	-1,19636	27	0,241957	14	15	35,49508	35,73247	1,013421	0,986252
%BF	11,5414	14,0713	-1,40699	27	0,170839	14	15	4,84202	4,83552	1,002691	0,990717
SBJ	2,1875	2,2033	-0,20513	25	0,839131	12	15	0,25595	0,13947	3,367781	0,035686
Illinois	17,3417	16,9240	1,50665	25	0,144434	12	15	0,90285	0,52383	2,970667	0,058532
20m	3,5167	3,6473	-1,89055	25	0,070329	12	15	0,19109	0,16786	1,295870	0,637969
Med ball	6,7708	7,4000	-1,09847	25	0,282468	12	15	1,29254	1,61024	1,551993	0,469273
P/ups	32,4167	32,6154	-0,05339	23	0,957880	12	13	10,00417	8,59785	1,353885	0,609340
Plank	101,8333	110,0714	-0,46131	24	0,648727	12	14	20,48429	58,72945	8,219968	0,001329
5m shuttle	654,0000	654,6667	-0,06056	25	0,952189	12	15	36,20899	20,30717	3,179320	0,044968
Age	14,6429	17,2000	-7,35801	27	0,000000	14	15	0,49725	1,20712	5,893333	0,002820

WITHIN GROUP STATISTICS

Control group

Mass

		T-test for Dependent Samples (PhD stats) Marked differences are significant at $p < ,05000$									
Variable	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p	Confidence -95,000%	Confidence +95,000%	
Mass PRE	66,92857	13,27110									
Mass POST	67,59286	14,15923	14	-0,664286	2,544559	-0,976802	13	0,346495	-2,13347	0,804899	

Flexibility

		T-test for Dependent Samples (PhD stats) Marked differences are significant at $p < ,05000$									
Variable	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p	Confidence -95,000%	Confidence +95,000%	
Flexibility PRE	44,42857	98,16996									
Flexibility POST	40,78571	94,58182	14	3,642857	44,20339	0,308355	13	0,762698	-21,8794	29,16513	

Sum of 7 skinfolds

		T-test for Dependent Samples (PhD stats) Marked differences are significant at $p < ,05000$									
Variable	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p	Confidence -95,000%	Confidence +95,000%	
Sum7 PRE	93,37143	35,49508									
Sum7 POST	93,75714	33,20497	14	-0,385714	16,31134	-0,088479	13	0,930844	-9,80360	9,032172	

Body fat percentage

		T-test for Dependent Samples (PhD stats) Marked differences are significant at $p < ,05000$									
Variable	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p	Confidence -95,000%	Confidence +95,000%	
%BF PRE	11,54143	4,842024									
%BF POST	11,59643	4,554873	14	-0,055000	2,378467	-0,086523	13	0,932369	-1,42829	1,318286	

Standing broad jump

		T-test for Dependent Samples (PhD stats) Marked differences are significant at $p < ,05000$									
Variable	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p	Confidence -95,000%	Confidence +95,000%	
SBJ PRE	2,187500	0,255952									
SBJ POST	2,237500	0,204634	12	-0,050000	0,129685	-1,33558	11	0,208663	-0,132398	0,032398	

Illinois agility test

		T-test for Dependent Samples (PhD stats) Marked differences are significant at $p < ,05000$									
Variable	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p	Confidence -95,000%	Confidence +95,000%	
Illinois PRE	17,37800	0,867023									
Illinois POST	15,87500	0,723959	10	1,503000	0,595708	7,978582	9	0,000023	1,076856	1,929144	

20m sprint

		T-test for Dependent Samples (PhD stats) Marked differences are significant at $p < ,05000$									
Variable	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p	Confidence -95,000%	Confidence +95,000%	
20m PRE	3,527000	0,171662									
20m POST	3,256000	0,189221	10	0,271000	0,089747	9,548859	9	0,000005	0,206799	0,335201	

Medicine ball throw

		T-test for Dependent Samples (PhD stats) Marked differences are significant at $p < ,05000$									
Variable	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p	Confidence -95,000%	Confidence +95,000%	
Med ball PRE	6,770833	1,292541									
Med ball POST	6,641667	1,115965	12	0,129167	0,547498	0,817257	11	0,431127	-0,218697	0,477030	

Push-ups

		T-test for Dependent Samples (PhD stats) Marked differences are significant at $p < ,05000$									
Variable	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p	Confidence -95,000%	Confidence +95,000%	
P/ups PRE	32,41667	10,00417									
P/ups POST	32,83333	9,83346	12	-0,416667	6,734691	-0,214320	11	0,834219	-4,69569	3,862352	

Plank

		T-test for Dependent Samples (PhD stats) Marked differences are significant at $p < ,05000$									
Variable	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p	Confidence -95,000%	Confidence +95,000%	
Plank PRE	101,8333	20,48429									
Plank POST	98,5833	27,53661	12	3,250000	25,11474	0,448276	11	0,662655	-12,7071	19,20714	

25m shuttle

		T-test for Dependent Samples (PhD stats) Marked differences are significant at $p < ,05000$									
Variable	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p	Confidence -95,000%	Confidence +95,000%	
5m shuttle PRE	654,8000	37,39222									
5m shuttle POST	694,5000	49,74658	10	-39,7000	39,04143	-3,21562	9	0,010563	-67,6286	-11,7714	

Experimental group

Mass

		T-test for Dependent Samples (PhD stats) Marked differences are significant at $p < ,05000$									
Variable	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p	Confidence -95,000%	Confidence +95,000%	
Mass PRE	74,12500	13,56896									
Mass POST	74,35833	13,42396	12	-0,233333	2,105980	-0,383807	11	0,708436	-1,57141	1,104742	

Flexibility

		T-test for Dependent Samples (PhD stats) Marked differences are significant at $p < .05000$									
Variable	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p	Confidence -95,000%	Confidence +95,000%	
Flexibility PRE	36,08333	94,98273									
Flexibility POST	78,08333	67,00130	12	-42,0000	59,37401	-2,45044	11	0,032221	-79,7244	-4,27556	

Sum of 7 skinfolds

		T-test for Dependent Samples (PhD stats) Marked differences are significant at $p < .05000$									
Variable	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p	Confidence -95,000%	Confidence +95,000%	
Sum7 PRE	115,5417	35,55453									
Sum7 POST	92,2167	24,80648	12	23,32500	16,92745	4,773323	11	0,000578	12,56981	34,08019	

Body fat percentage

		T-test for Dependent Samples (PhD stats) Marked differences are significant at $p < .05000$									
Variable	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p	Confidence -95,000%	Confidence +95,000%	
%BF PRE	14,96333	4,711445									
%BF POST	11,84167	3,543670	12	3,121667	2,064597	5,237715	11	0,000278	1,809884	4,433449	

Standing broad jump

		T-test for Dependent Samples (PhD stats) Marked differences are significant at $p < .05000$									
Variable	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p	Confidence -95,000%	Confidence +95,000%	
SBJ PRE	2,212500	0,140008									
SBJ POST	2,283333	0,096138	12	-0,070833	0,154417	-1,58903	11	0,140361	-0,168945	0,027279	

Illinois agility test

		T-test for Dependent Samples (PhD stats) Marked differences are significant at $p < .05000$									
Variable	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p	Confidence -95,000%	Confidence +95,000%	
Illinois PRE	16,83250	0,526932									
Illinois POST	15,08833	0,273191	12	1,744167	0,422169	14,31174	11	0,000000	1,475933	2,012400	

20m sprint

		T-test for Dependent Samples (PhD stats) Marked differences are significant at $p < .05000$									
Variable	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p	Confidence -95,000%	Confidence +95,000%	
20m PRE	3,637500	0,158809									
20m POST	2,870000	0,099178	12	0,767500	0,132879	20,00842	11	0,000000	0,683073	0,851927	

Medicine ball throw

		T-test for Dependent Samples (PhD stats) Marked differences are significant at $p < .05000$									
Variable	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p	Confidence -95,000%	Confidence +95,000%	
Med ball PRE	7,583333	1,748679									
Med ball POST	7,870833	1,832343	12	-0,287500	0,566539	-1,75792	11	0,106516	-0,647461	0,072461	

Push-ups

T-test for Dependent Samples (PhD stats) Marked differences are significant at $p < .05000$										
Variable	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p	Confidence -95,000%	Confidence +95,000%
P/ups PRE	32,72727	9,371136								
P/ups POST	39,54545	8,847188	11	-6,81818	5,510321	-4,10382	10	0,002132	-10,5201	-3,11630

Plank

T-test for Dependent Samples (PhD stats) Marked differences are significant at $p < .05000$										
Variable	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p	Confidence -95,000%	Confidence +95,000%
Plank PRE	113,5000	61,08042								
Plank POST	185,5000	46,29451	12	-72,0000	47,92798	-5,20396	11	0,000293	-102,452	-41,5480

25m shuttle

T-test for Dependent Samples (PhD stats) Marked differences are significant at $p < .05000$										
Variable	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p	Confidence -95,000%	Confidence +95,000%
5m shuttle PRE	653,7500	21,75535								
5m shuttle POST	742,0833	19,70906	12	-88,3333	21,24889	-14,4005	11	0,000000	-101,834	-74,8324

BETWEEN GROUPS STATISTICS

Mass

		T-test for Independent Samples (Spreadsheet1) Note: Variables were treated as independent samples									
Group 1 vs. Group 2	Mean Group 1	Mean Group 2	t-value	df	p	Valid N Group 1	Valid N Group 2	Std.Dev. Group 1	Std.Dev. Group 2	F-ratio Variances	p Variances
Mass C vs. Mass E	0.664286	0.233333	0.465419	24	0.645827	14	12	2.544559	2.105980	1.459878	0.536462

Flexibility

		T-test for Independent Samples (Spreadsheet1) Note: Variables were treated as independent samples									
Group 1 vs. Group 2	Mean Group 1	Mean Group 2	t-value	df	p	Valid N Group 1	Valid N Group 2	Std.Dev. Group 1	Std.Dev. Group 2	F-ratio Variances	p Variances
Flex C vs. Flex E	-3.64286	42.00000	-2.24362	24	0.034352	14	12	44.20339	59.37401	1.804187	0.310186

Sum of 7skinfolds

		T-test for Independent Samples (Spreadsheet1) Note: Variables were treated as independent samples									
Group 1 vs. Group 2	Mean Group 1	Mean Group 2	t-value	df	p	Valid N Group 1	Valid N Group 2	Std.Dev. Group 1	Std.Dev. Group 2	F-ratio Variances	p Variances
Sum7 C vs. Sum7 E	0.385714	-23.3250	3.631571	24	0.001329	14	12	16.31134	16.92745	1.076970	0.887292

Body fat percentage

		T-test for Independent Samples (Spreadsheet1) Note: Variables were treated as independent samples									
Group 1 vs. Group 2	Mean Group 1	Mean Group 2	t-value	df	p	Valid N Group 1	Valid N Group 2	Std.Dev. Group 1	Std.Dev. Group 2	F-ratio Variances	p Variances
%BF C vs. %BF E	0.055000	-3.12167	3.604765	24	0.001421	14	12	2.378467	2.064597	1.327161	0.645834

Standing broad jump

		T-test for Independent Samples (Spreadsheet1) Note: Variables were treated as independent samples									
Group 1 vs. Group 2	Mean Group 1	Mean Group 2	t-value	df	p	Valid N Group 1	Valid N Group 2	Std.Dev. Group 1	Std.Dev. Group 2	F-ratio Variances	p Variances
SBJ C vs. SBJ E	0.050000	0.070833	-0.357891	22	0.723836	12	12	0.129685	0.154417	1.417793	0.572391

Illinois agility test

		T-test for Independent Samples (Spreadsheet1) Note: Variables were treated as independent samples									
Group 1 vs. Group 2	Mean Group 1	Mean Group 2	t-value	df	p	Valid N Group 1	Valid N Group 2	Std.Dev. Group 1	Std.Dev. Group 2	F-ratio Variances	p Variances
Illinois C vs. Illinois E	-1.50300	-1.74417	1.109498	20	0.280378	10	12	0.595708	0.422169	1.991105	0.280148

20m sprint

		T-test for Independent Samples (Spreadsheet1) Note: Variables were treated as independent samples									
Group 1 vs. Group 2	Mean Group 1	Mean Group 2	t-value	df	p	Valid N Group 1	Valid N Group 2	Std.Dev. Group 1	Std.Dev. Group 2	F-ratio Variances	p Variances
20m C vs. 20mE	-0.271000	-0.767500	10.04130	20	0.000000	10	12	0.089747	0.132879	2.192183	0.248624

Medicine ball throw

		T-test for Independent Samples (Spreadsheet1) Note: Variables were treated as independent samples									
Group 1 vs. Group 2	Mean Group 1	Mean Group 2	t-value	df	p	Valid N Group 1	Valid N Group 2	Std.Dev. Group 1	Std.Dev. Group 2	F-ratio Variances	p Variances
Med ball C vs. Med ball E	-0.129167	0.287500	-1.83203	22	0.080521	12	12	0.547498	0.566539	1.070765	0.911751

Push-ups

		T-test for Independent Samples (Spreadsheet1)									
		Note: Variables were treated as independent samples									
Group 1 vs. Group 2	Mean Group 1	Mean Group 2	t-value	df	p	Valid N Group 1	Valid N Group 2	Std.Dev. Group 1	Std.Dev. Group 2	F-ratio Variances	p Variances
Plups C vs. Plups E	0.416667	6.818182	-2.48072	21	0.021661	12	11	6.734691	5.510321	1.493762	0.535113

Plank

		T-test for Independent Samples (Spreadsheet1)									
		Note: Variables were treated as independent samples									
Group 1 vs. Group 2	Mean Group 1	Mean Group 2	t-value	df	p	Valid N Group 1	Valid N Group 2	Std.Dev. Group 1	Std.Dev. Group 2	F-ratio Variances	p Variances
Plank C vs. Plank E	-3.25000	72.00000	-4.81752	22	0.000082	12	12	25.11474	47.92798	3.641841	0.042352

25m shuttle

		T-test for Independent Samples (Spreadsheet1)									
		Note: Variables were treated as independent samples									
Group 1 vs. Group 2	Mean Group 1	Mean Group 2	t-value	df	p	Valid N Group 1	Valid N Group 2	Std.Dev. Group 1	Std.Dev. Group 2	F-ratio Variances	p Variances
5m C vs. 5m E	39.70000	88.33333	-3.71608	20	0.001365	10	12	39.04143	21.24889	3.375819	0.061347

INTERACTION EFFECT STATISTICS

Mass

Repeated Measures Analysis of Variance (Spreadsheet1)					
Sigma-restricted parameterization					
Effective hypothesis decomposition; Std. Error of Estimate: 19,1887					
Effect	SS	Degr. of Freedom	MS	F	p
Intercept	258757,8	1	258757,8	702,7555	0,000000
con	629,8	1	629,8	1,7104	0,203319
Error	8836,9	24	368,2		
TIME	2,6	1	2,6	0,9398	0,342010
TIME*con	0,6	1	0,6	0,2166	0,645827
Error	66,5	24	2,8		

Flexibility

Repeated Measures Analysis of Variance (Spreadsheet1)					
Sigma-restricted parameterization					
Effective hypothesis decomposition; Std. Error of Estimate: 122,1526					
Effect	SS	Degr. of Freedom	MS	F	p
Intercept	128432,0	1	128432,0	8,607322	0,007258
con	2708,2	1	2708,2	0,181497	0,673886
Error	358110,0	24	14921,3		
TIME	4753,3	1	4753,3	3,555046	0,071527
TIME*con	6730,6	1	6730,6	5,033829	0,034352
Error	32089,6	24	1337,1		

Sum of 7skinfolds

Repeated Measures Analysis of Variance (Spreadsheet1)					
Sigma-restricted parameterization					
Effective hypothesis decomposition; Std. Error of Estimate: 44,7591					
Effect	SS	Degr. of Freedom	MS	F	p
Intercept	503792,2	1	503792,2	251,4711	0,000000
con	1375,0	1	1375,0	0,6863	0,415580
Error	48081,1	24	2003,4		
TIME	1700,1	1	1700,1	12,3441	0,001782
TIME*con	1816,3	1	1816,3	13,1883	0,001329
Error	3305,3	24	137,7		

Body fat percentage

Repeated Measures Analysis of Variance (Spreadsheet1)					
Sigma-restricted parameterization					
Effective hypothesis decomposition; Std. Error of Estimate: 6,1121					
Effect	SS	Degr. of Freedom	MS	F	p
Intercept	8058,472	1	8058,472	215,7099	0,000000
con	43,447	1	43,447	1,1630	0,291565
Error	896,590	24	37,358		
TIME	30,384	1	30,384	12,1100	0,001936
TIME*con	32,602	1	32,602	12,9943	0,001421
Error	60,215	24	2,509		

Standing broad jump

Repeated Measures Analysis of Variance (Spreadsheet1)					
Sigma-restricted parameterization					
Effective hypothesis decomposition; Std. Error of Estimate: 0,2407					
Effect	SS	Degr. of Freedom	MS	F	p
Intercept	238,7438	1	238,7438	4119,837	0,000000
con	0,0151	1	0,0151	0,260	0,615371
Error	1,2749	22	0,0579		
TIME	0,0438	1	0,0438	4,309	0,049809
TIME*con	0,0013	1	0,0013	0,128	0,723836
Error	0,2236	22	0,0102		

Illinois agility test

Repeated Measures Analysis of Variance (Spreadsheet1)					
Sigma-restricted parameterization					
Effective hypothesis decomposition; Std. Error of Estimate: 0,7994					
Effect	SS	Degr. of Freedom	MS	F	p
Intercept	11584,44	1	11584,44	18128,09	0,000000
con	4,84	1	4,84	7,57	0,012290
Error	12,78	20	0,64		
TIME	28,76	1	28,76	223,17	0,000000
TIME*con	0,16	1	0,16	1,23	0,280378
Error	2,58	20	0,13		

20m sprint

Repeated Measures Analysis of Variance (Spreadsheet1)					
Sigma-restricted parameterization					
Effective hypothesis decomposition; Std. Error of Estimate: 0,2049					
Effect	SS	Degr. of Freedom	MS	F	p
Intercept	481,7383	1	481,7383	11473,82	0,000000
con	0,2070	1	0,2070	4,93	0,038107
Error	0,8397	20	0,0420		
TIME	2,9413	1	2,9413	441,12	0,000000
TIME*con	0,6723	1	0,6723	100,83	0,000000
Error	0,1334	20	0,0067		

Medicine ball throw

Repeated Measures Analysis of Variance (Spreadsheet1)					
Sigma-restricted parameterization					
Effective hypothesis decomposition; Std. Error of Estimate: 2,1238					
Effect	SS	Degr. of Freedom	MS	F	p
Intercept	2499,853	1	2499,853	554,2272	0,000000
con	12,505	1	12,505	2,7725	0,110078
Error	99,231	22	4,511		
TIME	0,075	1	0,075	0,4847	0,493612
TIME*con	0,521	1	0,521	3,3563	0,080521
Error	3,414	22	0,155		

Push-ups

Repeated Measures Analysis of Variance (Spreadsheet1)					
Sigma-restricted parameterization					
Effective hypothesis decomposition; Std. Error of Estimate: 12,7694					
Effect	SS	Degr. of Freedom	MS	F	p
Intercept	54270,65	1	54270,65	332,8306	0,000000
con	141,52	1	141,52	0,8679	0,362116
Error	3424,22	21	163,06		
TIME	150,20	1	150,20	7,8605	0,010642
TIME*con	117,59	1	117,59	6,1540	0,021661
Error	401,28	21	19,11		

Plank

Repeated Measures Analysis of Variance (Spreadsheet1)					
Sigma-restricted parameterization					
Effective hypothesis decomposition; Std. Error of Estimate: 52,8581					
Effect	SS	Degr. of Freedom	MS	F	p
Intercept	748251,0	1	748251,0	267,8087	0,000000
con	29156,0	1	29156,0	10,4353	0,003846
Error	61467,5	22	2794,0		
TIME	14179,7	1	14179,7	19,3722	0,000226
TIME*con	16987,7	1	16987,7	23,2085	0,000082
Error	16103,1	22	732,0		

25m shuttle

Repeated Measures Analysis of Variance (Spreadsheet1)					
Sigma-restricted parameterization					
Effective hypothesis decomposition; Std. Error of Estimate: 41,8287					
Effect	SS	Degr. of Freedom	MS	F	p
Intercept	20552065	1	20552065	11746,43	0,000000
con	5906	1	5906	3,38	0,081088
Error	34993	20	1750		
TIME	44707	1	44707	95,71	0,000000
TIME*con	6451	1	6451	13,81	0,001365
Error	9342	20	467		