A LONGITUDINAL STUDY ON THE EFFECTIVENESS OF INJURY PREVENTION STRATEGIES ON INJURY EPIDEMIOLOGY OF THE ELITE CRICKET PLAYER

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Soli deo Gloria

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Summary

The primary aim of this study was to evaluate the effectiveness of an injury prevention and training programme for elite cricketers in regard to biomechanical, physical and motor and anthropometric variables over a period of six cricketing off-seasons (1998/1999–2003/2004). A secondary aim was to investigate the injury epidemiology of elite cricket players over a six-season period (1998/1999 – 2003/2004).

A total of 93 cricket players, who were part of the North-West professional cricket squad, were evaluated over a six-season period stretching from the 1998/1999 cricket season to 2003/2004 cricket season. The players were all evaluated at the end of the off-season (middle September) of the commencing season and the injury lists were compiled throughout each playing season. This included all players who needed medical attention due to injury sustained while representing the North-West cricket team in a cricket match.

An analysis was done of literature sources by making use of electronic media, library search and sports medicine journals. Databases such as Pubmed, EbscoHost (academic Search Elite), Sciencedirect, Medline, Eric, Health Source – Consumer Edition, Health Source: Nursing/Academic Edition and SPORTDiscus were used. Special consideration was given to cricket injury epidemiology, injury prevention strategies in cricket, biomechanics in cricket and general injury prevention strategies.

The recorded data were statistically processed and the practical significances were calculated. Three different protocols were followed to evaluate the effectiveness of the injury prevention and training programme. The recorded data were analysed for the six off-season periods (1998/1999–2003/2004, protocol 1) of the study for the biomechanical, physical and motor and

anthropometric evaluations, as well as for the injury epidemiology. The players were then divided into four exposure times (protocol 2) in the study for the biomechanical, physical and motor and anthropometric evaluations. Then the players were divided into two groups (protocol 3), with each group consisting of the same players, and over a three off-season period each evaluated for the biomechanical, physical and motor and anthropometric variables. Lastly, the results for the last three seasons of protocol 1 were compared with the result of the last three seasons of protocol 3 (group 2) for the biomechanical, physical and motor and anthropometric evaluations, as well as for the injury epidemiology.

The results for this study indicate that the injury prevention and training programme was successful in improving and maintaining the biomechanical, physical and motor and anthropometric profile of the cricketers over the six off-season periods (1998/1999–2003/2004). Although all injuries could not be prevented, injuries resulting from structural vulnerability did decrease. Injuries resulting from structural vulnerability (mechanism of injury) decreased from the 1998/1999 season (67,67% of the total injuries suffered during the 1998/1999 season) to the 2003/2004 season (10% of the total injuries suffered during the 2003/2004 season), indicating that the training and prevention programme played a role in the prevention of these injuries. Injury incidence per 10 000 hours of play was 5,82 injuries for the six-season period (1998/1999–2003/2004).

The injury prevention and training programme used in this study can be utilised to improve the biomechanical, physical and motor and anthropometric profile of cricketers. The biomechanical, physical and motor and anthropometric evaluations can also be used as injury prevention strategies by identifying possible injury risk factors as a result of poor biomechanical, physical and motor and anthropometric profiles.

Keywords: Cricket, injury epidemiology, injury prevention strategies, physical fitness evaluation, anthropometrical evaluation, biomechanical evaluation.

Opsomming

Die primêre doel van hierdie studie was om die doeltreffendheid van 'n beseringsvoorkoming- en oefenprogram vir elite-krieketspelers wat betref biomeganiese, fisiese en motoriese en antropometriese veranderlikes oor 'n tydperk van ses krieket-afseisoene (1998/1999–2003/2004) te evalueer. 'n Sekondêre doel was om die beseringsepidemiologie oor 'n tydperk van ses seisoene (1998/1999 – 2003/2004) te evalueer.

Altesaam 93 krieketspelers, wat deel was van die professionele Noordwes-krieketspan, is geëvalueer oor 'n tydperk van ses krieketseisoene wat vanaf die 1998/1999-seisoen tot die 2003/2004-seisoen gestrek het. Die spelers is almal geëvalueer aan die einde van die afseisoen (middel van September) van die seisoen wat daarna 'n aanvang geneem het, en die beseringslyste is deurgaans gedurende elk van die speelseisoene opgestel. Dit het alle spelers ingesluit wat mediese aandag nodig gehad het as gevolg van beserings wat opgedoen is terwyl hulle die Noordwes-krieketspan in 'n krieketwedstryd verteenwoordig het.

'n Ontleding is van literatuurbronne gedoen deur van elektroniese media, biblioteeksoektogte en sportgeneeskunde-vaktydskrifte gebruik te maak. Databasisse soos Pubmed, EbscoHost (Academic Search Elite), Sciencedirect, Medline, Eric, Health Source – Consumer Edition, Health Source: Nursing/Academic Edition en SPORTDiscus is gebruik. Spesiale aandag is gegee aan krieketepidemiologie, strategieë vir die voorkoming van krieketbeserings, biomeganika in krieket en algemene strategieë vir die voorkoming van beserings.

Die data wat opgeteken is, is statisties verwerk en die praktiese betekenisvolheid daarvan is bereken. Drie verskillende protokolle is gevolg om die doeltreffendheid van die beseringsvoorkoming- en oefenprogram te

evalueer. Die opgetekende data is vir die ses afseisoen-tydperke (1998/1999–2003/2004, protokol 1) van die studie ontleed met die oog op biomeganiese, fisiese en motoriese en antropometriese evaluerings, asook vir die beseringsepidemiologie. Daarna is die spelers vir die biomeganiese, fisiese en motoriese en antropometriese evaluerings in vier blootstellingstye (protokol 2) in die studie verdeel. Vervolgens is die spelers in twee groepe verdeel (protokol 3), met elke groep wat uit dieselfde spelers bestaan het, en is elk oor 'n tydperk van drie afseisoene ten opsigte van die biomeganiese, fisiese en motoriese en antropometriese veranderlikes geëvalueer. Laastens is die resultate vir die laaste drie seisoene van protokol 1 ten opsigte van die biomeganiese, fisiese en motoriese en antropometriese evaluerings, asook ten opsigte van die beseringsepidemiologie, met die laaste drie seisoene van protokol 3 (groep 2) vergelyk.

Die resultate van hierdie studie dui daarop dat die beseringsvoorkoming- en oefenprogram suksesvol was daarin om die biomeganiese, fisiese en motoriese en antropometriese profiel van die krieketspelers oor die tydperk van ses afseisoene (1998/1999–2003/2004) te verbeter en in stand te hou. Hoewel alle beserings nie voorkom kon word nie, het beserings wat die gevolg van strukturele swakheid was wel afgeneem. Beserings wat die gevolg van strukturele swakheid was (as meganisme van besering) het vanaf die 1998/1999-seisoen (67,67% van die totale beserings wat gedurende die 1998/1999-seisoen opgedoen is) tot die 2003/2004-seisoen (10% van die totale beserings wat gedurende die 2003/2004-seisoen opgedoen is) gedaal, wat 'n aanduiding daarvan is dat die oefen- en voorkomingsprogram 'n rol in die voorkoming van hierdie beserings gespeel het. Die voorkomssyfer van beserings per 10 000 uur se spel was 5,82 beserings vir die tydperk van ses seisoene (1998/1999–2003/2004).

Die beseringsvoorkoming- en oefenprogram wat in hierdie studie gebruik is, kan benut word om die biomeganiese, fisiese en motoriese en antropometriese

profiel van krieketspelers te verbeter. Die biomeganiese, fisiese en motoriese en antropometriese evaluerings kan ook as strategieë vir die voorkoming van beserings gebruik word deur moontlike beseringsrisikofaktore as gevolg van swak biomeganiese, fisiese en motoriese en antropometriese profiele te identifiseer.

Sleutelwoorde: Krieket, beseringsepidemiologie, beseringsvoorkoming-strategieë, fisieke fiksheidevaluering, antropometriese evaluering, biomeganiese evaluering.

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Chapter 1. Introduction and problem statement, literature survey and research aims

1.1 Introduction and problem statement

In recent years the pattern of sports injuries has gradually changed from acute traumatic injuries such as fractures, dislocations, ligament sprains and muscle tears to overuse injuries such as stress fractures and compartment syndrome. While the acute injuries are still present, it appears as if overuse injuries are becoming increasingly prevalent. This is the result of the increased demands of modern-day sports and the load placed upon musculoskeletal structures by these sports (Brukner & Khan, 2001).

Traditionally cricket has been regarded as a relatively injury-free sport, being classified as a sport with moderate injury risks (Weightman & Browne, 1971). Stretch (2003b) states that the nature of the game of cricket has changed and the demands placed on the cricketer by the game have increased in recent years. "*The sight of cricketers running often leads to muttering and head-shaking among the older brigade of diehards. During the first season in which I used a running programme, I took the Warwickshire players round the boundary at Bradford, where rain had prevented play for that day. As we loped round, several of the Yorkshire players were standing in the bar, with pint pots in their hands, telling us how daft we were. Just a few years later, everyone in the first-class games now takes part in running*" (Willis, 1984:82).

According to McGrath and Finch (1996) the pace of the game, hazards of play and expectations of the players have increased in recent years, resulting in cricketers becoming more injury-prone and leading to an increase in the number

of resulting injuries (Stretch, 2001a; Stretch, 2001c; Leary & White, 2000; Finch *et al.*, 1999).

Although cricket is strictly a non-contact sport, injuries in cricket may occur in a number of ways. Cricket players can suffer from a range of injuries associated with all aspects of the game, including running, throwing, catching, batting and bowling (Finch *et al.*, 1999; McGrath & Finch, 1996). Stretch (2003b) reports that modern-day cricket players have become more at risk to injuries associated with field sports. This can be attributed to the changes in the nature of modern-day cricket and the increased physical demands placed on modern-day cricketers.

Cricket players and the medical support team (doctors, physiotherapists and trainers) are increasingly confronted with injuries during the cricket season (Stretch, 2001c). This creates a situation where the medical support team is under tremendous pressure to keep players injury free and available to play throughout the season (Stretch, 2001a). The aim for the medical support team should therefore be to keep cricketers injury free for as long as possible (Stretch, 2003b).

According to Finch *et al.* (1999) a number of injury prevention strategies are suggested in the literature, and they also state that few studies have been done that formally assessed the effectiveness of these injury prevention strategies. With little knowledge available on the implications of excessive bowling, playing surfaces and physical preparation, more research into these aspects is needed (Gray *et al.*, 2000). Little research or literature is available on the role of physical motor, anthropometric and biomechanical components in the prevention of cricket injuries. It therefore seems that there is a need for research in this area of cricket.

1.2 Literature study

Injury is a multifaceted problem, requiring a multidisciplinary approach to find and implement effective solutions. Although certain injuries cannot be avoided, some are avoidable, or at least the severity of the injury can be reduced (Whiting & Zernicke, 1998).

Modern-day cricket players are expected to train harder and longer if they are to succeed at the elite level. Not only do modern-day cricketers spend more time developing their technical skills, they also need to possess a high level of physical fitness. This preparation of the modern-day cricketer makes him susceptible to overuse injuries as a result of repetitive training for a sport that is placing increasingly greater physical demands on the player. The game of cricket is very repetitive by nature, and often for long periods of time (Stretch 2003b). The hours of repetitious practice therefore plays a role in the deterioration of the functional capacity of the body (Stretch, 2003b; Elliott *et al.*, 1993; Micheli, 1983; Harvey 1983). Like a chain, the human body will only be as strong as its weakest link, and the weakest link will reveal itself when stressed daily through its range of motion (House, 1996).

In the study of Stretch (2001b), the most common injury mechanism in cricket was found to be overuse. Stretch (2001a) states that overuse injuries are a major reason why young cricket players are forced to miss large parts of the cricket season, which impacts negatively on their development as young cricketers.

Modern-day cricket demands greater physical effort from cricket players during the season (Stretch, 2003b). The medical support personnel need to adapt to these changes as well as develop the necessary tools that will allow them to prevent, assess and treat cricket injuries as efficiently as possible (Tillman *et al.*, 2002; Mullin & Skolfield 2001; Finch *et al.*, 1999). Many cricket injuries result from the interaction of a range of different factors (Stretch, 2001a; Finch *et al.*, 1999; Elliott *et al.*, 1989).). These factors include inadequate physical

preparation, inadequate physiological preparation (aerobic and anaerobic capacity), postural defects, technique faults and repetitive movements (Stretch, 2001c; Foster *et al.*, 1989). While a single mechanism may be responsible for a particular injury, mechanisms often act in combination (Whiting & Zernicke, 1998). The necessity for injury prevention strategies, structures or countermeasures to prevent unnecessary cricket injuries becomes increasingly prevalent (Belle-Jenje, 2003).

Employing a screening mechanism to assess athletes' susceptibility to injury could potentially decrease the incidence of injury (Mullin & Skolfield, 2001; Stone, 1996). One of the aims of screening athletes is to assess the presence of any predisposing factors to musculoskeletal injury, such as a lack of flexibility, muscle weakness, muscle imbalances, impaired proprioception and abnormal biomechanics. According to Brukner and Khan (2001) biomechanical abnormalities are one of the major causes of overuse injuries, therefore it is important to include biomechanical evaluations of the musculoskeletal system in the assessment of overuse injuries (Wilder *et al.*, 2001). The inclusion of physical evaluations gives an indication of whether the cricketer is properly conditioned for the rigours of the game and plays an important role in the prevention of injuries (Headley, 2003).

Anthropometric evaluation is also included as it has been shown through research that certain sporting codes tend to develop their own morphological identities and that these identities need to be present for one to be successful in the particular sporting code (Bloomfield *et al.*, 1994; Houtkooper & Going, 1994). This information can be helpful to evaluate if a player possesses the morphological build that is needed to participate in a particular sport and prevent injuries from occurring (Bloomfield *et al.*, 1994). The assessment of athletes' body composition is an important aspect in their physiological preparation with a view to injury prevention (Woolford *et al.*, 1993).

Screening provides an opportunity for the medical support team (doctors, physiotherapists and trainers) to offer advice regarding the prevention of injuries (Brukner & Khan, 2001). Finch *et al.* (1999) states that injury prevention strategies are measures that can counter that which is present or reduce the risk of injury and that the different links in the chain of events leading to an injury should be targeted as part of the injury prevention strategies.

Injury prevention strategies for cricket according to Finch *et al.* (1999) may be specific to cricket, or they may be generic. Specific injury prevention strategies may include important skills and techniques to prevent overuse injuries, and protective equipment to prevent impact injuries. The generic injury prevention strategies may include physical preparation, environmental conditioning, modified rules, first aid and appropriate rehabilitation to reduce the recurrence of an injury. The use of generic injury prevention strategies could prevent a wide range of injuries. Crisp and King (1994) state that cricket players are not always in peak physical condition and if greater emphasis is placed on improving their physical preparation it will reduce the possibility of injury. This is supported by Noakes and Durandt (2000) with the statement that superior physical preparation will be a factor in determining the longevity of a cricketer in the game. Finch *et al.* (1999) and Schwellnus and Derman (1996) stated that an important injury prevention strategy for a cricketer is a comprehensive physical conditioning programme before and during the season.

If one considers that cricket is one of the world's most popular team sports, quite limited amounts of literature on epidemiology mechanisms and prevention of cricket injuries is available (Orchard *et al.*, 2002; Leary & White, 2000; *Finch et al.*, 1999). In recent years major areas of concern have been impact injuries to the head, face and fingers, and injuries to the back (Stretch, 2001b). The focus in most research papers has been on determining the efficacy of a particular treatment approach or testing device in the context of rehabilitation of the injured athlete (Finch, 2001; Harter, 1996; Kibler *et al.*, 1989), with few evaluative

programmes that are actually aimed at injury prevention (Mullin & Skolfield, 2001). Therefore much more research needs to be done to have a full scientific understanding of the game of cricket. Bartlett (2003) and Belle-Jenje (2003) emphasise the need for more research to be done into injury mechanisms, fitness demands and injury prevention strategies, as well as their effectiveness.

1.3 Research aims

Research aim one.
The effectiveness of an injury prevention and training programme on biomechanical, physical and motor and anthropometric variables of elite cricket players over a six-season period (1998/1999–2003/2004).

Research aim two.
Injury epidemiology of elite cricket players over a six-season period (1998/1999–2003/2004).

To investigate research aim one, the effectiveness of the training and prevention programme, three different protocols were used to ensure that variables that could have played a role in the effectiveness of the injury prevention and training programme were controlled as much as possible. As part of the first protocol, all elite players were evaluated at the end of the off-season injury prevention and training programme (middle September) irrespective of the number of times they had been exposed to the injury prevention and training programme.

The reason for this protocol was that the more cricket players were exposed to the injury prevention and training programme, the more significant the results became. With this method it was also ensured that cricket players who had previous experiences of an injury prevention and training programme, players with no previous experience of an injury and prevention and training programme, players with serious shortcomings/defects in their biomechanical, physical and

motor and anthropometric profiles, players with and without injury, etc. were all part of the trial. This method also ensured that the practical situation experienced in modern-day cricket, namely the heterogeneity of the different variables that can play a role in the profession of elite cricket players, was addressed. Also this protocol was suggested by the senior statistician of the North-West University as the most applicable for this study. Several similar studies (Hattingh, 2003; Stretch 2003b; Orchard *et al.*, 2002; Leary & White, 2000) used this type of protocol and found this research methodology applicable to the science involving the study of elite sport.

A second protocol involved dividing players into groups that were exposed to the injury prevention and training programme for the first time, second time, third time and fourth time to evaluate their results. Thus for example if a player was drafted into the North-West professional squad in the 2001/2002 season and exposed to the training and prevention programme for the first time, his results were included with those of the other players that were exposed to the injury prevention and training programme for the first time (first exposure time) and not with the results of the players in for example the fourth exposure (i.e. players that were evaluated for the fourth time). The same procedure was followed for all players.

The third protocol involved monitoring the results of two different groups of players over a three-season period, each group consisting of the same players over time. This protocol can be seen as two different case studies. As a result of professionalism that exits in the sport, players move to other provinces or lose their contracts, which makes it difficult to monitor the same group of players for long periods. The numbers in the case studies were small but due to the fact that the study was done on elite cricketers, small numbers were acceptable due to the nature of the case study. The two case study groups were each evaluated over a period of three seasons because changes in the composition of the

groups meant that one group could become very small over the period of six seasons.

The results of the different protocols were firstly investigated individually and compared with each other to determine the effectiveness of the injury prevention and training programme in elite cricket players. The injury prevention and training programme did not just comprise physical training but also included passive training exercises (see annexure 3.5, p. 331). Biomechanical differences can be rectified with passive activities, which is the reason for the thorough biomechanical evaluation suggested by Hattingh (2003), Belle-Jenje (2003) Watson (2002) and Mullin and Skolfield (2001).

The second aim of this study was to investigate the epidemiology of cricket injuries among elite cricket players over the six-season period.

1.4 Method of investigation

1.4.1 Review of literature sources

Databases such as Pubmed, EbscoHost (academic Search Elite), Sciencedirect, Medline, Eric, Health Source – Consumer Edition, Health Source: Nursing/Academic Edition and SPORTDiscus were used. The focus was on cricket injury epidemiology, injury prevention strategies in cricket, biomechanics in cricket and general injury prevention strategies in particular.

1.4.2 Empirical investigation

1.4.2.1 Choice of participants

In this study, data of a total of 93 elite cricket players collected over a six-season period (1998/1999–2003/2004 seasons) were analysed. The North-West professional cricket squad was used as participants over the six-season period.

1.4.2.2 Test battery

From the literature numerous tests, analyses and protocols were obtained to identify and select important tests that have been proven to be advantageous to a high level of performance, and also specifically to evaluate the effectiveness of the injury and prevention programme. Three different test evaluations were used in gathering the data, and these are fully described in Chapter 3. They were:

1.4.2.2.1 Biomechanical evaluation of the musculoskeletal system (which will in the rest of this study be referred to as "the biomechanical evaluation")

The first set of evaluations used can be classified under biomechanics as used by Hattingh (2003) and Watson (2002). The biomechanical assessment protocol used to evaluate the players was divided into the following five body aspects: (1) lower limb, (2) pelvic girdle, (3) spinal column, (4) upper limb, and (5) neurodynamics (Hattingh, 2003).

1.4.2.2.2 Physical and motor evaluation

The second set of evaluations was done to evaluate the physical and motor attributes of the cricketers and consisted of: (1) multistage fitness test: shuttle run test (Ramsbottom *et al.*, 1988; Leger & Lambert, 1982); (2) sit-and-reach test (Kirby, 1991); (3) abdominal strength test (Kendall *et al.*, 1993,); (4) one minute oblique sit-up test: left and right anatomical side (Gray & Gray, 2001; United Cricket Board South Africa, 2001); (5) one minute push-up test (Jamison, 1994);

(6) run a three test (Jamison, 1994); (7) 505 agility test (Jamison, 1994); and (8) 5 metre multiple shuttle test (Boddington *et al.*, 2001).

1.4.2.2.3 Anthropometric evaluation

Certain anthropometric measurements needed to be substituted in the formulas that were used in order to calculate the body fat percentages, as well as to make the morphological calculations. Therefore these measurements are described and noted.

The third set of evaluations was done to determine the anthropometric status of the cricketers. The body fat percentage formula of (Whiters *et al.*, 1987) was used to calculate body fat percentages. This method is specifically recommended for the calculation of body fat percentages in sportspeople. To calculate the fat percentage, the following measurements were taken: age and body weight, as well as the triceps, subscapular, supraspinal, abdominal, mid-thigh and calf skinfolds.

The Carter & Heath anthropometric method was used to determine the somatotypes of the participants, namely ectomorphy, endomorphy and mesomorphy (Carter & Heath, 1990:409). To calculate these, the following measurements were taken: body stature, body weight, humerus breadth and femur breadth, biceps circumference and calf circumference, and triceps, subscapular, supra-spinal and calf skinfolds.

1.4.3 Test procedure

Three protocols were followed, as referred to in 1.3 under Research aims, and are fully described in Chapter 3.

The test procedure over the six seasons (1998/1999–2003/2004) was as follows:

During the off-season period (18 weeks, 1 May to middle of September, of each season) an injury prevention and training programme was followed by the cricketers. The effect of this injury prevention and training programme on the biomechanical, physical and motor and anthropometric variables was evaluated at the end of the off-season (middle September, see p.112 Chapter 3). The cricketers were evaluated at the North-West Cricket grounds. The biomechanical evaluations were done by the physiotherapist and fitness trainer of the North-West Cricket Board. The physiotherapist held a master's degree in Sports Medicine and the trainer a master's degree in Human Movement Science. The physical and motor evaluations and anthropometric evaluations were done by the fitness trainer of the North-West Cricket Board and a qualified sport scientist.

Biomechanical evaluations were done in the same order as described in Chapter 3, and it was also ensured that the players were not involved in any strenuous activities prior to the evaluation which could influence the results negatively, nor in any exercises that could influence the results positively. Players were evaluated when they were rested. Similar methods were followed with the physical and motor and anthropometric evaluations. The anthropometric evaluations were done first, in the mornings, after which the physical and motor evaluations were done. Enough recovery time was allowed between each of the physical and motor evaluations to ensure the players were rested when the next evaluation was done.

The injury incidence was recorded throughout the season. The injury results were kept by the physiotherapist of the North-West Cricket Board and were in the same format as the results provided to the medical research committee of the United Cricket Board of South Africa.

The results of the biomechanical, physical and motor and anthropometric evaluations, as tested every season at the end of the off-season (middle

September, 1998/1999–2003/2004), as well as the injury incidence of each season (at the end of each season 1998/1999–2003/2004) were used to make the necessary adjustments for the next season where shortcomings were identified in the injury prevention and training programme. During the official cricket playing season (estimated at 34 weeks, from middle October to middle March) a maintenance programme was followed by the cricketers, but not monitored as it was not part of this study. The details of the maintenance programme that was followed during the playing season can be viewed in annexure 3.5, p.383.

The injury prevention and training programme consisted of gymnasium training, both active and passive. The exercises in the gymnasium were used to develop or improve the existing posture of the cricketer, to develop the necessary core stability, scapula stabilisers and shoulder position and the necessary flexibility of all the body areas. The development of the necessary physical fitness levels, as well as the reduction or maintenance of body fat percentages and somatotypes, needed for the game of cricket also formed part of the injury prevention and training programme (see p.331, annexure 3.5).

1.4.4 Statistical data processing

After consultation with the senior statistician of the North-West University it was decided to report the results as follows: The statistical analysis was done with the help of the SAS statistical program, SAS Institute Inc., 1999. The SAS system for Windows release 8.02 TS Level 02M0 Copyright 1999-2001 by SAS Institute Inc., Cary, NC, USA (SAS Institute Inc., 1999) was used. The mean value, as well as the standard deviation, was calculated with the help of the SAS statistical program. Furthermore the SAS statistical program was used to determine practically significant differences (d-values) for each of the strategies employed over the six-season period covered in this study.

Chapter 2. Literature survey

2.1 Introduction

The ability to participate in sports at the highest level without injury depends on a host of different factors. Factors such as genetic endowment and environmental conditions cannot be altered, while psychological factors are difficult to measure but may be modified with the appropriate psychological programme. Physiological factors, strength, speed and flexibility, can be measured and can be altered by appropriate training (Kibler *et al.*, 1989). To ensure a high level of athletic performance and decrease the potential risk of injury, attention should be given to general medical fitness and sport-specific physiological variables (Kibler *et al.*, 1989). Although cricket is one of the oldest organized sports, there is a relative lack of scientific research on the sport or its players. There are few studies on the specific physiological, biomechanical or anthropometric attributes of the top-class cricket player (Noakes & Durandt, 2000).

The literature survey, in accordance with the research aims, focuses on the main aspects of the study, namely the biomechanical evaluation, physical fitness evaluation, anthropometric evaluation and injury epidemiology.

The biomechanical evaluation evaluates the whole athlete (Wilder *et al.*, 2001) in order to identify critical biomechanical variables that may predispose an athlete to injury or a lesser performance (Dillman *et al.*, 1993). Kibler (1989) makes the statement that biomechanical variables should target areas of athletic fitness that are specific to a particular sport, where a lack of such fitness may predispose an athlete to injury. Faulty biomechanics may result from abnormalities, comprising both static (anatomical) abnormalities or functional (secondary) abnormalities. Brukner and Khan (2001) indicate that abnormal biomechanics should always be considered as a potential cause of sports injuries.

It is stated by different authors (Belle-Jenje, 2003; Mullin & Skolfield, 2001; Finch *et al.*, 1999) that a thorough biomechanical evaluation (including a postural evaluation) of the cricketer is an important tool in injury prevention. Similar statements have been made regarding the evaluation of physical fitness (Noakes & Durandt, 2000; Crisp & King, 1994), and anthropometric evaluation (Houtkooper & Going, 1994; Woolford *et al.*, 1993).

Parkkari *et al.* (2001) report that one of the most common injuries suffered in modern-day societies are sports injuries. Competitive sport, school sport, recreation activities and fitness activities are just part of the wide range of activities that are responsible for sports injuries (Cassell *et al.*, 2003). Hrysomallis and Morrison (1997) state that with participation in competitive sports the risk of potential injury will increase. Dalton (1992) also states that with increased participation in competitive sports, the incidence of injuries (both acute and overuse injuries) increases.

It has been found in New Zealand that rugby union has the highest injury rate of all major sports played in New Zealand (Gerrard *et al.*, 1994; Hume & Marshall, 1994). D'Souza (1994) found the injury incidence in track and field events to be as follows: 67,5% of athletes who participated in sprinting events suffered injuries, 66,7% of athletes who participated in hurdling events, 62,5% of athletes who participated in long distance running events, 61,9% of athletes who participated in throwing events and 52,6% of athletes who participated in jumping events. In Sweden it was found that soccer accounted for 42% of all sports-related visits to the emergency room serving a the population of a whole municipal area (De Loës, 1990). Finch *et al.* (1998) found Australian football to have the highest number of injury presentations in the period 1983–1993, with 21,6% of injuries in total. Soccer was second with 10,0% of the total injuries and cricket was fifth with 7,3% of the total injuries suffered by adults leading to emergency department visits.

Sports injuries are identified as a significant health issue with impacts beyond just elite athletes or the delivery of medical care (Cassell *et al.*, 2003; Finch & Owen, 2001). Finch and Owen (2001) state that a strong preventative approach is needed if injury rates in sport are to be reduced and performance and participation are to be increased. Treatment of sports injuries tends to be expensive, and sometimes difficult and time-consuming, so that from both a medical and an economic perspective, the employment of injury prevention strategies is justified (Parkkari *et al.*, 2001).

As a result of this paradigm shift in the thinking about sports injuries and the factors that may lead to the occurrence of sports injuries (Finch, 2001), sports-injury epidemiology has emerged as a sub-discipline in its own right (Caine *et al.*, 1996; Meeuwisse, 1994; Van Mechelen *et al.*, 1992). Whiting and Zernicke (1998) define epidemiology as the study of the incidence, distribution and control of disease and injury in a given population. Injury incidence is defined by Van Mechelen *et al.* (1992) and Steiner *et al.* (1989) as the number of new injuries in a fixed time period divided by the number of people at risk. Incidence as described by Van Mechelen *et al.* (1992) gives an estimate of risk that occurs in a given sport or population.

The next section discusses the biomechanical evaluation and the kinetic chain.

2.2 Biomechanical evaluation and kinetic chain

The importance of the biomechanical evaluation will be described below. The biomechanical evaluation serves various purposes: (1) to identify potential risk factors that may predispose an athlete to injury, hence the thorough biomechanical evaluation employed in this study; (2) to identify if the structures (e.g. injury prevention and training programme) that were put in place were successful in improving for example the biomechanical profile of an athlete, specifically in this study the elite cricketer; (3) to identify shortcomings in the structures (e.g. injury prevention and training programme) that were put in place

and where adjustments should be made in the structures; and (4.) to identify if an improved biomechanical profile played a role in injury prevention.

In conjunction with the biomechanical evaluation the kinetic chain will be described and discussed. The kinetic chain and the biomechanical evaluation together describe how structures are linked to each other and what their roles are in injury prevention. Some of the information in the biomechanical evaluation will be repeated in the kinetic chain description. This will be done to indicate how these two aspects are interlinked in injury and injury prevention.

2.2.1 Biomechanical evaluation

Schwellnus and Derman (1996) report that up to 50–60% of all high-level athletes, including cricketers, suffer some sort of injury during a sports season. Stretch (2003b) makes the statement that injury prevention strategies should be put in place to help reduce the injury rate and to ensure that cricket players are injury-free for extended periods throughout the cricket season. A thorough biomechanical evaluation of an athlete is seen as an important tool in injury prevention for the cricketer (Belle-Jenje, 2003; Mullin & Skolfield, 2001; Finch *et al.*, 1999).

Elliott (1999) identifies biomechanics as one of the disciplines of the field of Human Movement and Exercise Science and states that it can be divided into three broad categories from a research perspective, as follows: (1) clinical biomechanics, involving research in the areas of gait, neuromuscular control, tissue mechanics and movement evaluation during rehabilitation from either injury or disease; (2) occupational biomechanics, involving research in the areas of ergonomics and human growth or morphology and how they influence movement; and (3) sports biomechanics, which is in turn divided into the following three broad categories: technique modification for movement enhancement (such as matching impulse curves in rowing); stress and injury reduction (such as the assessment of the knee joint during downhill walking or

internal rotation of the upper arm in hitting or throwing); and equipment design (to optimise performance and reduce injury through protective gear).

Elliott (1999) further states that biomechanical research may play a vital role in reducing sports injuries suffered in a particular sport, as well as in reducing the severity of injuries suffered in the particular sport. This may include identifying the causes of back injuries suffered in cricket and what can be done to prevent this injury from happening, as well as what can be done in order to prepare the player better and decrease the severity of the injury when suffered.

Agosta (2001) reported that biomechanical evaluation of the musculoskeletal system of the athlete (cricketer) and its association with injuries are still in the beginning phase. Scientists are making more and more clinical associations between biomechanical abnormalities and their role in injury occurrence. Elliott (1999) states that biomechanical research into sports injury and reducing sport injuries requires conclusions being made from different factors, such as kinetics of activity, incidence of pain, site and type of injury. Therefore sporting injuries could occur as a result of overuse, poor technique or poor physical preparation.

Brukner and Khan (2001) state that biomechanical abnormalities are one of the major causes of overuse injuries therefore it is very important to include biomechanical evaluation in the assessment of players, abnormalities such as muscle tightness, muscle weakness, joint stiffness and increased neural tension. Wilder *et al.* (2001) states that subtle changes in the normal functioning of a joint, muscle strength deficits or imbalances, shortening of the musculotendinous segment (a tight muscle) are factors that may go undetected, which may influence normal movement and lead to potential injury. Faulty biomechanics may result from either static (anatomical) abnormalities or functional (secondary) abnormalities. Abnormal biomechanics should always be considered as a potential cause of sports injuries (Brukner & Khan, 2001). Static abnormalities can be a true leg-length discrepancy or genu valgum, and these abnormalities' secondary effects can be corrected by a shoe build-up or orthotics. Functional

abnormalities can be from a poor technique (Agosta, 2001). According to Brukner and Khan (2001) a major factor in injury prevention in sport is correct biomechanics in its various forms, as described by Elliott (1999).

Agosta (2001) identified three main biomechanical abnormalities that affect lower limb biomechanics, namely: (1) excessive pronation; (2) excessive supination; and (3) abnormal pelvic movement. The most common abnormalities that influence abnormal pelvic movement are as follows: (1) excessive anterior tilt of the pelvis; (2) excessive lateral tilt of the pelvis; and (3) asymmetrical pelvic movement. Biomechanical abnormalities (asymmetries) can be corrected with the appropriate muscle stretching and muscle strengthening, as well as retraining.

Biomechanical abnormalities associated with injury are: anterior pelvic tilt which plays a role in hamstring strain injuries, illiotibial band friction syndrome resulting from a lateral pelvic tilt, Achilles tendinopathy resulting from a pronated foot, patellar tendinopathy as a result of anterior pelvic tilt and tight quadriceps, hamstrings and calves (Agosta, 2001). Elliott (2000) found that bowlers with a low longitudinal arch were more likely to develop a stress fracture of the lumbar vertebrae. Elliott *et al.* (1992) reported that bowlers with poor hamstring flexibility displayed an inter-vertebral disc abnormality. Moreland (1994) found that with a clinical presentation of spondylolysis or spondylolisthesis in young bowlers, in addition to pain, there was evidence of hamstring tightness.

The biomechanical evaluation looks at the whole athlete and the design should be at the level of the basic physiological variables of muscle function, as all aspects of muscle function are used in varying combinations in different sports (Wilder *et al.*, 2001; Dillman *et al.,* 1993; Kibler *et al.*, 1989).

Various authors (Belle-Jenje, 2003; Schwellnus & Derman, 1996; McGrath & Finch, 1996) state that to reduce the risk of injury and re-injury, cricket players should be encouraged to undergo regular thorough postural and biomechanical evaluation of the musculoskeletal system in order to identify any inherent

problems. The thorough postural and biomechanical evaluation of the musculoskeletal system according to Stretch (2001a) should be carried out pre-, in- and post-season to allow for the implementation of effective injury prevention and rehabilitation programme, and also to ensure the appropriate maintenance programme is being followed to minimize the potential risk of injury as a result of faulty biomechanics and to correct the faulty biomechanics identified by the postural and biomechanical evaluation of the musculoskeletal system (Schwellnus & Derman, 1996). McGrath and Finch (1996) recommend as an injury prevention strategy that fast bowlers should undergo a pre-participation posture and biomechanical evaluation of the musculoskeletal system and that these evaluations should be an ongoing process.

The pre-season biomechanical evaluation of the musculoskeletal system plays a very important role in reducing the risk of potential injury as well as the severity of injury by identifying physical factors predisposing to injury, such as deviations or imbalances in posture, body alignment, muscular strength, balance and flexibility. The gathered information can be used to recommend the appropriate rehabilitative (injury prevention) procedures or adjust the programmes being used to minimize the potential risk of injury (Kibler *et al.*, 1989). Different authors (Wilder *et al.*, 2001; Cowan *et al.*, 1996; Watson, 1995 Kibler *et al.*, 1989) state that the pre-season biomechanical evaluation should focus on those aspects of athletic fitness (physical and anatomical) that can be measured easily and efficiently and that are most directly related to a particular group of athletes. According to Kibler *et al.* (1989) the majority of sports-related injuries occur in muscles, as muscles are the basic anatomical and physiological unit in sports performance. The pre-season biomechanical evaluation according to Allman *et al.* (1983) should be a process that assists the athlete to achieve an optimal level of performance before the specific sports season starts.

The information gathered by a thorough biomechanical evaluation of the musculoskeletal system could be used to develop a sport-specific profile of possible problem areas that may lead to potential injury risk for each cricketer.

This profile can then be used to develop the necessary injury prevention and training programmes to improve the biomechanical profile of the cricketers so as to minimize the potential risk of injury, to improve performance of the cricketers as well as to reduce the number of injuries they suffer and the severity of the injury suffered. Additionally, the injury prevention and training programme may be adjusted where necessary and the necessary orthotics can be identified by the biomechanical evaluation.

Next follows a discussion of the kinetic chain, the role the kinetic chain plays in sports activities and how the kinetic chain and the biomechanical evaluation are integrated.

2.2.2 Kinetic chain

All athletic activities (running, jumping, throwing stopping or kicking) involve the movement of joints and limbs in co-ordinated ways to perform a task. The task might be throwing a ball, hitting a ball or jumping over an object. To allow for efficient execution of the specific tasks, the individual body segments and joints, collectively called links, must move in specific sequences (Brukner & Khan, 2001). The sequencing of the links is called the kinetic chain of an athletic activity (Mullin & Skolfield, 2001; Kibler, 1998).

According to Brukner and Khan (2001), the basic organization of each kinetic chain stays the same although each kinetic chain has its own sequence. The basic organization includes proximal to distal movement in a sequenced order, proximal base of support or core control and the successive activation of each segment of the link and each successive link. This results in the generation of force and energy in each link and in efficiently transferring the force and energy developed in each link to the terminal link. In sports where a high velocity, yet control, of an implement is required, a number of body segments must be co-ordinated in such a way that this high velocity is achieved at impact or release.

The progressive movement of segments participating in high-velocity striking or throwing skills is generally sequenced in a proximal to distal fashion. That is, the sequence of the segments involved in a movement if maximal hand velocity is to be achieved would be the lower limbs and trunk, followed by upper arm, forearm and then the hand (Brukner & Khan, 2001; Mullin & Skolfield, 2001; Kibler, 1998). One of the most popular principles underlining the description of this sequencing in sports movements is the summation of velocity principle (Bunn, 1972), which suggests that the velocity of the distal end of a linked system is built up by summing the individual velocities of all segments participating in the sequence.

Injuries or adaptations in some areas of the kinetic chain may result in problems or injuries not only at the specific segment but also beyond the segment (distally), leading to the compensation of the distal links, resulting from the lack of force and energy delivered through the more proximal links (Brukner & Khan, 2001; Mullin & Skolfiled, 2001). Thus by breaking down the movement into links, a cause of injury could be identified.

Calculations done by Kibler and Chandler (1995) showed that if a 20% decrease in kinetic energy delivered from the hip and trunk to the arm is experienced, an increase of 80% in mass or a 34% increase in rotational velocity will be needed by the shoulder to provide the same amount of resultant force, as compared to when the deficiency was not present. The repeated use of the shoulder, with a 20% decrease in kinetic energy, may cause a problem as the required adaptation is relatively large. If an unstable scapula is also present, in addition to the decrease of 20% in kinetic energy, there will not be a stable base for glenohumeral rotation as the link sequencing unfolds. The result will be an arm functioning off an unstable base, leading to a decrease in the mechanical efficiency of the entire structure.

Examples of how the biomechanical evaluation and the kinetic chain are integrated in throwing:

Huijbregts (1998) states that the overhead throwing motion is a total body motion with a host of injury causative factors throughout the kinetic chain.

Kibler (2001) describes throwing, which is a whole-body activity, as follows: "throwing begins with drive from the large leg muscles and rotation of the hips, progressing through the segmental rotation of the trunk and shoulder girdle. It continues through a 'whip-like' transfer of momentum through elbow extension and through the small muscles of the forearm and hand, transferring propulsive force to the ball".

Kibler (1998) states that the kinetic chain is the most efficient system to deliver developed energy and force to the hand. The scapula and shoulder are important in their role as links in the chain, directing the forces from the legs and the trunk (larger segments) to the rapidly moving segments of the arm (smaller segments). Any deficiency in the motion or position of the scapula will lead to the transmission of the forces generated from the lower extremity to the upper extremity being compromised. This means that the resultant maximum force that can be delivered to the hand will be reduced and a situation created where the more distal links must work at a higher level of activity to compensate for the loss of the proximally generated force, something that is also known as "catching up". This will give rise to a situation where the load or stress is much higher than the distal link can safely handle, because the distal links may not have the size, the muscle cross-sectional area or the time in which to efficiently develop the larger forces now requited to perform the task. All of these factors may result in anatomic or biomechanical situations that increase injury risk, perpetuate injury patterns or decrease performance (Brukner & Khan, 2001; Mullin & Skolfield, 2001; Kibler, 2001).

Thus by following the chain of events along the kinetic chain to where the injury occurred, a possible mechanism of injury can be identified. By using the biomechanical evaluation in conjunction with the knowledge of the kinetic chain,

the possible site of origin of an injury can be identified. This will be further explained below in the evaluation of the scapula.

Kibler (1998) stated that the evaluation of the scapula in the throwing action needs to be along the kinetic chain, locally and distantly. The evaluation should further include the evaluation of the legs, back and trunk, the degree of lumbar lordosis, leg-length asymmetry and any hip rotational abnormalities. It should also include thoracic and cervical posture, as excessive thoracic kyphosis or scoliosis can have a direct relationship to the motion of the scapula, while the presence of cervical lordosis can also indicate the amount of posterior cervical tightness, which can have an effect on scapular retraction and protraction. Any abnormalities must be noted. Kibler,(1998) further emphasises the importance of the role of the leg and trunk muscles in throwing activities and points out that any inability to achieve normal motions or generate normal velocity in the lower extremity or trunk can affect the transfer of force to the scapula and the arm (Watkins *et al.*, 1989). Kibler (2001) also stresses the importance of assessing the scapula-humeral, trunk, legs and shoulder mechanics in the throwing athlete. Wilder *et al.* (2001) report that any functional asymmetries, muscular imbalance, inflexibility patterns, malalignment and poor foot mechanics can all potentially lead to injury.

All the above aspects are part of the internal risk factors that may lead to overuse injury. By using biomechanical evaluation, the possible injury-causing areas can be identified and rectified by the appropriate training measures.

Dillman *et al.* (1993) reported the internal rotation of the upper arm, in many over-arm and side-arm movements, as a key factor in the development of endpoint speed. The internal rotation of the upper arm occurs very late in the kinetic chain and can generate a large percentage of endpoint speed at either impact or release. Elliott (1999) therefore states that training and rehabilitation programmes employed must be examined and adapted for better preparation of

the shoulder region to the demands placed on the shoulder by endpoint speed, and to protect this area from injury.

Bloomfield *et al.* (1994) describe fast bowling as an impact activity in which the bowler experiences a series of 'collisions' or minor impacts with the grass surface in the run-up. This is followed by two heavy impacts when landing on the rear foot and then on the front foot, on a very hard turf or concrete surface during the delivery stride. Peak vertical ground reaction forces of approximately five times the bowler's body weight have been recorded when the front foot is planted and these impact forces are transmitted through bones, cartilages, tendons and muscles to the joints of the body.

Mullin and Skolfield (2001) emphasize the importance of gaining insight into the intricacies of true kinetic chain dysfunction, stating that it is the key to injury prevention. In throwing (as in batting, bowling, fielding and running in cricket), a series of movements is carefully balanced along the kinetic chain with little room for adjustments. If any compensatory patterns are introduced, especially early in the task, a series of adjustments has to be made by the body to complete the task or process. This disruption along the kinetic chain of a specific sports movement can result in injury at or beyond the segment. By using the kinetic chain, the injury pattern can be traced by using the movement sequence of the specific sports task or process. If the movement sequence is then compared with the biomechanical evaluation, the cause of the injury can be identified. This may consist of factors such as muscular strength deficiencies, muscle imbalances, postural faults and inflexibility along the kinetic chain of movement for a particular sports task or process.

The use of the biomechanical evaluation and kinetic chain together as part of an injury prevention strategy by identifying potential injury causes could possibly decrease injury incidence in cricket.

In the next section components of physical fitness and motor evaluations will be described.

2.2.3 Physical fitness and motor evaluations

Several factors are fundamental to the quality of performance in the game of cricket: skill, correct mental approach and physical fitness (Headley, 2003; Bourdon *et al.*, 2000; Jamison, 1994; Stretch & Buys, 1991). Cricket is a largely technical game (Bull *et al.*, 1992), as well as a game which requires the player to concentrate for extended periods of time. High physical fitness on its own cannot fully compensate for this aspect of cricket (Noakes & Durandt, 2000), although at the highest level physical fitness is being increasingly acknowledged as centrally important to top-level performance (Bull *et al.*, 1992).

Whiting and Zernicke (1998) state that a person's physical condition is a primary factor in his or her chances of suffering an injury. A physically better-condition person may decrease the likelihood of injury, and if an injury does occur, the severity of injury in a better-conditioned person will be less and recovery time shorter. Jamison (1994) and Foster and John (1989) state that injury can be the result of poor physical preparation. Historically, as Bartlett (2003) reports, cricket is not a game associated with high fitness except, perhaps, for fast bowlers. Bull *et al.* (1992) reported the lack of detailed research into the physical demands of cricket.

Noakes and Durandt (2000) report that one of the earliest studies to attempt a physiological analysis of the demands of international five-day test match cricket was that of Fletcher (1955). The data were collected during the 1953 Ashes Test series between England and Australia and were used in attempt to predict the average energy expenditure of the international cricketers involved in that competition. The data Fletcher recorded showed that the mean energy expenditure of the average test cricketer was slightly more than the energy expended when standing normally. It also showed that the mean energy expenditure was somewhat higher when batting and bowling, but still lower than the energy needed to walk at 6 $km.h^{-1}$. The results also indicated that when the cricketers had a net practice the energy expenditure was higher than that

achieved in playing tennis (the popular sport at the time of the study). The result therefore may have confirmed the perception that cricket is a undemanding sport.

To illustrate this point further, the calculations made by Fletcher (1955) show the following: The mean daily physical activity calculated for an 'ideal' player during the 1953 five-match test series was as follows: batting for 38,5 minutes and scoring 14 runs; bowling for 14 minutes for a total of 4,2 overs; fielding for 116 minutes, during which 16 balls were fielded; and resting in the pavilion for 191,5 minutes. As a result, the mean rate of energy expenditure was 86,4 $kcal.m^{-2}.h^{-1}$. for an average cricketer with a body surface area of 1,8 m^2, which corresponds to an energy expenditure of approximately 650 $kJ.h^{-1}$.

However, Bartlett (2003) states that the successes of the obviously fit test sides, such as Australia and South Africa, have added a strong argument to the case for training to improve fitness of cricketers. Bull *et al.* (1992) in turn state that cricket can be physically demanding and performing at top level throughout a long day's play requires an appropriate level of physical fitness.

According to Bourdon *et al.* (2000) it is important to explain several features of the modern game and the effect these changes have on the game need to be highlighted. Firstly, changes have been made to the game in recent years. One-day games are now an integral part of most programmes (international and domestic) and has its own demands, such as fast scoring, quick over rates and fielding restrictions requiring players to field athletically in a variety of positions. Secondly, an important (integral) factor in performance is fitness; as fatigue develops, skill deteriorates. Being fit delays the onset of fatigue. Optimal fitness will be beneficial to bowlers, batsmen and fielders alike. It will enable them to perform their respective tasks for longer periods at a higher level of performance. Thirdly, fitness plays an important role in injury prevention. Cricketers possessing the appropriate levels of muscular strength, endurance and flexibility (range of motion) in the muscle groups used in cricket may improve their potential to

perform better, decrease potential risk of injury and decrease recovery time from injury (Bull *et al.*, 1992; Stretch & Buys, 1991).

Noakes and Durant (2000) and Jamison (1994) emphasise that modern-day cricketers will benefit from superior physical fitness and in the case of cricketers of equal skill, physiological factors determining their fitness will play a role in their success and longevity in the sport over a period of time.

To illustrate that the modern day cricketers need to be much fitter: Noakes and Durant (2000) found that the demands of the South African national cricket team in the 1998/1999 season to play cricket had increased by approximately 280% from the national team that played in 1970. The national team in the 1970's would have played about 35 days of cricket whereas the team in the 1998/1999 season would have played approximately 99 days of cricket. These results show that modern-day international cricketers have to face greater physical and psychological demands.

Headley (2003) reported that in 1980 the total number of international matches played were 92 (test and one-day internationals), while in 2002 a total of 199 matches were played (test and one-day internationals) indicating an increase of approximately 216% in the number of international games played. The increase in the amount of cricket played places the modern-day cricketer under pressure to perform consistently as well as to stay injury free. In light of the above Headley (2003), states that it is essential for the modern-day cricketer to have superior levels of physical fitness. Noakes and Durant (2000) further state that a better prepared cricketer will not only perform more consistently but that the risk of potential injury to him will also be less.

Noakes and Durant (2000) state that the answer to the question of why cricket players need to be fit could be found in one-day cricket. To illustrate, Noakes and Durandt (2000) sketch a hypothetical situation where two batsmen have scored a 100 runs in a one day game. They hypothesize that the two batsman scored 50 singles each, 20 twos, 10 threes and 20 fours. Each batsman would

have covered 3,2 kilometers in an activity time of 8 minutes with an overall running speed of 24 $km.h^{-1}$. They also noted that the number of decelerations required to score these runs would be a minimum of 110.

To estimate the physical activity in bowling during one-day cricket Noakes and Durant (2000) suggest that fast bowlers deliver about 64 deliveries (60 legal and 4 wides or no-balls) in 40 minutes. During this time, they are expected to run 1,9 km in about 5,3 minutes, which is at an average speed of 21,6 $km.h^{-1}$.

The results indicate that elite players need to be athletic to be able to reproduce these performances frequently. Apart from bowling and batting, the player needs to participate in the fielding activity as well, incorporating vigorous fielding for an average of 3,5 hours in one-day competitions (Noakes & Durant, 2000). They conclude that the physical demands placed on modern-day cricketers are high.

This is indicative of a great demand on all the energy systems and fitness components of the cricketer participating in the game. The energy systems and components of fitness which cricketers need to develop according to Jamison (1994) are aerobic capacity, anaerobic capacity, flexibility, speed, agility, muscular strength, muscle power and muscle endurance. The energy systems and components of fitness which cricketers need to develop according to Bull *et al.* (1992) are aerobic endurance, flexibility, speed, agility, strength and power. This indicates that the cricketer must pay attention to all aspects of physical fitness. The energy systems and components of fitness which cricketers need to develop according to Headley (2003) are aerobic fitness, anaerobic fitness, muscular strength, muscle endurance, muscle power, flexibility and agility.

In the game situation for many sports, agility is an important physiological parameter. Agility is a combination of neurological processing ("reading the game"), co-ordination and speed (Bourdon *et al.*, 2000). The player in many sports (rugby, soccer and cricket) is required to perform sudden changes in body direction accompanied by rapid movements of the limbs. The changes can be in a horizontal plane (player might be dodging a ball) or in a vertical plane (player

might be jumping) (Ellis *et al.*, 2000; Bloomfield *et al.*, 1994). Effective use of agility in manoeuvring ability in a game will depend on a host of other factors, such as visual processing, reaction time, timing, perception and anticipation (Ellis *et al.*, 2000). Therefore motor skills play an important role. The run a three test and 505 agility test are cricket-specific settings to asses agility in relation to performance in cricket (Bourdon *et al.*, 2000).

To illustrate further, and to add to the statements of Noakes and Durandt (2000) regarding the fitness of bowlers, Foster and John (1989) describe the physiological requirements of fast bowling as follows: aerobic capacity, anaerobic capacity, muscular strength, muscle endurance and flexibility. They also describe the physical requirements of fast bowling to be optimal levels of body fat, posture and co-ordination.

Physical and motor fitness is an important aspect in preparing for a career in cricket and with the correct attention to physical fitness a cricket player will not only prolong his playing career but will also reduce the possible risk of injury.

In the next section components of anthropometry will be described. The focus will be on body fat percentage and somatotype. Body fat percentage and somatotype were described as an internal injury risk factor to injury, constituting risk factors a player can control by appropriate training.

2.2.4 Anthropometric

Human size and proportions are assessed by the use of anthropometry (Bloomfield *et al.*, 1994). Researchers have shown through their research that certain sports codes tend to develop their own morphological identities and that these identities need to be present in a person to be successful in the particular sports code (Bloomfield *et al.*, 1994; Houtkooper & Going, 1994; Carter, 1982; Broms *et al.*, 1981). This information can be helpful in two ways: (1) physical training programmes can be developed to help players develop the morphological build that is needed for a particular sport; and (2) morphology can

be used to help players participate in a sport for which their builds are suited (Bloomfield *et al.*, 1994; Stretch, 1991; Carter, 1978). The assessment of athletes' body composition is an important component in their physiological preparation (Woolford *et al.*, 1993).

Body fat percentage will be discussed first. Some body fat is necessary as an energy source, to protect the body from injury and to assist with heat retention. Too much body fat may be detrimental to performance in two ways: (1) excess body fat does not contribute to energy production; and (2) the body must consume energy to support excess fat and carry it about. Fat makes no contribution to movement. Excess fat is dead weight, which will affect speed, agility, flexibility and stamina (endurance) (Dintiman *et al.*, 1997; Woolford *et al.*, 1993; Bull *et al.*, 1992). An excess of body fat will generally lead to the earlier onset of fatigue, which will increase the load on the aerobic energy system (Woolford *et al.*, 1993). In cricket the cricketer needs to perform rapid movements and these rapid movements must be performed for longer periods of time. Unnecessary body fat would hinder a cricketer in achieving an optimal performance (Stretch, 1991; Stretch, 1987). Thus, in a sport involving movement of body mass, a relatively low percentage body fat would be advantageous both mechanically and metabolically (Dintiman *et al.*, 1997; Houtkooper & Going, 1994; Woolford *et al.*, 1993). Foster and John (1989) state that it would be advantageous for fast bowlers to be relatively lean and to keep body fat levels to minimal levels.

Payne *et al.* (1987) report that very little information about body composition has been generated. They state that the only available information concerning body fat percentages is that of the unpublished data of a Victorian Sheffield Shield squad in Australia. The mean for the group was 12,3%, with a range of 9,6% to 15,3%. Stretch (1987) found the fat percentage for first-class cricketers in South Africa to be 9,3%, and Stretch (1991) found the fat percentage for the first-class cricketers in South Africa for the 1991 season to be 10,3%. Woolford *et al.* (1993) found the fat percentage for the national senior side in Australia to be 11,1% and

for the Australian shield side to be 11,6%. Bull *et al.* (1992) indicate that cricketers must keep their body fat percentages around 15%, preferably below 15%. Noakes and Durandt (2000) found that batters in South Africa had an average body fat percentage of about 12%, the same as the bowlers. As sprinting is a part of cricket that affects all cricketers, e.g. to stop the ball from going over the boundary rope or to run between the wickets, the following will also apply to cricketers: Dintiman *et al.* (1997) state that for optimum sprinting speed, athletes in sprinting sports should strive for a body fat percentage in the range of 10–15%(males) and 15–20%(females) or lower. Headley (2003) also indicates that cricketers should have a body fat percentage lower than 15%. For optimum performance in cricket the body fat percentage of cricketers needs to be between 10 and 15%, according to the literature. A percentage point lower than 15 is preferable.

As stated earlier, body fat has an effect on stamina (aerobic capacity) if the body fat percentage is too high. The high amount of body fat requires more energy to move the body around in a day's play, which at times can be longer than six hours. This leads to premature tiredness, which in turn can lead to injury.

Somatotype has been described earlier as an internal risk factor to injury, a risk factor a cricketer has control over and that can be reduced with the appropriate training. According to Stretch *et al.* (2000) research done on somatotype has been conducted as part of research on cricketers in general and includes the studies of Peens (1996); Stretch (1990); Stretch (1987); Foster and Elliott (1985).

Jones *et al.* (1965) in England found a somatotype rating of 3,4 – 4,7 – 2,3 for professional cricketers, Mean somatotype ratings of 2,5 – 5,3 – 2,1 (Stretch, 1987) for first-class provincial cricketers in South Africa, 3,1 – 5,5 – 2,0 (Stretch, 1990) in South Africa for first-class provincial cricketers and 3,8 – 4,4 – 2,4 (Peens, 1996) in South Africa for club cricket players have been documented (Stretch *et al.*, 2000). Sharma and Shukla (1988) in India found the somatotype

ratings for cricketers to be 1,2 – 5,1 – 3,8 and Stretch (1991) in South Africa found the somatotype ratings for cricketers to be 3,1 – 5,5 – 2,0.

The literature indicates that cricketers need to possess a low body fat percentage (≤15%) and a high mesomorphic aspect of somatotyping. Findings by Stretch (1987) also indicate that cricketers have an athletic build. The athletic build of cricketers is echoed by Noakes and Durandt (2000), referred to earlier in regard to physical fitness. By making sure the player possesses a similar morphology to what has been seen in the literature, the possibility of injury can be reduced. If the player has a morphological composition closer to the ideal for cricketers, there is one less aspect of concern regarding injury occurrence.

In the next section of chapter 2 the focus will be on the potential risk factors of injury as well as causes of injury (the mechanisms of injury) in cricket.

2.3 Injury Epidemiology in Cricket

In this section of chapter 2, attention will be given to injury mechanisms, principles of mechanical loading, overuse injuries and the intrinsic and extrinsic risk factors of overuse injuries.

2.3.1 Injury mechanisms

Injury mechanisms are numerous and varied. Mechanical concepts and tissue responses, or a combination, play a role in the categorization of injury mechanisms (Whiting & Zernicke, 1998). Leadbetter (1994) identified a useful sports medicine classification system for the mechanism of injury, consisting of seven basic mechanisms of injury:

1. contact or impact (in cricket this can happen in multiple ways, e.g. being hit by a ball on the head, fingers or a body part while batting).

2. dynamic overload (by participating in the sport and preparing for participating in the sport, a dynamic overload may occur).

3. overuse (repeated use with insufficient time for recovery, an aspect that will receive more attention later in the chapter).

4. structural vulnerability (posture or build plays a role in the occurrence of the injury; this is where the biomechanical evaluation plays a vital role in determining the areas of the player's build which could potentially lead to injury, areas like core stability and dynamic stability. The biomechanical evaluation will receive more attention later in the chapter).

5. inflexibility (areas where potential injury could occur because of an inflexible structure around the specific area. This goes hand in hand with the biomechanical evaluation. Inflexibility in the iliopsoas muscle area, for example, may pull the pelvis forward and cause anterior rotation of the pelvis, which may lead to a hamstring injury).

6. muscle imbalance (plays a vital role in the prevention of injury, e.g. the shoulder has an internal rotation to external rotation muscle balance of 3:2. If this ratio is not achieved, a shoulder injury can occur because the muscles do not work in the correct order; the same holds true for the ratio of the leg quadriceps muscle to the hamstring muscle group. If the correct ratio is not achieved a muscle injury could occur in these areas).

7. rapid growth (the body of a particular athlete is not yet developed to the extent that the body can withstand the rigours of a particular sport, which in turn can affect the biomechanics of the player. This may be why so many young schoolboys suffer lower-back injuries while bowling. The body is not yet fully developed and is thus unable to withstand all the forces of bowling).

As a result of the variability among types of injury mechanisms it is suggested by Whiting and Zernicke (1998) that there are many potential injury mechanisms.

Understanding these mechanisms of injury and how they are connected to a sport could be helpful in reducing injuries in a particular sport.

2.3.2 Principles of mechanical loading

Whiting and Zernicke (1998) define load as the application of an external force to a body, and they identified seven factors that characterize load:

1. magnitude (the intensity of the load on the specific body area).
2. location (the specific site where the load occurs on the body area).
3. direction (whether the load is applied upwards, downwards or sideways).
4. duration (the time of the load applied to a specific body area).
5. frequency (the number of times the load is applied to a body area).
6. variability (the different ways in which the load is applied to a body area).
7. rate (the time the load is applied to a body part, whether it happens quickly or is applied slowly).

While participating in a sports activity or during normal daily activity body tissues continuously experience loads without suffering any obvious injury. These loads on the body tissues are within a physiological range. Injury probability will increase when the experienced loads exceed the physiological range of a body tissue. Injury may result when a single overload exceeds a tissue's acute injury threshold. Use is a normal functional loading. Repeated overload is overuse. Many injuries (tendonitis) are termed overuse injuries as a result of the repeated overloads the tissues or musculoskeletal system endures, and with the repeated overloads the tissues or musculoskeletal system has insufficient recovery time (Whiting & Zernicke, 1998; Bloomfield *et al.*, 1994). It is important to take into consideration the influence of load on the body during training or performance and its role in sports injuries (Bloomfield *et al.*, 1994: Le Veau, 1990).

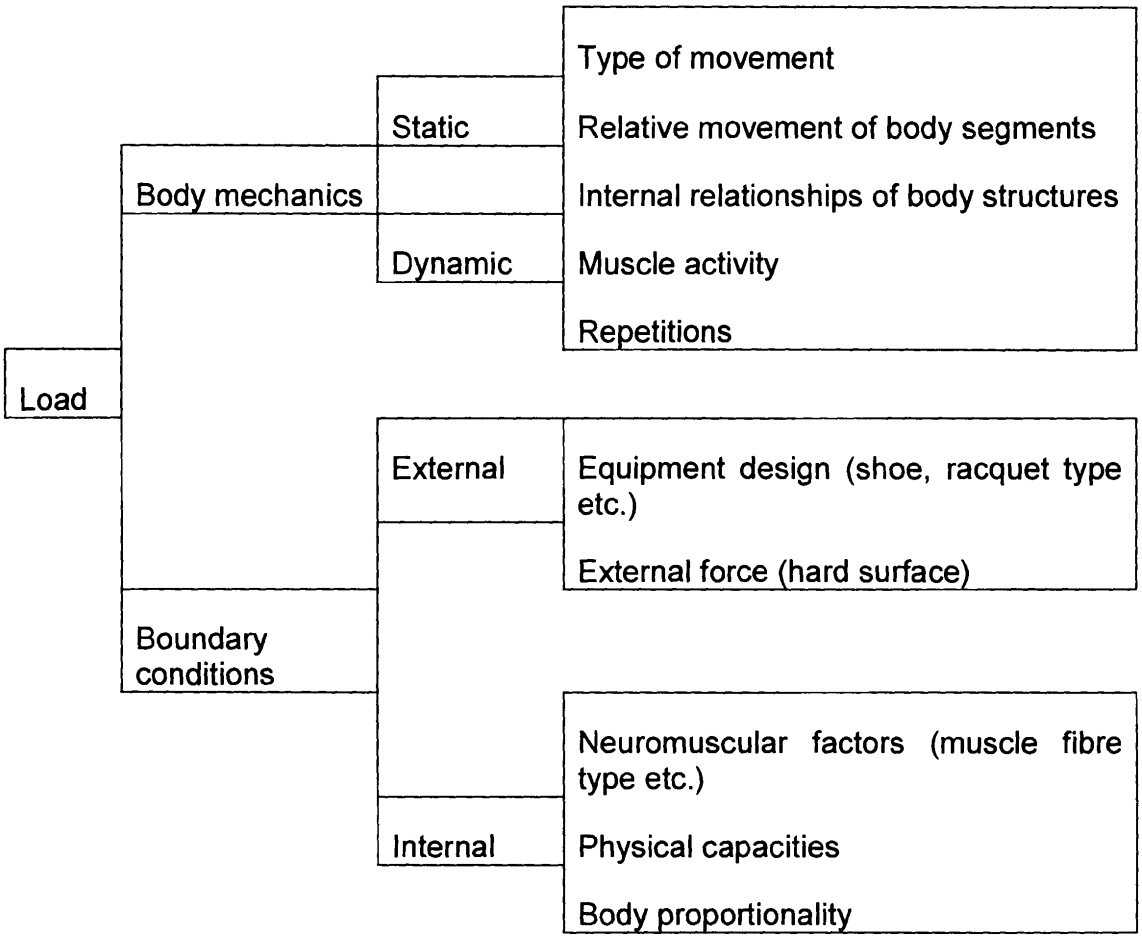


Figure 2.1. A diagram of the principal factors influencing load in sports movements (Bloomfield *et al.*, 1994 adapted from Nigg *et al.*, 1984).

Figure 2.1 (*In*: Bloomfield *et al.*, 1994 adapted from Nigg *et al.*, 1984) shows that there are two areas which influence the load experienced in sports movement: (1) body mechanics and (2) boundary conditions. Body mechanics are then also divided into static and dynamic forces. These are further subdivided into type of movement, relative movement of body segments, internal relationships of body structures, muscular activity and repetitions. These descriptions are similar to those descriptions set out earlier in the second part of chapter 2 under the heading of injury mechanics and mechanical loading, showing that a combination

of static and dynamic forces may lead to the occurrence of an injury, and also that there is a link between injury mechanics, mechanical loading and injury occurrence.

Boundary conditions are also subdivided into internal and external conditions. External conditions are further divided into equipment design and external force (e.g. hard surface), and internal conditions are divided into neuromuscular type (e.g. muscle fibre type), physical capabilities and body proportionality. These internal and external conditions will receive more attention later in the chapter as they are seen as one of the potential forces in the occurrence of overuse injury.

Bloomfield *et al.* (1994) state that the loads experienced in sport are generally of two types. Type one is associated with a high number of repetitions of an activity, such in fast bowling, throwing (high velocity) and running in cricket. In fast bowling at each strike of the foot forces from the ground (ground reaction forces) have to be absorbed by the footwear and the body. Throwing repeatedly places stress on the shoulder region as a result of the high number of upper limb rotations. Type two is associated with smaller numbers of repeated performances requiring high levels of skill/technique and power, such as gymnastics.

Nigg *et al.* (1984) recorded peak vertical ground reaction forces (GRF) of approximately five times the bowler's body weight when the front foot is planted and further states that these forces are transmitted through the bones, cartilage, tendons and muscles to the joints of the body.

Running plays a part in all aspects of the game. It might be in preparation for or to participate in the game by running to field a ball, stopping a ball that has been hit, running between the wickets or bowling. Ground reaction forces (GRF), depending on the application, produce different effects on the body: for walking, the GRF is 1,2 and body weight (BW) is 0,2, increasing to approximately a GRF of 2,5 and a BW of 0,5 for running, and levels of approximately a GRF of 3,6 and a BW of 0,8 for sprinting (Bloomfield *et al.*, 1994).

The internal forces associated with walking, running and sprinting (locomotor system) can easily be a multiple of the external GRF. The direction of the acting forces and the geometry of the locomotor system may be an influencing factor in the stress pattern exerted on the body, and therefore the stress effect on the body can be greater than the GRF would signify (Nigg, 1986).

Shortly before maximum external rotation in throwing, the arm is externally rotated at 165°, the elbow flexed at 95°. At this instant there is a 67 N.m of internal rotation torque, 310–350 N of anterior force at the shoulder, and 64–120 N.m of varus torque at the elbow (Huijbregts, 1998; Fleisig *et al.*, 1995).

The above shows the loads experienced by cricket players while participating in bowling, running and throwing. Mechanical load may directly or indirectly be the cause of injury. Injury may be the result of a single load of large magnitude or of repetitive loads of low magnitude. Le Veau (1990) states if the mechanism or loads responsible for injuries are known, resultant injuries may be prevented or the severity of the injury may be reduced.

Overuse was found by the epidemiology studies to be the second most frequent mechanism of injury. The next section reports on a study of overuse injuries, how they occur, what may potentially contribute to an overuse injury and what could be done to reduce the possibility of overuse injuries occurring.

2.3.3 Overuse injuries

Overuse injuries are described by Whiting and Zernicke (1998) as a broad class of conditions distinguished by an aetiology of repeated force application. Injuries resulting from repeated force application are referred to as chronic injuries and may also be referred to as cumulative trauma disorders or repetitive stress syndromes. On the other side of the continuum are acute injuries. These injuries are the result of a single load or a few loading episodes. Chronic and acute injuries can be distinguished, although sometimes there is a relation between the two, e.g. chronic loading (overuse) may weaken a tissue, lower its maximum

strength and then increase the likelihood of an acute injury. The loading of the musculoskeletal system by a number of repetitive forces results in overuse injuries. These repetitive forces, each lower than the acute threshold for any tissue, produces a combined fatigue effect in a tissue over a period of time, leading to possible injury. Overuse injuries are the result of repetitive microtrauma, with the intrinsic risk factors contributing more to the overuse injury (Wilder *et al.*, 2001; Bloomfield *et al.*, 1994; Meeuwisse, 1994).

Similar to present-day athletes, modern-day cricket players at the elite level are expected to train harder and longer to succeed at the elite level. Cricketers can experience a wide range of overuse injuries associated with all aspects of the game, including running (e.g. lower limb), throwing (e.g. shoulder and elbow), and bowling (e.g. lower back) (Finch *et. al.*, 1999; McGrath & Finch, 1996). The hours of repetitive practice produce a gradual deterioration in the functional capacity of the body (McGrath & Finch, 1996; Elliott *et al.*, 1993; Harvey 1983; Micheli, 1983). The deterioration in the functional capacity often results in an overuse injury. There is little specific literature focusing on these overuse injuries in the literature as they relate to cricket (McGrath & Finch, 1996).

Key contributing factors to overuse injuries are described by Bloomfield *et al.* (1994) and are as follows: poor technique, an excessive number of attempts at an activity, inappropriate footwear (particularly when performing on hard surfaces), musculoskeletal immaturity and a body build that may predispose an athlete to injury in a particular sport or activity.

Finch *et al.* (1999) describe the risk factors for overuse injuries in cricket, namely hereditary factors, incorrect (bowling) technique, poor preparation, bowling too many overs in a single spell, or bowling for too many spells. Excessive bowling through the growth period (younger players), increased stiffness of the lumbar vertebrae in the off season and tightness in the muscle groups around the pelvis, which can lead to forward rotation of the pelvic area thereby increasing the forward curvature of the lumbar spine. Decreased flexibility in the lower back, too

much reliance on upper body strength in attempting to bowl too fast and poor hamstring or lower-back flexibility predispose bowlers to an intervertrabral disk abnormality. A body which is not physically prepared for the rigours of the game of cricket, excessive body fat, adverse posture, height of the longitudinal arch of the foot, excessive shoulder rotation to attain side-on bowling action, higher release of the ball and a mixed bowling technique have also been identified as risk factors to cricketers.

McGrath and Finch (1996) highlight training, technique, footwear, surface, rehabilitation, warm-up and conditioning as factors that may all contribute to overuse injuries in cricket

All the above authors, as far as risks factors in overuse injuries are concerned, involve similar aspects that are a risk or contributing factor to overuse injuries. These factors also are similar to the injury mechanisms and the principles of mechanical loading that lead to injury, showing that a line can be drawn to connect the cause of the injury and the occurrence of the injuryand .

The epidemiology studies (to follow later in Chapter 2) indicated that the third most frequent injury site was the upper limb area. In this body area the shoulder was the site where most injuries occurred. The next part will focus on the shoulder, as it is an area that affects all players participating in the sport of cricket and can potentially be a site for overuse injuries.

Bowling, batting and fielding are the three skills in cricket. Cook and Strike (2000) state that biomechanical research into cricket has mainly focused on bowling and batting. The third skill, fielding, has not received the same amount of attention as bowling and batting. Fielding is a skill that incorporates both the pick-up and the throwing phase of the cricket ball. An integral part of the game of cricket and highlights the importance of throwing in cricket. More and more, there is an increasing emphasis on good fielding in cricket to the extent that three or four quality fielders are deemed as important as two bowlers who have the ability to take wickets.

It is stated by various authors that the shoulder plays a vital role in many athletic activities (Tyler *et al.*, 2000; Huijbregts, 1998; Elliott & Anderson, 1990). Overhead motions such as throwing, swimming and serving in tennis repetitively place the shoulder in vulnerable positions (Tyler *et al.*, 2000; Huijbregts, 1998; Elliott & Anderson, 1990). Throwing has been classified as high-repetition, moderate-force activity (Bloomfield *et al.*, 1994). Throwing in cricket can result in overuse shoulder problems, which are believed to be becoming more prevalent at the elite level (Stretch, 2001c; McGrath & Finch, 1996; Hackney, 1996). Stretch (2001b) states that the medical support team should be aware of shoulder injuries and that prevention strategies should be put into place to prevent shoulder injuries.

Bartlett (2003) states that throwing in cricket has received little attention since the study of Elliott and Anderson (1990), which focused largely on age-related differences in throwing patterns. Most of the studies on throwing have been done on pitching in baseball. Barker and Barker (1997) state that throwing injuries are not exclusive to pitchers and that field players can suffer the same throwing injuries as pitchers. Cook and Strike (2000) found similar results for throwing in cricket to the previously reported results on throwing studies for baseball. Fleisig *et al.* (1996) contended that similarities in all overhand throws are present, as well as quantifiable differences in the mechanics of overhand throwing in various sports. Baseball pitching is essentially a closed skill which is initiated from a static position. Over-arm throwing often requires the movement of the whole body prior to the delivery of the ball. In this way each throw, within each different sport utilizing the throw, may have unique requirements within the "preparation to throw" manoeuvres (Elliott & Anderson, 1990).

This indicates that there is a definite crossover in the rationale of how an individual should throw specific to the demands of cricket and baseball. Relatively few differences exist between the two styles of throwing. The differences are greater elbow flexion at lead foot contact and less external rotation of the throwing arm during the preparation phase. This can be attributed

to the demands placed on the fielder and the pitcher in their respective sports. The pitcher in baseball has minimal time constraints relative to the cricketer, who tries to achieve a run-out, which restricts the time that the cricketer has to perform the total throwing technique. Resulting in limited external rotation of the throwing arm in order to achieve a quick release of the cricket ball (Cook and Strike, 2000).

It is stated by Kaufman (1999) that once the physical demands of overhead activity exceed the shoulder's static and dynamic capacities to maintain functional stability, debilitating injuries such as tendonitis, impingement or lesions could occur. As a result Kaufman (1999) further stresses the importance of working preventatively regarding the overhead throwing athlete with the following: "...an ounce of prevention is worth a pound of cure. Even with the marvels of modern medicine, it is rare to overcome the devastation of shoulder surgery; therefore prevention is the key to a healthy and competitive overhead career".

Meyers and O'Brien (2001) state that the shoulder injuries that do occur in cricket were largely attributable to throwing accurately for distance and that bowling could then further aggravate these injuries. Eccentric loading in the later phases of the throwing action can lead to rotator cuff lesions, most commonly from the mid-supraspinatus to the mid-infraspinatus. Whiting and Zernicke (1998) and Halbach and Tank (1990) reported that the largest loads in throwing develop during the eccentric actions that resist and control high-velocity motions. With the repeated application of these high loads it may lead to progressive degeneration and eventual tissue failure. In the deceleration or follow-through phase, the final phase of throwing, the peak eccentric muscular activity is generated at the shoulder, and maximum compressive force occurs in the posterior rotator cuff (Fleisig *et al.*, 1995), especially the infraspinatus and teres minor muscles from the rotator cuff muscle, as well as in the scapular muscles (Huijbregts, 1996).

The shoulder plays an important role in cricket. It also suffers from injury quite often, and it is important to identify factors that could help reduce the possibility of overuse injuries in the shoulder in cricket. They are as follows:

Scapula stabilizers

Kibler (2001) states the importance of the roles the scapula stabilizers play in the shoulder joint movement. The scapula stabilizers are the trapezius (upper, middle and lower), serratus anterior (upper and lower portions), rhomboids (minor and major), levator scapula and pectoralis minor) (Kibler, 2001). These muscles mainly act as force couples. Kibler (1998) and Halbach and Tank (1990) defines force couples as muscles that are paired to control the movement or position of a joint or a body part. According to Kibler (1998) the appropriate force couples for scapular stabilization are the upper and lower portions of the trapezius muscle working in accordance with the rhomboid muscles and paired with the serratus anterior muscle.

Kaufman (1999) and Hackney (1996) emphasises how critical scapular stabilization is to the success of the throwing athlete. Kibler (2001, 1998) describes the roles of the scapula in overhead throwing activities to be: (1) to be a stable part of the glenohumeral articulation; (2) retraction and protraction along the thoracic wall; (3) elevation of the acromion; (4) to be the base for muscle attachment; and (5) to be a link in the proximal-to-distal sequencing of velocity, energy and forces that allow optimal shoulder function.

Kibler (1998) and Huijbregts (1998) reported that normal biomechanics is created when optimal shoulder function is achieved. This occurs when normal anatomy interacts with normal physiology. If the scapula fails to perform these roles it causes inefficient physiology and biomechanics and therefore inefficient shoulder function, leading to a possibly poor performance and causing or worsening a shoulder injury.

The scapula plays a vital role in the performance and injury conditions of the shoulder. Kibler (1998) and Jobe *et al.* (1996) state that the evaluation of the scapula should be done locally at the scapula as well as distantly in its relationship to its role in the kinetic chain. Therefore it is important to evaluate the trunk and back, as well as the degree of lumbar lordosis, leg-length asymmetry and hip rotational abnormalities. Muscle activity of the leg and trunk plays an important role in throwing activities (kinetic chain) and a result of the important role they play must also be assessed. If normal motions or the generation of normal velocities cannot be achieved by the lower extremity and trunk, the transfer of force to the scapula and the arm will be affected.

Posterior capsule tightness

Tyler *et al.* (2000) reported that the smooth operation of the glenohumeral joint can be affected by posterior shoulder inflexibility, the result of either capsular or muscular tightness. The result of this tightness is a wind-up effect where the moving arm actually pulls the glenoid and scapula forward and into an inferior direction. Tyler *et al.* (2000) and Turkel *et al.* (1981) reported that anterior glenohumeral subluxation are promoted by tightness in the posterior capsule as well as limited internal rotation. Kibler *et al.* (1988) have shown that the ability of the overhead athlete to perform has improved by increasing internal rotation and eliminating posterior capsular tightness.

Winging

This is the medial and inferior border protrusion of the scapula from the thorax (Kaufman, 1999). The serratus muscles – and especially the lower trapezius muscles – appear to be the first muscles involved in inhibition-based muscle function (Klbler, 1998). They are also seen as the two most important muscles in providing a stable glenoid for the rotator cuff muscles (Hackney, 1996).

Shoulder ratios/ muscle imbalances

The normal external-to-internal rotation strength ratio has been found to be 2:3 (Dintiman *et al.*, 1997; Ivey *et al.*, 1985). A muscle imbalance can lead to increased humeral head translation and possibly glenohumeral instability (Ellen *et al.*, 2000).

Anterior rotated shoulders

Excessive drooping of the shoulder, also known as "the tennis shoulder" (Kibler, 1998) or protracted shoulders (Halbach & Tank, 1990), can affect the positioning of the scapula, leading to impingement or problems with muscle function (Kibler, 1998).

Huijbregts (1998) states that the overhead throwing motion requires precise co-ordination between the active and passive structures involved. Muscular fatigue, muscular weakness, muscular tightness, restrictions in joint range of motion, capsuloligamentous laxity and faulty throwing in athletes may lead to a cascade of trauma involving joint surfaces, labrum, bursae, tendons, capsule, ligaments and muscles.

All the above-mentioned factors are included in the biomechanical evaluation of the player, and the tests done will be described in chapter 3.

The next section consists of a description of internal and external risk factors and how they can contribute to potential injury.

2.3.4 Intrinsic and extrinsic risk factors to overuse injuries

According to Backx *et al.* (1990) and van Vulpen (1989) risk factors can be divided into two main categories. The first category comprises the internal personal factors, the second the external, environmental factors.

Data from the literature (van Mechelen *et al.*, 1987) enable the factors to be classified into two types, internal and external risk factors, or intrinsic and extrinsic risk factors (Wilder *et al.*, 2001; Meeuwisse, 1994).

The internal or intrinsic risk factors which may play a part in sport injuries as described by van Mechelen *et al.* (1987) are as follows: physical defect, physical fitness, previous injury, psychological factors, physical build, age and sex. Physical fitness is divided into the following categories: aerobic endurance, strength, speed, sporting skill, co-ordination and flexibility of the muscles. Psychological factors are divided into the following categories: self-concept, risk acceptance, type A and type C personality and locus of control. Physical build is divided into the following categories: weight, height, joint stability and body fat.

The external risk or extrinsic risk factors which may play a part in sports injuries as described by van Mechelen *et al.* (1987) are as follows: sports-related factors, venue, equipment, weather conditions, trainer, conduct of match, the rules and the referee's application of the rules. Sports-related factors are divided into the following categories: type of sport, exposure, nature of event, role of opponents and team mates. Venue is divided into the following categories: state of floor or ground, lighting and safety measures. Equipment is divided into the following categories: tools (e.g. stick or racket), risk acceptance, protective equipment and other equipment (shoes, clothing). Weather conditions are divided into the following categories: temperature, relative humidity and wind.

Meeuwisse (1994) also described external and internal risk factors associated with injury. The internal risk factors are biomechanics, conditioning, maturational age and somatotype. The external risk factors described are weather, field conditions and equipment.

Brukner and Khan (2001) describe internal and external risk factors that predispose a player to overuse injuries. The internal risk factors are malalignment, leg-length discrepancy, muscle imbalance, muscle weakness, lack of flexibility, sex, size, body composition and others. Malalignment is divided into the following categories: pes planus, pes cavus, rearfoot varus, tibia vara, genu valgum, genu varum, patella alta, femoral neck anteversion and tibial torsion. Lack of flexibility is divided into the following categories: generalized muscle

tightness, focal areas of muscle thickening and restricted range of motion. Other risk factors are divided into the following categories: genetic factors, endocrine factors and metabolic conditions.

The external risk factors are training errors, surfaces, shoes, equipment, environmental conditions and inadequate nutrition. Training errors are grouped into the following: excessive volume, excessive intensity, rapid increase, sudden change in type, excessive fatigue, inadequate recovery and faulty technique. Surfaces are divided into the following categories: hard, soft and cambered. Shoes are categorized into the following: inappropriate and worn out. Equipment has one subcategory, namely inappropriate equipment, and environmental conditions are divided into the following categories: hot, cold and humid.

The internal risk factors described by the different authors are similar in content. The internal risk factors are also factors about which something can be done by the individual player. There is some sort of control that can be exercised by the player to reduce the possibility of injury. By doing the right exercises the body can be conditioned to reduce the possibility of injury for one, or by reducing body fat percentage. By doing this, the player is being pro-active in reducing the possibility of injury by the internal risk factor described above.

The external risk factors described above by the different authors are also similar in content. The external risk factors are difficult to control and very little can be done to control them. Weather conditions are difficult to control and if the sport is practised outside, it can have a profound effect on the players participating in the game.

Internal and external risk factors are contributors to overuse injuries. External risk factors play a role in the injuries occurring, but most injuries are caused by internal risk factors. This indicates that the possibility of an injury can be reduced by focusing on that which is controllable. The internal risk factors can be changed because it is in the power of the player to do the right exercises to nullify the risk. These internal risk factors are also incorporated into the biomechanical

evaluation, fitness evaluations and anthropometric evaluations. Any discrepancy can thus be detected and the necessary adjustment in the training procedure made to reduce the possibility of injury occurring.

2.3.5 Description of the preventive measures designed to address the injury causes and the potential risk factors in cricket

According to Finch *et al.* (1999) injury prevention strategies are measures that can "counter", prevent or reduce the risk of injury. Injury prevention strategies should focus on the links involved in the chain of events leading to injury. Brukner and Khan (2001) stated injury prevention strategies are intended to ensure the recovery time as a result of injury is minimal. Brukner and Khan (2001) list the following as important factors that may assist in the prevention of injury: warm up, stretching, taping and bracing, protective equipment, suitable equipment, appropriate surfaces, appropriate training, adequate recovery, psychology and nutrition.

Quarrie *et al.* (2001) documented the following points for successful sports injury prevention: screening (biomechanical evaluations), warm-up/cool-down, physical conditioning, technique, fair play, protective equipment, hydration and nutrition, injury surveillance, environmental factors (conditions) and injury management. Finch *et al.* (1999) divided the primary injury prevention strategy into three areas where prevention of injuries could occur: (1) pre-event; (2) event; and (3) post-event.

The pre-event area focuses on the aspects that can be taken care of before the event starts. This includes making sure the player has done the appropriate pre-season conditioning or training, gone through a biomechanical evaluation (pre-participation screening) and has the right footwear, also making sure the coach has the right information regarding the game and the training needed by the players and making sure the right nutrition is being made available to the players, and that players have the right orthotics for their shoes.

Regarding the event or game, it is necessary to make sure that the players have the right equipment (helmets, padding, gloves, boxes and visors) at their disposal to participate in the game; also, to make sure that the surface on which the game is being played is suitable for participation. Lastly (post-event), it has to be ensured that the proper post-event strategies are in place to cope with injury. These include the availability of first-aid equipment, prompt first aid, rehabilitation, rest, ice, compression, evaluation and referral.

All the above authors have similar views regarding injury prevention strategies. This indicates that if these points regarding injury prevention are followed, there may be a reduction in injury occurrence. Quarrie *et al.* (2001) found a reduction of 47% in the injury rate after the implementation of their injury prevention strategy in rugby.

According to Brukner and Khan (2001), prevention techniques may be general (e.g. ankle bracing in all players in a team) or athlete-specific (addressing the underlying cause of a previous injury). According to Finch *et al.* (1999) injury prevention strategies for cricket can either be specific (e.g. improved skills, techniques to prevent overuse injuries and protective equipment to prevent impact injuries) or more generic (e.g. physical preparation, environmental conditions, modified rules, education, coaching, first aid and appropriate rehabilitation to reduce recurrence of an injury). The use of an injury prevention and training programme could therefore contribute to improving the physical profile of cricketers (biomechanical, physical and motor and anthropometric profile).

Next will be a discussion of the studies done on the epidemiology of cricket injuries.

2.4. Results of studies done on injury epidemiology in cricket

2.4.1 Introduction

Finch *et al.* (1999) state that for one of the world's most popular team sports relatively few publications are available in the medical literature on cricket injuries. Many of the published epidemiological data on cricket injuries, particularly at the elite level, have come from South Africa (Orchard *et al.*, 2002). These studies are: cricket injuries: a longitudinal study of the nature of injuries to South African cricketers (Stretch, 2003a); cricket injuries: a longitudinal study of the nature of injuries to South African cricketers (Stretch, 2003b); the incidence and nature of epidemiological injuries to elite South African cricket players over a two-season period (Stretch, 2001a); incidence and nature of epidemiological injuries to elite South African cricket players (Stretch, 2001b); epidemiology of cricket injuries (Stretch, 2001c); the incidence and nature of injuries in club and professional cricketers (Stretch, 1995); the incidence and nature of injuries in schoolboy cricketers (Stretch, 1993); further studies include the following: injuries in Australian cricket at first class level 1995/1996 to 2000/2001 (Orchard *et al.*, 2002); comparing injuries of spin bowling with fast bowling in young cricketers (Gregory *et al.*, 2002); acute injury incidence in professional county club cricket players (1985–1995) (Leary & White, 2000); and a prospective survey of injuries at first class counties in England and Wales 2001 and 2002 seasons (Newman, 2003).

Attention will be given to the following studies: (1) Leary and White (2000); (2) Stretch (2003a, 2001a and 2001c); and (3) Orchard *et al.* (2002). The reasons for the attention to these studies are twofold: (1) they represent information regarding the epidemiology of cricket injuries from three different countries (England, South Africa and Australia); and (2) although the methodologies of the selected studies differ, it will help establish the extent (incidence and severity) of cricketing injuries worldwide.

2.4.2 Results from the study done in England

The purpose of the study of Leary and White (2000) was to investigate the incidence, nature and site of acute cricket injuries suffered by the professional cricketers of an English county cricket club for the period 1985–1995. Results of 54 cricketers who played in the first team for the county cricket club in any or all of the seasons between 1985 and 1995 were investigated.

The incidence of injury shows that a total of 990 injuries were recorded for the duration of the study. A total of 17 247 days of injury exposure were calculated and an injury incidence rate of 57,4 injuries per 1 000 days of cricket played for the period of the study. Injury incidence was highest in the 1985 season, with 76,6 injuries per 1 000 days played and the lowest in the 1990 season, with 42,6 injuries per 1 000 days played.

As for the seasonal distribution the most injuries occurred consistently in the months of April and May (the start of the English cricket season) of every season in the study and declined progressively to the end of the season in September (end of the cricket season in England).

The types of injury suffered most by the cricketers in any month during the study were injuries involving muscle/tendon strains, contusions/haematomas and ligament/joint sprains. These injuries were most prevalent during in the early season (April and May). Injuries to these areas declined towards the end of the season in September. Injuries such as fractures/dislocations, tendonitis, operations or "other" remained relatively stable throughout the early to mid-season. These injuries also declined towards the end of the season.

As for site of injury, the thigh/calf, the fingers and the lumbar spine areas made up half of the injuries suffered (49,3%, 488/990) during the study. The body area most frequently injured was the lower limb region (44,9%), secondly the upper limb region (20,0%), and the head and neck were injured least (5,7).

Results indicating type and site of injury showed 72,1% of the muscle/tendon strains and tears were to the thigh and calf area in the lower limb region. The muscle/tendon strains and tears suffered in the lower limb area made up 57,5% of all the muscle/tendon strain and tear injuries suffered. Finger injuries were in most cases contusions, which accounted for 40,0% of all finger injuries, together with fractures/dislocations (28,9%) and ligament/joint sprains (23%). Most of the injuries to the lumbar spine involved injuries to the ligaments and joints (63,3%) of the lumbar spine. Injuries suffered to the knee mostly involved ligament injuries and joint sprains (27,6%), tendonitis (26,5%) and contusions (16,3%). Injuries to the foot and ankle were mainly contusions/haematomas (40,7%) and ligament/joint sprains (29,1%). Injury to the shoulder joint was mainly tendonitis, which accounted for 45,7% of all injuries to this joint.

Results regarding injury exposure and playing position showed bowlers (including medium to fast bowling, spin bowling) suffered the highest incidence of injury (70,1 injuries per 1 000 days played) of all the disciplines in cricket. All-rounders had the second highest injury incidence (55,0 injuries per 1 000 days played), and batsmen had the third highest incidence (49,4 injuries per 1 000 days played), and the wicket keepers the lowest (47,3 injuries per 1 000 days played). No significant differences in the site-specific and total injury among the five player positions (medium to fast bowlers, spin bowlers, batsmen, all-rounders, wicket keepers) per 1 000 days of play were found.

Medium to fast bowlers suffered most muscle/tendon complex injuries (32,1 injuries), spin bowlers suffered 28,3 injuries and all-rounders (players that bowl and bat in the team) suffered 26,6 injuries.

The top six injury sites identified in this study by Leary and White (2000) for injury are: (1) thigh and calf (24,6%); (2) fingers (13,6%); (3) lumbar spine (11,0%); (4) the knee (9,9%); (5) foot and ankle (8,7%); and (6) the shoulder (7,1%). Collectively these sites were associated with 74,9% of all the injuries recorded.

An area of concern highlighted by the authors was the fact that so many injuries occurred at the beginning of the cricketing season as it is the period when the least amount of cricket is being played. The type of Injuries suffered most in this period were muscle/tendon strains, contusions/haematomas and ligament/joint sprains. The injury sites with the most injuries were the thigh and calf complex, the fingers and the lumbar spine. The lower limb region had the highest injury rate (44,9%), then the upper limb (29,4%), the trunk (20,0%), with the head, face and neck last (5,7%).

It becomes clear from the results that the cricketers are not well enough conditioned at the start of the season and it is here where biomechanical, fitness and anthropometric evaluation can play a vital role in identifying potential injury risks factors in order to reduce the possibility of injury.

2.4.3 The results of the identified South African studies done on injury epidemiology

The incidence and nature of epidemiological injuries to elite South African cricket players over a two-season period (Stretch, 2001a) were studied to identify the incidence and nature of cricket injuries suffered by elite cricketers for the 1999/2000 season and to compare the results to those obtained in the 1998/1999 season. A further aim was to identify any possible factors that may contribute to injury, and to identify any patterns of injury.

Stretch (2001a) reports that 258 injuries were suffered by 160 elite cricket players in the 1998/1999 season and the 1999/2000 season. An average of 1,61 injuries were suffered per player (in the two-season period), with 106 of the 160 players suffering only one injury per season, and the rest multiple injuries.

According to Stretch (2001a) the following main conclusions regarding chronicity and occurrence of injuries over the two-season period (1998/1999 and 1999/2000) were arrived at: a total of 60,3% acute injuries were suffered for the

two seasons, with 62,6% acute injuries suffered during the 1998/1999 season, and 58,9% suffered during the 1999/2000 season. A decrease of 3,7% occurred in acute injuries suffered from the 1998/1999 season to the 1999/2000 season. An average of 16,6% chronic injuries were suffered during the two seasons. This study by Stretch (2001a) further indicates (Table 2.1) an increase of 3,1% in the chronicity of injuries suffered from the 1998/1999 season (14,7%) to the 1999/2000 season (17,6%). Acute or chronic injuries increased from 22,7% in the 1998/1999 season to 23,3% in the 1999/2000 season, with an average of 23,1% for the two seasons. First-time injuries decreased from 63,6% in the 1998/1999 season to 59,3% in the 1999/2000 season, with an average of 61,0% for the two seasons. Recurrent injuries from the previous season averaged 21,3% for the 1998/1999 and 1999/2000 seasons, with a decrease of 11,7% from the 1998/1999 season (28,4%) to the 1999/2000 season (16,7%). Injuries recurring in the same season increased from 8% in the 1998/1999 season to 24% in the 1999/2000 season, with an average of 17,9% for the two seasons combined.

Areas of concern are the chronic injuries and the same injuries occurring again in the same season, the percentages of which increased most from the 1998/1999 season to the 1999/2000 season. This may highlight that the players were not fully recovered from injury and that the area in which the injury had occurred had not been properly rehabilitated, and thus not fully conditioned so that the players could be back playing the sport.

Furthermore, Stretch (2001a) found the body region where the most injuries occurred was the lower limb area. Of the injuries suffered during the two-season period, 49,9% occurred in this area, with 49,7% being suffered in the 1998/1999 season and 50% in the 1999/2000 season. Stretch (2001a) also reports that most injuries in the lower limb area were to the hamstring and quadriceps muscles, the knee and the ankle. These injuries were responsible for 54,3% of the 129 lower-limb injuries suffered.

The second most injured body regions were the back and trunk, with 24,7% of the injuries suffered for the two-season period occurring there. 24,5% of the injuries were suffered during the 1998/1999 season and 24,8% in the 1999/2000 season. Stretch (2001a) further reports that the lumbar spine had sustained 30 injuries, while 13 injuries had occurred to the abdominal muscles; these together were responsible for 67,2% of the 64 back and trunk injuries suffered during the period of the study.

The third most injured body region was the upper limb region, with 20,4% of the injuries suffered during the two seasons. 21,5% of the injuries were suffered in this area during the 1998/1999 season and 19,8% in the 1999/2000 season. It is further reported by Stretch (2001a) that 13 injuries were suffered to the gleno-humeral joint and 12 were soft-tissue injuries. These injury sites made up 49% of the upper limb injuries suffered during the period of the study.

The least injured body region is the head, neck and face area, with an average of 5,0% for the two seasons. 4,3% of injuries were suffered to this area in the 1998/1999 season, and 5,4% in the 1999/2000 season.

It is thus clear from this study that the main areas of concern regarding the regional distribution of injuries are (1) the lower limbs; (2) the back and trunk; and (3) the upper trunk, and that special attention should be given to these areas.

According to Stretch (2001a) the activity during which injuries was sustained the most was bowling, with 40,4% of the total injuries suffered for the two-season period 1998/1999 and 1999/2000. A total of 40,5% of these injuries occurred in the 1998/1999 season and 40,3% in the 1999/2000 season. Leary and White (2000) also found that the bowlers had the greater incidence of injury. Stretch (2001a) reported that 104 bowling injuries were suffered and that 52 (50%) were lower limb injuries and 34,6% injuries to the back and trunk. Fielding was the activity responsible for the second most injuries, with 25,7% in the 1998/1999

season and 27,5% in the 1999/2000 season, an average of 26,8% for the two-season period. An average of 17,1% of injuries for the two-season period was sustained during batting. Warming up was last, with 6,7% of injuries suffered.

Regarding the level of activity where injuries were sustained, the majority of injuries occurred during 3-, 4-, and 5-day matches, according to the results of the study by Stretch (2001a), an average of 27,1% for the two-season period. 33,1% occurred in the 1998/1999 season and 23,3% in the 1999/2000 season. Practice and training and limited-overs matches were two activities during which injury occurrence had similar percentages. Practice and training had an average of 25,4% injuries for the two seasons, with 19,6% occurring in the 1998/1999 season and 29,1% in the 1999/2000 season. Limited-overs matches had an average of 25,2% injuries for the two seasons, with 27,0% occurring in the 1998/1999 season and 24,0% in the 1999/2000 season. An increase in injuries suffered during practice and training need to be taken note of; as stated earlier in chapter 1, players need to train and work harder at their sport if they want to succeed at the elite level. Injuries with a gradual onset of were also at a higher level in the 1999/2000 season, with an increase of 5,2% in injuries.

Injury occurrence according to the results of the study by Stretch (2001a) was found to be at its highest during the early season (33,5%, October and November), middle season (25,5%, December and January) and the preseason (9,6%, September). The injury occurrence decreased accordingly towards the end of the season. As in the case in the study of Leary and White (2000) the early part of the cricket season seems to be the period when most injuries are suffered by cricketers. These results indicate that the most dangerous time for cricket players is early season and mid-season. This shows the need for biomechanical evaluation, fitness testing and anthropometic measurements, for the following reasons: (1) to see if the player is prepared to face the rigours of the season lying ahead; (2) to identify potential causes of injury; and (3) to reduce

the possibility of potential injury by doing the correct conditioning. This will help the player prepare to the best of his ability for his role in the team.

The results found by Stretch (2001c) in a study of the epidemiology of cricket injuries, specifically regarding the anatomical site of injury, indicate that the head had an acute injury rate of 2,4–2,8%, with no chronic injuries. The face had an acute injury rate of 2,0–2,8% and a chronic injury rate of 0,8%.

The results further indicate that injuries were suffered to the following areas in the upper limb region: shoulder, upper arm, elbow, forearm, wrist, hand and other areas not specified. Under the above-mentioned areas the anatomical sites that had the highest acute percentage of injury were, first, the hand with 6,3-8,5% and, second, the shoulder with 3,7–6.3%. The same was found for the percentage of chronic injury suffered to the hand, with 0,8–1,2% of injury suffered, and the shoulder, with 0,6-0,8% chronic injury suffered.

Regarding the trunk region, injuries were suffered to the following areas: chest, thoracic spine, lumbar spine, abdominal region and other areas not specified. Stretch (2001c) found the most frequent anatomical site of injury in the trunk area to be the lumbar spine with 7,5–8,0% acute injuries suffered and 2,4–4,4% chronic injuries suffered. The abdominal region suffered 1,9–4,8% of acute injuries and 0,5% of chronic injuries, while the chest area suffered 2,0–3,7% acute injuries and 0,5–0,6% of chronic injuries.

The results of the study (Stretch (2001c)) on the lower limb area showed that injuries to the following areas were suffered: the hip, groin, pelvis, thigh, knee, lower leg, ankle, foot and other areas not specified. The thigh area was found by Stretch (2001c) to have been injured most. It is reported that the thigh area suffered 11,1–13,0% of the acute injuries suffered by the lower limb area and had a chronic injury percentage of 2,4–3,6%.

The second most frequently occurring anatomical site of injury found by Stretch (2001c) for the lower limb was the knee, with an acute injury percentage of 6,8–7,1% and a chronic injury percentage of 1,2–1,6%. The ankle had an acute injury percentage of 4,9–6,7% and chronic injury percentage of 1,2%.

The results found by Stretch (2001c) indicate the lower limb area to be a region very vulnerable to injury. This is similar to the results found by Leary and White (2000), who also found the lower limb area the most vulnerable to injury.

The purpose of the study by Stretch (2003a), entitled *Cricket injuries: A longitudinal study of the nature of injuries to South African cricketers* was to identify the incidence and nature of cricketing injuries suffered by elite cricketers for a four-season period. This was done to identify any patterns that may be associated with injury occurrence.

The results indicated an average of 1,9 injuries per player for the four season period. A total of 1 155 injuries were suffered by the 594 cricketers surveyed in this study. Bowling had the highest injury incidence, with 42,1% of the injuries suffered by all the disciplines in cricket combined. The second-highest injury incidence occurred in fielding and wicket-keeping, with 28,6% of the injuries suffered. Batting had the third-highest injury incidence, with 16,9% of injuries suffered.

The occurrence of injury was mostly during first-class matches (28,6%), limited-overs matches (25,6%) and practice (27,8%). Most of the injuries sustained were during the early part of the season. Again a trend can be seen in all the studies described above. The early part of the season is the major area of concern and needs to be looked at very carefully.

Results for this study (Stretch 2003a) indicate the body area injured most was the lower limb area, as in the study of Stretch (2001a), with 49,8% of the injuries suffered in this area. Second were the upper limb (23,0%) and back and trunk

(23,0%), with similar percentages of injury. This differs a little from the results of the 2001 study by the same author (Stretch (2001a)).

The delivery and follow-through of fast bowlers were the major mechanisms of injury (26,1%), consistent with the finding of 2001 by the same author. Overuse injuries as mechanism of injury made up 18,5% of the injuries. Running, diving, catching and throwing the ball when fielding were responsible for 21,9% of the injuries suffered. Being hit by a ball when batting (7,3%), running between the wickets (4,8%) and batting for extended periods of time (4,0%) accounted for the rest of the mechanisms of injury.

66,3% of the injuries suffered were acute injuries and shows a high correlation with the finding of Orchard *et al.* (2002). Injuries were mostly soft tissue injuries, with most injuries occurring in the muscle complex (41,1%). Joint injuries (17,9%) were second, followed by tendon injuries (13,1%) and ligament injuries (5,8%). Fractures were responsible for 5,2% of the injuries, stress fractures made up 2,9% and dislocations 2,6%.

As with Leary and White (2000), it was found by Stretch (2003a; 2001a) that the body area with the most injuries were the lower limb area (the thigh area), and the types of injury suffered most were soft tissue injuries and injuries to the muscle complex. The injury occurrence was at its highest in all the studies in the pre- and early season. Results from the studies regarding upper limb injuries showed the shoulder to be vulnerable to injury. Results from the studies regarding the trunk and back highlighted the lumbar spine as an area prone to injury. All the above studies found that bowlers suffered the most injuries of all cricket disciplines.

The severity of injury can determine the time a player cannot participate in the game. Three categories were chosen by Stretch (2001c) to describe the severity of the injury, as follows: (1) one to seven days; (2) eight to 21 days; and (3) more than 21 days. Stretch (2001c) found the following regarding the severity of injury

and the percentage of time the player was injured: (1) one to seven days lay-off occurred in 47,3% of injuries suffered in the 1998/1999 season and in 69,0% of the injuries in the 1999/2000 season. (2) eight to 21 days lay-off occurred in 19,6% of the injuries suffered in the 1998/1999 season and 29,1% of the injuries suffered in the 1999/2000 season. (3) more than 21 days lay-off occurred in 5,0% of the injuries suffered in the 1998/1999 season and 23,6% of the injuries suffered in the 1999/2000 season. Stretch (2003b) found the severity of injury as follows: (1) 12% of the injuries suffered in this area for the period of the study resulted in a lay-off of one to three days; (2) 12,6% of the injuries suffered in this area for the period of the study resulted in a lay-off of three to seven days; (3) 12,1% of the total injuries suffered during the period of the study resulted in a lay-off of eight to 21 days; and (4) 27,2% of the total injuries suffered in this area during the period of the study resulted in a lay-off of 21 days and longer.

The results of the Australian study by Orchard *et al.* (2002) are discussed next, firstly to report on the injuries suffered in Australian cricket and secondly to determine if similar results regarding injury incidence to what had previously been reported by Leary and White (2000) and Stretch (2003a; 2001a) have been found in Australian cricket.

2.4.4 Results of the Australian study on cricket injuries

The aims of the study of Orchard *et al.* (2002) entitled *Injuries in Australian cricket at first-class level 1995/1996 to 2000/2001* were to present a profile of injuries in Australian cricket at the elite level, as well as to present a preliminary analysis of some of the risk factors for injury for the seasons from 1995/1996 to 2000/2001.

Orchard *et al.* (2002) reported the injury incidence as injuries suffered per 10 000 player hours. The results found for the Australian domestic matches (one-day and more-day matches) were 18,4 injuries per 10 000 player hours. One-day matches had 23,8 injuries per 10 000 player hours and more-day matches had

an incidence of 17,3 injuries per 10 000 player hours. Results also indicated that injuries suffered per 10 000 player hours for the preceding three seasons were higher than had been recorded over the duration of the study. 21 had been injuries suffered per 10 000 player hours (one-day and more-day matches). Rates were found to be 29,3 injuries per 10 000 player hours for the last three seasons of the study for the one-day competition and 19,0 injuries per 10 000 player hours for the more-day competition. The indication that more injuries occurred during the last three seasons underlines the fact, as stated earlier in Chapter 1, that the cricketer these days is expected to train harder and longer and to play more matches. This more intensive training and playing schedules place more stresses on the body of the cricketer and can lead to the occurrence of injuries. Headley (2003) as well as Noakes and Durandt (2000) reported that modern cricketers are playing more matches than was previously the case .

Results from the study of Orchard *et al.* (2002) indicate the body area injured most during the period of the study to be lower limb area, followed by the upper limb region, with the trunk and back region third and the head and neck region being least injured. The order of the body areas injured is similar to the results of Leary and White (2000). Stretch (2001a) found the order to be the lower limb first, with the trunk and back second, the upper limb third, and head, neck and face last.

Results by Orchard *et al.* (2002) for the body area head and neck found that the most injuries were lacerations and other head injuries (2%) during the period of the study, and in this case batsmen suffered most injuries, with 7% of the total injuries suffered by the batsman being lacerations and other head injuries.

Regarding the upper limb area, most injuries were suffered to the wrist and the hand, with 11% of the total injuries suffered. Wrist and hand injuries accounted for 28% of the injuries suffered by fielders.

The second most injuries suffered in the body region of the upper limb were shoulder tendon injuries, with 6% of the total injuries suffered (a total of 29

injuries for the duration of the study). Injuries to the shoulder tendon made up 6% of the total injuries suffered by the bowlers. Shoulder tendon injuries were responsible for a total of 8% of fielding injuries. Sixteen other shoulder tendon injuries were suffered for the duration of the study. The results of Leary and White (2000) also have the upper limb as the second most injured body area (29,4%), while injury to the shoulder made up 7,1% of the total shoulder injuries that had occurred. Gregory *et al.* (2002) found that 10% of the fast bowlers in their study developed shoulder injuries. The shoulder plays a very important role in any overhead activity. In cricket it plays a role in bowling and fielding, thus it has an impact on every player participating in the game of cricket. The shoulder, its role and the role of the kinetic chain in throwing will be looked into later in the chapter.

In the body region of the trunk and back, side and abdominal strains were the most frequent, with 45 injuries suffered in this area, a total of 9% of the total injuries suffered in the study of Orchard *et al.* (2002). Side and abdominal strains were suffered most by bowlers, making up 21% of the total injuries suffered by bowlers over the period of the study. Payne *et al.* (1987) found that bowlers suffered regularly from chronic abdominal strains. Tucker (1990) found that bowlers suffered from quadratus lumborum strains from the side bending in bowling.

Lumbar injuries (other than stress fractures) had the second highest occurrence with 42 injuries, 8% of the total injuries suffered. Lumbar injuries (other than stress fractures) accounted for 8% of the injuries the bowlers suffered. Lower back injuries have been found to be alarmingly high in the fast-bowling population (Gregory *et al.*, 2002; Gray *et al.*, 2000; Annear *et al.*, 1992). The back plays a very important role in bowling and is a subject that has been researched very well (Elliott, 2000).

The lower limb was the body area where most injuries occurred. Schwellnus and Derman (1996) reported that the lower limb area is an area for batsman, bowlers

and fielders where a host of injuries could occur. In the lower limb area, hamstring strain injuries showed the highest incidence, with 56 injuries (11% of the total injuries). 15 hamstring injuries (12% of total injuries) occurred in the case of bowling, 12 in the case of batting (21% of the total batting injuries) and in the cas eof other injuries, 20 were hamstring injuries. Tucker (1990) also found hamstring injuries to be one of the injuries bowlers suffer from most.

Groin injuries were second, with 38 injuries in total (7% of total injuries). Bowlers had ten groin injuries (8% of bowling injuries), batsman had five groin injuries (9% of batting injuries) and there were 21 other injuries. Payne *et al.* (1987) also found that groin injuries were one of the injuries that bowlers suffer from.

Knee cartilage injuries were third-most, with 31 injuries (6% of the total injuries suffered). Other knee injuries were the most in regard to the different disciplines in cricket, with 21 injuries. Bowlers had the most knee cartilage injuries with seven injuries (6% of total bowling injuries). Crisp and King (1994) also found that the bowlers suffered knee cartilage injuries, especially in the case of straight front knee bowlers.

Ankle and foot sprains are also injuries that need to be taken note of. There were 22 injuries of this body area (4% of the total of injuries that occurred). Bowlers had five injuries (4% of total bowling injuries) and fielders had four injuries (7% of total fielding injuries). This was also found by Crisp and King (1994) regarding bowling. Gregory *et al.* (2002) found that the ankle was one of the primary injury areas (8,6%) in fast and spin bowling.

Injury prevalence indicates the percentage of players missing games through injury (Orchard *et al.*, 2002). It was found by Orchard *et al.* (2002) that the injury prevalence and injury incidence in this study were quite similar except for lumbar stress fractures. The severity of the injury accounts for the large portion of playing time missed. Bowlers missed 126 games as a result of this injury.

The body area that caused most missed games, and the highest percentage of players to miss games through injury, was the lower limb area. Second were the trunk and back area, and third the upper limb area. Last were the head and neck.

The highest injury prevalence in the lower limb area consisted of knee cartilage injuries. Bowlers suffered most from these injuries, with 70 missed games through the injury (0,8% of the bowlers unavailable as result of this injury). 36 games were missed by batsman through this injury (0,5% of the batsman were unavailable through this injury). Groin injury led to 87 games being missed by bowlers (1% of the injuries suffered by the bowlers) and 30 games missed by the batsman with this injury (0,4% of the batsman missed games through this injury). Hamstring strain injuries led to 85 matches being missed by bowlers (1% of the bowlers missed games through this injury) and 18 games were missed by batsman through this injury (0,2% of the players not available through this injury).

As regards the trunk and back area, the highest injury prevalence occurred in the case of lumbar stress fractures, with 126 games missed through this injury by bowlers (1,5% of the bowlers were unavailable through this injury). Second were side and abdominal strains, with the bowlers missing 124 matches through this injury (1,5% of the bowlers missed games through this injury).

Shoulder tendon injuries had the highest injury prevalence in the case of the upper limb, with 73 games missed by bowlers through this injury (0,9% of the bowlers missed games through this injury). Thirty-five games were missed by spin bowlers (1,1% of the spin bowlers were not available for games through shoulder tendon injuries). The batsmen missed 25 games through this shoulder injury (0,3% of the batsman were not available to play owing to this injury).

The average injury prevalence (in units or percentage of players through injury) was 7% for domestic matches. One-day internationals had an average injury prevalence of 10%. Injury prevalence was higher in pace bowlers (14%) than spin bowlers (4%), batsmen (4%) and wicket keepers (2%).

The injury prevalence rates for the seasons surveyed were similar, with an average injury prevalence for all players of 7,8% for the entire study and 8,1% for the seasons surveyed prospectively.

Conclusion

Several epidemiology studies from different cricket-playing countries have been described in this chapter. This includes the studies of Leary and White (2000) of England, Stretch (2003a), Stretch (2001a) and Stretch (2001c) of South Africa and Orchard *et al.* (2002) of Australia. Although their methods differ, similar results for injury incidence, body area and site of injury have been found by the authors of the different studies. This suggests that even if the game of cricket is played in a different country, the injuries that occur are specific to the game of cricket. By using the epidemiology of cricket injuries, a pattern of potential injury risks can be and has been identified.

It is clear from the above that cricketers suffer from a wide variety of injuries. These injuries can occur at any time while cricket players are involved in the game of cricket, or even when they are practising their different cricketing skills.

One of the major body areas of injury identified by all the different epidemiological studies is the lower limb area. As a subdivision of the lower limb body area, most injuries occurred to the hamstring, quadriceps and groin areas. It was also identified as an injury that occurs across different disciplines (batting, bowling and fielding, including wicket keeping) in the game of cricket. As stated previously, Agosta (2001) identified three main biomechanical abnormalities that affect lower limb biomechanics, which are as follows: (1) excessive pronation; (2) excessive supination; and (3) abnormal pelvic movement. The most common abnormalities that influence abnormal pelvic movement are as follows: (1) excessive anterior tilt of the pelvis; (2) excessive lateral tilt of the pelvis; and (3) asymmetrical pelvic movement. Biomechanical abnormalities (asymmetries) can be corrected with appropriate muscle stretching and muscle strengthening and

retraining. Therefore it is essential to evaluate the lower limb area thoroughly as part of the biomechanical evaluation.

The second area that features high throughout most of the studies is the body area consisting of the trunk and back. In the studies by Stretch (2003a) and Stretch (2001a) it was found to be the area with the third highest injury rate. The majority of the other studies found the trunk and back to be the area with the second highest injury rate. Most injuries in this body area were lower-back injuries. This was also shown to be the area where the bowlers suffered most injuries. Batsmen also suffered from injury in this area, but not as much as the bowlers.

Side and abdominal strains also made up a great number of injuries. All the studies showed that this is one of the injuries occurring a number of times. Again it was found that bowlers suffered most from this injury, although this injury was suffered by batsman alike.

The third most injury-prone area was the upper limb. Stretch (2003a) and Stretch (2001a) found this area to be the second most injured in the respective studies. Here shoulder tendon injuries came to the fore as one of the subdivisions where injury occurred most.

Hand and finger injuries also occurred a great number of times. This could be impact injuries, like being hit by the ball on the hand while batting, or injury caused by incorrectly catching a ball while fielding. Overuse injuries were one of the major mechanisms of injury in all the studies.

With injury epidemiology of cricket and the extent of the injury problem in cricket described (the distributions and the severity of cricket injuries), it becomes clear that there is a need for preventive measures to reduce the number of cricketing injuries occurring.

Results from the different studies indicated the pre-season and early season to be a period of injury risk to cricketers, as a result of poor physical preparation. The literature study also stressed the importance of strategies to prevent injuries from occurring in cricket and also indicates that these strategies must be evaluated and be adjusted regularly. The literature also indicated the importance of the biomechanical evaluation (musculoskeletal system), physical fitness assessment and anthropometric assessment, as well as the importance of the correct training programme, as areas that can be used in prevention strategies.

The empirical research of this study will focus on those aspects that were highlighted by the literature study. The research was done over a period of six seasons and the results found will be used to evaluate the training and prevention programme that was provided to the cricketers for the six-season period. The injury prevention and training programme will be adjusted for each year according to the result of the biomechanical, physical and motor and anthropometric evaluation, as well as for a shortcoming identified by the different evaluations. The injury epidemiology will also be reported and used to improve the injury prevention and training programme. The elite cricketer of the North-West cricket union was provided with an injury prevention and training programme over the six-season period and the players were evaluated each season at the end of the off-season, i.e. at the start of the pre-season, to evaluate the effectiveness of the injury prevention and training programme. After the six-season period an injury prevention and training programme was compiled which trainers and coaches may implement to prepare their cricket players during the off-season, so as to be prepared for the actual season when it commences, as well as to reduce the risk of possible injury as a result of poor off-season preparation.

Chapter 3. Empirical investigation

3.1 Introduction

The following will be discussed in chapter 3: (1) the choice of participants, data sampling and test protocols; (2) the battery of tests (the biomechanical variables, physical and motor variables and the anthropometric variables); (3) the injury report form used to determine the injury incidence for each season; (4) the injury prevention and training programme; and (5) the statistical methods used in this study over the six-season period (1998/1999–2003/2004).

3.2 Choice of participants, data sampling and test protocols

3.2.1 Choice of participants

The North-West professional cricket squad was used as participants over the six-season period. A total of 93 cricket players were evaluated over the six-season period, stretching from the 1998/1999 season to the 2003/2004 season.

Table 3.1 Total number of cricketers evaluated per season

	1998/ 1999	1999/ 2000	2000/ 2001	2001/ 2002	2002/ 2003	2003/ 2004
Total number of cricketers evaluated per season	**9**	**11**	**18**	**23**	**16**	**16**
First evaluation	9	3	7	12	4	4
Second evaluation		8	4	3	10	2
Third evaluation			7	3	1	9
Fourth evaluation				5	0	1
Fifth evaluation					1	

Some players had been part of the North-West cricket squad for several seasons, and others only for one season, as can be seen in Table 3.1, something that may be attributed to the nature of the professional game. In the 1998/1999 season, nine players were evaluated for the first time. Eleven players were evaluated in the 1999/2000 season. Eight players were evaluated for the second time and three players for the first time in the 1999/2000 season. Eighteen players were evaluated in the 1999/2000 season. Seven players were evaluated for the third time (1998/1999 group), four for the second time and seven for the first time. Twenty-three players were evaluated in the 2001/2002 season. Five players were evaluated for the fourth time, three players for the third time, three players for the second time and twelve players for the first time in the 2001/2002 season. Sixteen players were evaluated in the 2002/2003 season. One player was evaluated for the fifth time (remaining from the 1998/1999 season), one for the third time, ten for the second time and four for the first time in the 2002/2003 season. Sixteen players were evaluated in the 2003/2004 season. One player was evaluated for the fourth time, nine players for the third time, two players for the second time and four players for the first time in the 2003/2004 season.

The turnover of players in a typical professional team during a season is not conducive to a longitudinal study; however, this is part of the nature of professional sport. The statistical method used in this study has been sanctioned for this study by the senior statistician of the North-West University. This could be compared to attempting to assess the handling skills of a Springbok rugby team. It is highly unlikely that the same players will be evaluated over a period of five years, due to the changes in players from season to season. The purpose of such a hypothetical assessment of handling skills would be to determine if the programme had played a role in improving handling skills, and would not actually be player-specific. The same applies to this study, where the purpose had been to determine the effect of the injury prevention and training programme on elite cricketers.

3.2.2 Data sampling

The players were all evaluated at the end of the off-season (middle September, after the off-season injury and prevention programme) of the season commencing. Players were evaluated at the grounds of the North-West Cricket Board. The biomechanical evaluations were done by the physiotherapists and fitness trainer of the North-West Cricket Union. The physiotherapist held a master's degree in Sports Medicine and the trainer a master's degree in Human Movement Science. The physical and motor evaluations and anthropometric evaluations were done by the fitness trainer of the North-West Cricket Board and a qualified sport scientist.

To ensure that the best results were achieved for the three evaluations (biomechanical evaluation of the musculoskeletal system, physical and motor evaluation and the anthropometric evaluation) no official training sessions or exercises were scheduled prior to the completion of the evaluations, which could have influenced the result negatively or positively. The evaluations of the players were spread over two days. On the first day the players were evaluated biomechanically as a group, one by one, by the physiotherapist and the fitness trainer.

The next day, the anthropometric evaluation was done as a group, in the morning. Players were evaluated according to the procedure described later in Chapter 3 (see p 105). The appropriate anthropometric landmarks were marked by the fitness trainer before the measurements were done. Then the measurements were done. One skinfold was measured, followed by a break of a few seconds, then taken again and measured again if a discrepancy of more than one millimetre was present. After all the players had been evaluated anthropometrically, the physical and motor test were performed. Players were evaluated in the same order as the tests (biomechanical, physical and motor and anthropometric evaluations) are described in Chapter 3.

To record the information regarding the physical and motor evaluations as well as the anthropometric evaluations, an easy to follow schematic was drawn up on which to report the results (see annexure 3.3.2, p.326 and annexure 3.3.3, p. 327).

As the official cricket playing season ended in middle March and the off-season training programme only started at the beginning of May, ample recovery time was available for the injured player to recover from injury and to be rehabilitated if he suffered an injury towards the end of the playing season (middle of March). Therefore the players who started the off-season injury and prevention programme were all without injury. Players were all injury-free when assessed at the end of the off-season injury prevention and training programme as their results in the evaluations served as criteria to be selected for the official North-West cricket team for the matches during the pre-season and the playing season.

The injury incidence was recorded throughout the playing season (middle September to middle March). This included all players who needed medical attention due to injury sustained while representing the North-West cricket team in a cricket match. No medical illness was considered. The lists were compiled and completed by the physiotherapist and the fitness trainer of the North-West Cricket Board. The injury results were held by the physiotherapist of the North-West Cricket Board and were according to the results provided to the medical research committee of the United Cricket Board of South Africa. These injury results were used by Stretch (as part of the work of the medical research committee of the United Cricket Board of South Africa) in his publications on the injury epidemiology of injury in cricket in South Africa. The injury report forms were similar to the injury report forms used by Stretch (2003a and 2001a) in his epidemiology studies on injury in cricket.

3.2.3 Test protocols

The following four research protocols were followed in this study:

In the first protocol all elite players were evaluated at the end of the off-season injury prevention and training programme (middle September), irrespective of whether it was their first, second, third, fourth, fifth or other exposure to the injury prevention and training programme. The reason for this protocol was that the more the cricket players who were exposed to the injury prevention and training programme, the more significant the results became. With this method it was also ensured that cricket players who had previous experience of an injury prevention and training programme, players with no previous experience of an injury and prevention and training programme, players with serious shortcomings/defects in their biomechanical, physical and motor and anthropometric profiles, players with and without injury, etc. were all part of the study. This method also ensured that the practical situation experienced in modern-day cricket, the heterogeneity of different variables that can play a role in the profession of elite cricket players, was accounted for. This protocol was also suggested by the senior statistician of the North-West University as most applicable for this study. Several similar studies (Hattingh, 2003; Stretch 2003b; Orchard *et al.*, 2002; Leary & White, 2000) used this type of protocol and found this research methodology applicable to the science involving the study of elite sport.

A second protocol involved dividing players into groups that were exposed to the injury prevention and training programme for the first time, second time, third time and fourth time, in order to evaluate their results. Thus for example if a player was drafted into the North-West professional squad in the 2001/2002 season and exposed to the training and prevention programme for the first time, his results were placed with the players who were exposed to the injury prevention and training programme for the first time (first exposure time) and not

with the results of the players in the fourth exposure (players who were evaluated for the fourth time). The same procedure was followed for all the players.

The third protocol involved monitoring the results of two different groups of players, each group consisting of the same players, over a three-season period. This protocol can be seen as two different case studies. As a result of the professionalism that exists in the sport, players moved to other provinces or lost their contracts, which made it difficult to monitor the same group of players over longer periods. The numbers in the case studies were small, but due to the fact that the study was done on elite cricketers, small numbers are acceptable in this type of case study. The two case-study groups were each evaluated over a period of three seasons, due to the fact that it was not possible to evaluate one group over the period of six seasons for reasons already mentioned.

The results of the different protocols are first discussed individually and then compared with each other to determine the effectiveness of the injury prevention and training programme in the case of elite cricket players. The injury prevention and training programme did not comprise physical training only, but also included passive training exercises (see annexure 3.5, p. 331). Biomechanical differences can be rectified with passive activities, which is the reason for the complete biomechanical evaluation suggested by Hattingh (2003), Belle-Jenje (2003) Watson 2002 and Mullin and Skolfield (2001).

The fourth protocol consisted of the epidemiology of cricket injuries among elite cricket players over the six-season period (1998/1999–2003/2004).

The four protocols are summarized in Table 3.2

Table 3.2 Summary of research protocols				
Method	**Subjects**	**Duration of programme followed**	**Evaluations done**	**Number of players evaluated per season**
Protocol 1	All elite players at the end of the off-season exposed to the injury prevention and training programme (1998/1999-2003/2004)	18 week programme, six evaluations done over a period of six seasons (1998/1999-2003/2004)	- biomechanical evaluation - physical and motor evaluation - anthropometric evaluation	1998/1999 = 9 1999/2000 = 11 2000/2001 = 18 2001/2002 = 23 2002/2003 = 16 2003/2004 = 16
Protocol 2	All elite players divided according their exposure to the off-season injury prevention and training programme (1998/1999-2003/2004)	18 week programme over a period of six seasons and four evaluations (1998/1999-2003/2004)	- biomechanical evaluation - physical and motor evaluation - anthropometric evaluation	Exposure 1 = 39 Exposure 2 = 27 Exposure 3 = 20 Exposure 4 = 6 All exposures measured = 1998/1999-2003/2004
Protocol 3	Two elite groups over a period of three seasons each, same players throughout each of the three seasons per group	18 week of training – three evaluations each per group	- biomechanical evaluation - physical and motor evaluation - anthropometric evaluation	Group 1 = 7 (1998/1999 - 2000/2001) Group 2 = 9 (2001/2002 – 2003/2004)
Protocol 4 (Aim 2)	All elite players throughout the playing season (1998/1999–2003/2004)	Approximately 34 weeks of the playing season, six evaluations done over a period of six seasons (1998/1999–2003/2004)	Cricket injuries: - number of injuries suffered - anatomical site of injury - nature of injury suffered - mechanism of injury - severity of injury - injury per 10 000 hours of play	1998/1999 = 9 1999/2000 = 11 2000/2001 = 18 2001/2002 = 23 2002/2003 = 16 2003/2004 = 16

3.3. Battery of tests

This study focused on the effect of the injury prevention and training programme at the end of the off-season (middle September of each season) on the biomechanical attributes, physical and motor attributes and anthropometric attributes of the cricketers over the six-season period (1998/1999–2003/2004). The injury incidence was also recorded throughout the official cricket playing season. No analysis of the technique of the cricketers was done, although technique may have played a part in certain injuries suffered by the cricketers. An example could illustrate this: in bowling a mixed bowling action may lead to a lower back stress injury, while in throwing the wrong technique may lead to a shoulder injury. The literature states that a thorough biomechanical evaluation of the musculoskeletal system should be done in order to identify possible areas of potential injury risks. All the biomechanical evaluations cannot be altered with exercise/training but if an area of potential risk is identified by the biomechanical evaluation of the musculoskeletal system, steps can be put in place to reduce the possibility of injury as a result of this biomechanical abnormality. This entails that the injury prevention and training programme be adjusted accordingly.

3.3.1 Biomechanical evaluation of the musculoskeletal system and postural analysis

From extensive studies done in the literature, a range of tests, analyses and protocols were obtained to identify and select important tests that have been proven to measure attributes that are advantageous to a high level of sports performance. The tests include those used by the following authors: Hattingh (2003); Derman (2001a); Derman 2001b; Brukner and Khan (2001); Rocabaco (2000); Mullin (1999); McConnell (1999); Gilleard *et al.* (1998); Kapandji, (1998); Peers (1994); Butler (1991); McPoil and Brocato (1990); Hunt (1990); Saudek (1990); Gould III (1990); Halbach and Tank (1990); Saunders (1990); Porterfield and DeRosa (1990); Wallace *et al.* (1990); Kapandji (1987); McConnel (1986);

Kapandji (1982); and Hoppenfeld (1976) (biomechanical evaluation form (see annexure 3.3.1, p. 321).

These tests, analyses and protocols were combined into the biomechanical evaluation used in this study and will be described below in the order in which they were performed. This biomechanical evaluation was successfully used by Hattingh (2003) in his study entitled *A prevention programme for rugby injuries based on an analysis among adolescent players*. It was also ensured that no strenuous exercises that could have influenced the biomechanical evaluation positively or negatively preceded the biomechanical evaluation.

3.3.1.1 Lower limb region: Ankle dorsiflexion

Apparatus: Long-arm goniometer; plinth.

Test procedure: The subject was placed in a supine position, legs straight and the heels just over the edge of the plinth. With the right hand on the ball of the foot, the forefoot was pushed into dorsiflexion. Degrees of forced plantar flexion were measured on the lateral aspect of the ankle joint with the long-arm goniometer. Range of movement (ROM) was graded from 1 to 3, as follows: 1, a range of 30° or more (ideal); 2, between 10° and 30° (non-ideal); 3, less than 10° (highly unsatisfactory) (Hattingh, 2003; McPoil & Brocato, 1990; Kapandji, 1987).

3.3.1.2 Lower limb region: Modified Thomas test

Apparatus: Plinth; marker; long-arm goniometer.

Test procedure: For the modified Thomas test three lower limb mobility measurements were assessed. This test was used as a functional combination test for all three measurements and was conducted as follows:

- The subject stood at the end of the plinth, with the posterior aspect of the thighs firmly against the plinth.
- The left hip and knee were flexed toward the chest; the ankle was gripped on the anterior aspect with the fingers locking.
- The subject then lay back in the supine position; the left leg was still locked in the hand grip; elbows were extended. The right leg was relaxed and left hanging over the edge of the plinth.

From this position the functional combined mobility of the lower limb hanging was measured.

Iliopsoas mobility

The lateral midline of the hip joint was identified and marked by the examiner. The long-arm goniometer was placed on the identified point, with one goniometer arm parallel to the horizontal and the second arm in line with the femoral shaft. The angle was measured. This was classified as follows: 1, >30° (ideal); 2, 15–30° (non-ideal); 3, <15° (highly unsatisfactory). (Hattingh, 2003; Hunt, 1990; Saudek, 1990; Kapandji, 1987).

Quadriceps mobility

The midline of the knee was clearly marked on the lateral aspect. The long-arm goniometer was placed on the identified point; the control arm was positioned in line with the femoral shaft and the other in line with the lower limb. The angle was measured and was classified into three categories: 1, >50° (ideal); 2, 30°–50° (non-ideal); 3, <30° (highly unsatisfactory). (Hattingh, 2003; Hunt, 1990; Saudek, 1990; Kapandji, 1987).

Illiotibial band mobility (ITB)

The anterior aspect of the ankle joint was clearly marked. With the long-arm goniometer the deviation from the coronal mid-position was measured (rotation or deviation of the sagittal mid-position from the midline). Measurements were classified into three categories: 1, neutral, 0°–10° of deviation (ideal); 2, 10°–30°

of deviation (non-ideal); more than 30° (highly unsatisfactory) (Hattingh, 2003; Hunt, 1990; Saudek, 1990; Kapandji, 1987).

The same test protocol was then performed on the opposite limb.

3.3.1.3 Lower limb region: Gluteus maximus mobility test (short hip extensor mechanism mobility test)

Apparatus: Plinth; long-arm goniometer; marker.

Test procedure: The subject was positioned supine on the plinth and the legs extended. The examiner was positioned at the side of the plinth facing the lower limbs. The examiner flexed the knee that was closest at an angle of 90° with the lateral aspect of the ankle resting on the opposite knee. After dropping the thigh into external rotation, the flexed knee (90°) and externally rotated hip were flexed cephalate (the examiner maintained the degrees of external rotation up to maximum hip flexion). With the lower limb position maintained at full hip flexion, the long-arm goniometer was used to measured range of motion (ROM). ROM was classified into three categories: 1, >90° (ideal); 2, 60°–90° (non-ideal); 3, <60° (highly unsatisfactory) (Hattingh, 2003; Kapandji, 1987; Hoppenfeld, 1976).

The same procedure was followed for the right and left anatomical side of gluteus maximus mobility.

3.3.1.4 Lower limb region: Adductor mobility test

Apparatus: Plinth; long-arm goniometer.

Test procedure: The subject was positioned supine on the plinth with knees extended. The examiner was positioned at the side of the plinth facing the subject's lower limbs. The opposite leg was abducted and the heel hooked over

the edge of the plinth. The limb closest to the examiner was abducted, stabilized and rotation-controlled by the examiner. The hip rotation was controlled in neutral by the examiner. Movement was continued until maximum range was reached. The long-arm goniometer was placed on the umbilicus with the arms representing the femoral shaft positions, and the angle was measured. Measurements were classified into three categories: 1, >120° (ideal); 2, 100°–120° (non-ideal); 3, <100° (highly unsatisfactory) (Hattingh, 2003; Kapandji, 1987; Hoppenfeld, 1976).

3.3.1.5 Lower limb region: Hip joint

External rotation mobility test

Apparatus: Plinth; long-arm goniometer; marker.

Test procedure: The subject stood at the end of the plinth on the right leg. The left leg was supported over the side of the plinth (knee crease at the edge). The apex of the patella on the flexed knee was marked by the examiner. With the left hand of the examiner stabilizing the inferior portion of the thigh and the right hand holding onto the ankle, the hip joint was externally rotated to the maximum. The long-arm goniometer was placed on the identified area to measure the rotation in comparison with the vertical axis measured. Measurements were classified into three categories: 1, >90° (ideal); 2, 60°–90° (non-ideal); 3, <60° (highly unsatisfactory) (Hattingh, 2003; Kapandji, 1987; Hoppenfeld, 1976).

Internal rotation mobility test

Apparatus: Plinth; long-arm goniometer; marker.

Test procedure: The subject was placed in the same position as for the external rotation mobility test. ROM for internal rotation was now tested. Measurements

were classified into three categories: 1, >30° (ideal); 2, 15°–30° (non-ideal); 3, <15° (highly unsatisfactory) (Hattingh, 2003; Kapandji, 1987; Hoppenfeld, 1976).

3.3.1.6 Lower limb region: The knee region

Quadriceps angle test (Q-angle test)

Apparatus: Plinth; long-arm goniometer; marker; tape measure.

Test procedure: The subject was positioned supine on the plinth with the legs extended. With the marker the examiner identified the tibial tuberosity and the apex of the patella. After the medial and lateral aspects of the patella base had been carefully marked, the midpoint between the medial and lateral aspects of the patella was identified by measuring. The anterior superior iliac spine was palpated, identified and marked. A straight line was drawn from the anterior superior iliac spine through the superior patella mid-position extending caudate. A second line was drawn from the tibial tuberosity through the apex of the patella cephalate. The Q-angle of the measured leg was indicated at this point where the two lines crossed. The long-arm goniometer was placed on the crossing lines and the angle was measured. Measurements were classified into two categories: 1, <9° (ideal); 2, >9° (non-ideal). (Hattingh, 2003; Gilleard *et al.*, 1998; Kapandji, 1987; McConnel, 1986).

Patella tilt test

Apparatus: Plinth.

Test procedure: The subject was positioned supine on the plinth with legs extended. The examiner was positioned laterally at the level of the left knee.

- Phase one: Using an imaginary coronal axis through the anterior surface base of the patella, the degree of surface deviation from this line was

noted and documented. With no discrepancy, the patella was categorized as 1, not tilted (ideal);

- Phase two: With deviation the examiner placed the thumbs on the lateral aspect of the patella and gently gilded it medially (<1 cm) only; with the range limited, the patella was categorized as 2, tilted (non-ideal).

The procedure was then repeated on the opposite knee (Hattingh, 2003; McConnell, 1999).

Patella squint test

Apparatus: Plinth; marker; tape measure.

Test procedure: The subject was placed in the same position as for the patella tilt test. The examiner was positioned laterally at the level of the knee. The apex of the patella was identified and marked by the examiner. The medial and lateral aspects of the patella base were identified and marked, as well as the midpoint between these landmarks. A line was drawn from the patella mid-position through the inferior pole of the patella. Patella squint (rotation) was identified and categorized in comparison with the mid-limb sagittal line. 1, < 10° (ideal); 2, > 10° (non-ideal) (Hattingh, 2003; McConnell, 1999).

Vastus medialis obliques-lateralis comparison test (VMO-L)

Apparatus: Plinth.

Test procedure: The subject was positioned supine on the plinth, knees extended. The examiner was positioned at the lower limb level, facing the knees. The subject was instructed to contract the quadriceps (one leg) isometrically and to hold the contraction. The examiner compared the muscle bulk of the vastus medialis obliques to the vastus lateralis obliques of the contracted leg. The procedure was repeated for the other leg. Measurements were divided into two

categories: 1, no apparent difference (ideal); apparent difference (non-ideal) (Hattingh, 2003; McConnell, 1999; Wallace *et al.*, 1990).

3.3.1.7 Lower limb region: The foot

Longitudinal arch status test

Apparatus: None.

Test procedure: The subject stood upright, with feet shoulder width apart, facing the examiner. The longitudinal medial arch (plantar vault) was inspected by inserting the index finger between the plantar surface of the foot and the ground. The foot arches were classified into three categories: 1, resisted movement (dropped arch/hypermobile); 2, easily inserted index finger (ideal); 3, excessive play between plantar aspect and ground (high arch/hypomobile) (Hattingh, 2003; Hunt, 1990).

Forefoot positional test

Apparatus: Marker; goniometer.

Test procedure: The subject stood as for the longitudinal arch status test. The marker was used to identify the lateral aspect of the talus neck. The Z axis was identified and marked. The goniometer was placed on the marked area, the control arm on the Z axis and the second arm measured the degrees of forefoot valgus. Measurements were classified into two categories: 1, 10°–0° deviation from Z axis (ideal); 2, more than 10° deviation from Z axis (non-ideal) (Hattingh, 2003; Derman, 2001b; Hunt, 1990).

Rear foot standing test

Apparatus: Plinth; goniometer; marker; tape measure; bench.

Test procedure: The subject laid prone on the plinth with both feet just over the edge of the plinth. First, the mid-point of insertion of the Achilles tendon (TA) into the calcaneus was identified and marked. Second, the mid-position of the posterior calcaneus was identified and marked by placing the index finger and thumb of the left hand on either side of the calcaneus. The two marks were connected by drawing a line which bisected the calcaneus. Third, the mid-point of the proximal calf muscle bulk was identified and marked. Fourth, the point where calf muscle bulk inserted into the Achilles tendon was identified. A line was drawn between these two points, which represented the pulling direction of the calf muscle complex.

The subject stood upright with feet together on the bench, facing away from the examiner. The angle between the two drawn lines was measured. Measurements were classified into three categories: 1, >9° (rear foot pronation); 2, 0°–9° (ideal); 3, <0° (rear foot supination) (Hattingh, 2003; McPoil & Brocato, 1990).

Rear foot lying test

Apparatus: Plinth; goniometer; marker.

Test procedure: The subject was marked as for the rear foot standing test protocol and lay prone on the plinth. The examiner was positioned at the end of the plinth, placing the left hand on either side of the talus, approaching from the frontal aspect of the right foot. With the thumb of the right hand placed on the plantar aspect of the fourth and fifth metatarsal heads, the foot was eased into dorsiflexion, whilst the neutrality of the talocrural joint system was controlled by the examiner with the index finger and thumb of the left hand. This position was held in neutral (0°) and the rear foot status was measured with the goniometer. Measurements were classified into three categories: 1, >9° (rear foot pronation);

2, 0°–9° (ideal); 3, <0° (rear foot supination) (Hattingh, 2003; McPoil & Brocato, 1990; Kapandji, 1987).

Transverse arch area comparison test

Apparatus: Plinth.

Test procedure: The subject was placed in the same position as for the rear foot lying test protocol. The examiner inspected the transverse arch area and was seated at the end of the plinth. The transverse arch areas were classified into two categories: 1, normal plantar aspect with slight transverse arch (ideal); 2, callus plantar aspect with flat arch (non-ideal) (Hattingh, 2003; McPoil & Brocato, 1990; Kapandji, 1987).

Foot mobility test

Apparatus: Plinth.

Test procedure: The subject and the examiner were in same positions as for the transverse arch area comparison test. The examiner first flexed the medial aspect of the subject's foot maximally and then extended it; the degree of mobility was noted. Mobility status was grouped into three categories: 1, hypermobile; 2, ideal; 3, hypomobile (Hattingh, 2003; Kapandji, 1987).

Toes positional test

Apparatus: None.

Test procedure: The subject stood erect, feet shoulder width apart, facing the examiner. The toes' position was evaluated and grouped into two categories: 1,

ideal position (no valgus, rotation or deviation); 2, non-ideal (valgus, rotation, deviation present) (Hattingh, 2003; Hoppenfeld, 1976).

3.3.1.8 Pelvic girdle region: Leg-length discrepancy test

Apparatus: Plinth.

Test procedure: The subject was positioned supine on the plinth with the heels just over the edge of the plinth. The examiner was positioned at the end of the plinth and made sure the subject was positioned symmetrically. The thumbs of the examiner were placed firmly against the inferior aspect of the medial malleoli. The subject's extended legs were lifted (30°) from the plinth, elongated and placed back onto the plinth. Differences in the malleoli position were noted and recorded. The differences were grouped into three categories: 1, medial malleoli height left equals right (ideal); 2, <1 cm discrepancy slightly displaced (non-ideal); 3, >1 cm discrepancy (highly unsatisfactory) (Hattingh, 2003; Rocabaco, 2000; Peers, 1994; Hoppenfeld, 1976).

3.3.1.9 Pelvic girdle region: Anterior superior iliac spine (ASIS) comparison test

Apparatus: Plinth; marker.

Test procedure: The subject was positioned as for the leg-length discrepancy test. After the subject had been requested to expose the anterior superior iliac spine, the inferior aspect of both prominences was marked by the examiner. The subject was then positioned symmetrically. The thumbs of the examiner were then placed on the marked areas and signs of asymmetry were recorded. The status was grouped into two categories: 1, symmetrical (ideal); 2, asymmetrical (non-ideal) (Hattingh, 2003; Rocabaco, 2000; Peers, 1994; Hoppenfeld, 1976).

3.3.1.10 Pelvic girdle region: Posterior superior iliac spine (PSIS) comparison test

Apparatus: Plinth; marker.

Test procedure: The subject was placed in the four-point kneeling position on the plinth. The subject was requested to sit back on his heels (with gluteal area touching the heels) and, while sustaining this position, to flex forward until his head touched the plinth. The inferior edge of the posterior superior iliac spine was carefully exposed, palpated, identified and marked by the examiner. The thumbs of the examiner were then positioned on the marked areas and the symmetry assessed. The status was assessed and grouped into two categories: 1, symmetrical (ideal); 2, asymmetrical (non-ideal) (Hattingh, 2003; Rocabaco, 2000; Peers, 1994; Porterfield & DeRosa, 1990; Hoppenfeld, 1976).

3.3.1.11 Pelvic girdle region: Pubic tubercle height (Pelvic rami positional test)

Apparatus: Plinth.

Test procedure: The subject lay supine with the superior pubic area just exposed; the symmetrical positioning of the subject was ensured by the examiner. The thumbs of the examiner were placed on the superior medial rami to asses the area for asymmetry. The status was assessed and grouped into two categories: 1, symmetrical (ideal); 2, asymmetrical (non-ideal) (Hattingh, 2003; Rocabaco, 2000; Peers, 1994; Hoppenfeld, 1976).

3.3.1.12 Pelvic girdle region: Sacroiliac cleft test

Apparatus: Plinth.

Test procedure: The subject was positioned as for the posterior superior iliac spine comparison test. The examiner carefully exposed the sacroiliac joint (SIJ) area. The examiner then placed his thumbs on the joint margin and assessed for cleft asymmetry. The status was assessed and grouped into two categories: 1, symmetrical (ideal); 2, asymmetrical (non-ideal) (Hattingh, 2003; Porterfield & DeRosa, 1990).

3.3.1.13 Pelvic girdle region: Bilateral pelvic positional test

Apparatus: Tape measure; marker; one stool.

Test procedure: The subject stood erect and relaxed with both the ASIS and PSIS exposed. The examiner faced the subject side-on and was seated. The inferior edge of the anterior superior iliac spine (ASIS) and the posterior superior iliac spine (PSIS) were palpated, identified and marked. The difference in height between the lower ASIS and PSIS were measured and recorded. The measurements were grouped into three categories: 1, 2–3 cm discrepancy (ideal); 2, 3–5 cm discrepancy (non-ideal); 3, >5 cm discrepancy (highly unsatisfactory) (Hattingh, 2003; Kapandji, 1998).

3.3.1.14 Spinal region: Spinal dynamic mobility. Thoraco-lumbar fascia mobility test

Apparatus: Plinth; tape measure.

Test procedure: The subject was placed in a side-lying position with the head placed at the top end of the plinth. The top leg was bent at a 90° angle at both the hip and the knee. The examiner then assisted the subject first onto the elbow (sideline) and then onto the hand, which was placed at the end of the plinth. The examiner ensured that the subject was positioned in a straight line before the test procedure was executed. The distance between the iliac crest and superior plinth

surface was measured. Measurements were grouped into three categories: 1, 1 cm and less (ideal); 2, 1–3 cm (non-ideal); 3, >3 cm (highly unsatisfactory) (Hattingh, 2003; Kapandji, 1998).

3.3.1.15 Spinal region: Spinal dynamic mobility. Sacral rhythm test

Apparatus: Plinth.

Test procedure: The subject was positioned in a prone position on the plinth with the head close to the top edge. With the hands on both corners of the plinth, the arms of the subject were positioned for a push-up. The examiner, positioned on the side of the plinth, placed both thumbs on the L5 transverse processes. Without lifting the hips from the plinth, a push-up was performed, elbows locked in extension, and the examiner assessed the symmetry of the extension movement in this region. The results were grouped into two categories: 1, symmetrical movement (ideal); 2, asymmetrical movement (non-ideal) (Hattingh, 2003; Gould III, 1990)

3.3.1.16 Spinal region: Spinal dynamic mobility. Functional extension mobility test

Apparatus: Plinth.

Test procedure: The subject was in the same position as for the sacral rhythm test. The push-up was performed with the elbows locked in extension. The distance between the ASIS and the superior aspect of the plinth was measured. Measurements were grouped into three categories: 1, 1 cm and less (ideal); 2, 2–3 cm (non-ideal); 3, >3 cm (highly unsatisfactory) (Hattingh, 2003; Gould III, 1990).

3.3.1.17 Spinal region: Spinal dynamic mobility. Functional flexion mobility test

Apparatus: None.

Test procedure: Standing upright and relaxed with feet shoulder width apart, the subject was instructed to flex forward. The subject attempted to touch the ground without bending his knees and to touch the ground with his hands crossed. Flexion was grouped into three categories: 1, palms flat on the ground (ideal); 2, fingers touching the ground (non-ideal); 3, unable to touch the ground (highly unsatisfactory) (Hattingh, 2003; Kapndji, 1998).

3.3.1.18 Spinal region: Spinal dynamic mobility. Rotational mobility test

Apparatus: Plinth.

Test procedure: With the subject seated on the edge of the plinth, his upper body was in the upright position and the lower limbs over the edge of the plinth. His arms were crossed, with his hands on the opposite shoulders. Positioned behind the subject the examiner placed his hands on the subject's shoulders and rotated the trunk to the end of its range. The range was noted and was grouped into three categories: 1, 90° and more (ideal); 2, rotation of 70–90° (non-ideal); 3, rotation less than 70° (highly unsatisfactory) (Hattingh, 2003; Kapandji, 1998).

3.3.1.19 Spinal region: Spinal dynamic mobility. Side flexion mobility test

Apparatus: Plinth.

Test procedure: The subject was placed in the same position as for the rotational mobility test. The examiner, from the rear, stabilized the pelvic girdle on the left and laterally flexed the trunk to the right up to the end of its range (no rotation).

The procedure was then repeated on the other side. The range was grouped into three categories: 1, easy elbow contact with the plinth without stretching sensation and resistance (ideal); 2, contact with stretching sensation and resistance (non-ideal); 3, unable to touch surface (highly unsatisfactory) (Hattingh, 2003; Gould III, 1990; Kapandji, 1998).

3.3.1.20 Spinal positional alignment: Coronal axis

Apparatus: High stool.

Test procedure: The subject stood erect, relaxed and with feet shoulder width apart. The examiner faced the subject laterally and was seated on a high stool. The postural position was evaluated by using an imaginary coronal axis passing through the midline (median) of the subject. The following spinal regions were positionally categorized: the cranial (head), cervical, thoracic and lumbar regions. Regions were grouped into two categories: 1, ideal (within acceptable anatomical postural limits close to the coronal axis); 2, non-ideal (exceeding acceptable limits) (Hattingh, 2003; Kapandji, 1998).

3.3.1.21 Spinal positional alignment: Sagittal axis

Apparatus: High stool.

Test procedure: The subject was positioned as for the coronal evaluation. The examiner was now positioned posteriorly on a high stool. The postural position was evaluated by using the imaginary sagittal axis line passing through the midline of the subject. The following regions were categorized: the cranial (head), cervical, thoracic and lumbar. Regions were grouped into two categories: 1, ideal (within acceptable anatomical postural limits close to the sagittal axis); 2, non-ideal (deviating from the axis) (Hattingh, 2003; Kapandji, 1998).

3.3.1.22 Upper limb region: hand behind back range of motion (ROM) test

Apparatus: Marker; tape measure.

Test procedure: The subject stood upright, relaxed, feet shoulder width apart and the examiner positioned posteriorly. With a single movement, the left arm was internally rotated behind the back and with the index finger the highest possible position was achieved. This position was carefully marked on the spinous process. The procedure was then repeated with the right arm. Differences in height were noted and measured. Measurements were grouped into three categories: 1, distance between the two marks equal or less than 1 cm (ideal); 1–3 cm (non-ideal); 3, >3 cm (highly unsatisfactory) (Hattingh, 2003; Kapandji, 1982).

3.3.1.23 Upper limb region: Hand behind neck range of motion (ROM) test

Apparatus: Marker; tape measure.

Test procedure: The subject and examiner were in the same position as for the hand behind back ROM test. With a single movement the left arm was externally rotated behind the neck and the lowest possible point achieved with the index finger. The point achieved was marked on the spinous process. The test was repeated for the right arm. Differences in height between the two marks were noted and measured. Measurements were grouped into three categories: 1, distance between the two marks equal or less than 1 cm (ideal); 1–3 cm (non-ideal); 3, >3 cm (highly unsatisfactory) (Hattingh, 2003; Brukner & Khan, 2001; Kapandji, 1982).

3.3.1.24 Upper limb region: Shoulder coronal positional test

Apparatus: High Stool.

Test procedure: The subject stood erect, relaxed and with feet shoulder width apart. The examiner was positioned laterally to the subject, seated on a high stool. Using an imaginary coronal axis (median) passing through the midline of the subject, the shoulder postural position was noted and grouped into two categories: 1, anterior displacement of the shoulder less than two thirds (ideal); 2, anterior displacement more than two thirds (non-ideal) (Hattingh, 2003; Brukner & Khan, 2001; Kendall *et al.*, 1993; Kapandji, 1982).

3.3.1.25 Upper limb region: Winging positional test

Apparatus: High stool; marker.

Test procedure: The subject stood upright, relaxed with feet shoulder width apart. The examiner was positioned posteriorly and seated on the high stool. The inferior medial margins of both the scapulae were carefully marked, as well as the spinous process of T9. Distances between the spinous process (T9) and the margins were noted and recorded. Measurements were grouped into two categories:

- 1, distance equal with no winging (ideal);
- 2, discrepancy more than 1 cm. Winging on larger measurement side. Contra-lateral side, no winging, categorized as 1.

Equal distance (larger) plus winging, non-ideal, both categorized as 2 (Hattingh, 2003; Brukner & Khan, 2001; Halbach & Tank, 1990; Kapandji, 1982).

3.3.1.26 Upper limb region: Shoulder outline composition

Apparatus: High stool.

Test procedure: The subject stood erect, relaxed, feet shoulder width apart and the examiner positioned laterally. The shoulder outline was grouped into two

categories: (1.) predominantly muscular with very few to no visible bony landmarks (ideal); and (2.) less muscular with prominent bony landmarks well visible (non-ideal) (Hattingh, 2003; Brukner & Khan, 2001; Halbach & Tank, 1990).

3.3.1.27 Upper limb region: Throwing position (ROM) test

Apparatus: None.

Test procedure: The subject stood upright, relaxed, feet shoulder width apart and the examiner positioned laterally on the right side. The right shoulder was flexed actively to the maximum ROM with elbow extended. With the left hand the examiner stabilized the trunk and passively flexed the shoulder to the end of its range. Using an imaginary coronal axis passing through the midline (median) of the subject, the range was noted. The ranges were grouped into two categories: 1, exceeding coronal midline (ideal); 2, short of coronal midline (non-ideal) (Mullin, 1999).

3.3.1.28 Neurodynamics: Straight leg raise (SLR)

Apparatus: Plinth; long-arm goniometer.

Test procedure: The subject was positioned supine on the plinth. It was ensured the trunk and hips were in a neutral position. One hand was placed under the Achilles tendon and the other hand above the knee. The limb was lifted perpendicular to the plinth, as a solid lever moving at a fixed point in the hip. The hand on the knee prevented any knee flexion. The limb was lifted up to a symptom response or the end of its range. The result was noted. Using the long-arm goniometer (with the apex of the trochanter as midpoint) the range of movement was noted and grouped into three categories: 1, 90° and more (ideal);

2, 70–90° (non-ideal); 3, less than 70° (highly unsatisfactory) (Hattingh, 2003; Butler, 1991, Saunders, 1990).

3.3.1.29 Neurodynamics: Upper limb tension test

Apparatus: Plinth.

Test procedure:

- The subject was placed in the neutral supine position, towards the left side of the plinth. The examiner held the left hand of the subject in his right, with the upper left arm resting on the thigh of the examiner
- The left shoulder girdle was depressed by the examiner with his left hand, ensuring maintenance of the neutral position of the girdle. The glenohumeral joint was abducted to 110° in the coronal plane.
- With this positioned maintained, the forearm was supinated and the wrist and fingers extended.
- The shoulder was rotated laterally.
- The elbow was slowly extended.
- With this position maintained, the subject added lateral flexion of the cervical spine to the left and then to the right.

Results were grouped into three categories: 1, 180°–0° with slight symptoms (ideal); 2, 180°–0° with symptoms (non-ideal); 180° to more than 10°, with symptoms (highly unsatisfactory) (Hattingh, 2003; Butler, 1991; Halbach & Tank, 1990).

3.3.1.30 Neurodynamics: Lumbar 3,4 prone knee bend (nerve flexibility test)

Apparatus: Plinth.

Test procedure: The subject was positioned prone on the plinth. The lower limb was passively flexed towards the gluteal area until either a symptom response or

end of range was reached. The range was noted and grouped into three categories: 1, heel touching gluteal area with little resistance (ideal); 2, heel touching the gluteal area with strong resistance (non-ideal); 3, heel not touching (highly unsatisfactory) (Hattingh, 2003; Butler, 1991; Gould III, 1990).

3.3.1.31 Neurodynamics: Slump test

Apparatus: Plinth.

Test procedure:

- The subject was positioned well back with legs over the side of the plinth (knee crease at edge). Both hands were linked in a relaxed position behind the back.
- The subject was requested to slump with the cervical spine in extension. The examiner applied overpressure to the thoracic and lumbar spine. This position was maintained.
- The subject was requested to flex the cervical spine and to press the chin to the chest, again with gentle overpressure by the examiner.
- With this positioned maintained, the subject was requested to extend the knees, first the left and then the right. Range and discomfort were noted.
- With the position as mentioned above, dorsiflexion of the ankle and foot were carefully added. Range and discomfort were noted.
- With the position as mentioned above, neck flexion was carefully released. Signs and symptoms were noted.
- The test was repeated for the opposite side.
- Finally, with the subject in the slump position with overpressure, both knees were extended. Discomfort and range were noted.

Subjects were classified into three categories: 1, full range, with dorsiflexion, asymptomatic (ideal); 2, full range, with dorsiflexion, and discomfort (non-ideal);

3, limited range with tension (highly unsatisfactory) (Hattingh, 2003; Gould III, 1990).

3.3.2 Physical and motor variables

The physical and motor tests were performed all at once on the same day. Enough rest time was allowed between each of the tests to allow for the best possible results. The tests were carried out in the order described below.

3.3.2.1 Multistage fitness test: Shuttle run test (bleep test)

The progressive shuttle run test is used to estimate the maximum aerobic capacity of a cricketer (Kirby, 1991).

Apparatus: Cassette player; tape; markers (beacons); tape measure.

Test procedure: Two lines of markers were placed 20 m apart on a level grass surface. The test required individuals to run along the 20 m track for as long as possible at a set pace. The pace would increase every minute as the test progressed. The subjects were required to stay with the beep that would go off regularly. The subjects had to stay with the bleeps by turning with one foot on or behind the 20 m markers. The subjects were all instructed on what was required from them while undergoing the test (Ramsbottom *et al.*, 1988; Leger & Lambert, 1982).

Shuttle run classifications (Jamison, 1994).

Level	Shuttles	Classification
14 and above	130 +	Excellent
12–14	105–129	Very Good
10–12	82–105	Good

8–10	61–82	Fair
Below 8	< 61	Poor

Shuttle run classification (UCBSA, 2001).

Provincial	level 12,01 (105 shuttles)
National	level 13,01 (117 shuttles)

3.3.2.2 Sit-and-reach test

The purpose of the sit-and-reach test was to measure the range of motion in the cricketers' hips and backs, along with extension of the hamstrings muscles of the leg (Kirby, 1991)

Apparatus: Sit-and-reach box.

Test procedure: The subjects sat with the soles of their bare feet against the sit-and-reach box with their knees fully extended. The feet were in line with the 23 cm line on the arm of the sit-and-reach box. The subject then flexed maximally at both the hips and the lower back with the hands together, palms facing down and outstretched. The furthermost point was reached for and held for 2 seconds, with the knees still touching the ground, with the position of the finger tips measured on the ruler. Three attempts were made by the subject and the average calculated (Kirby, 1991).

Sit-and-reach classification (Jamison, 1994; Foster & John, 1989).

Scores (past the vertical mark at the toes (23 cm)		Classification
Over 14 cm	(37 cm)	Excellent
10–14 cm	(33–37 cm)	Very good
5–9 cm	(28–33 cm)	Good
0–4 cm	(23–27 cm)	Fair
Under 0 cm	(23 and less)	Poor

3.3.2.3 Abdominal strength test

The purpose of the abdominal strength test was to evaluate the strength of the abdominal muscles (Ellis *et al.,* 2000).

Apparatus: Floor mat.

Test procedure: The subject lay supine on the floor with a 90° bend at the knee. The feet, without shoes, had to be comfortably apart, in contact with the floor and not held. The subject was allowed up to three attempts to pass each stage. The execution of the test and classification of each stage of the test are described below under the heading of abdominal strength classification. All the movements had to be made in a smooth, controlled manner. The subject's score is the last stage completed successfully. Any attempt was regarded as unsuccessful if the subject: (1) lifted either foot partially or totally off the floor; (2) threw his arms and/or head forward in a jerky manner; (3) moved his arms from the stipulated position; (4) lifted the hips from the floor; (5) failed to maintain a 90° angle at the knee; and (6) was unable to complete the attempted sit-up (Ellis *et al.*, 2000: Kendall *et al.*, 1993).

Abdominal strength execution and stages (Kendal *et al.*, 1993).

0 = unable to raise more than the head off the table
1 = arms extended towards the knees, until scapula lifted from the table
2 = arms straight, until lumbar spine lifted from the table
3 = arms bent, until lumbar spine lifted from the table
4 = arms bent crossed over the chest, until lumbar spine lifted from the table
5 = hands behind neck, until lumbar spine lifted from the table

3.3.2.4 One minute oblique sit-up test (left and right anatomical side)

The purpose of the oblique sit-up test is to identify the asymmetrical endurance capacity of the oblique muscles by comparing the dominant and non-dominant sides (Gray & Gray, 2001; UCB, 2001).

Apparatus: Stop watch; floor mat.

Test procedure: The subject lay supine with the left leg crossed over the right and the left ankle on the right knee. The subject then placed his right hand behind his head and rotated his trunk towards the bent knee. Both hips were to remain on the ground. The repetition was only counted if the subject's hand did not lose contact with his head, his hips stayed in contact with the floor, the bent elbow touched the bent knee and his lower back made contact with the ground. The maximum repetitions in 60 seconds were recorded. After 60 seconds' rest, the test was repeated on the other side (Gray & Gray, 2001; UCB, 2001).

Oblique sit-up classification (UCB, 2001), left and right side.

Number	Classification
65 (National Standard)	Excellent
45+ (Provincial Standard)	Good

3.3.2.5 One minute push-up test

The purpose of the one minute push-up test was to measure the muscular endurance of the cricketers' elbow extensor and shoulder flexor muscles (Kirby, 1991).

Apparatus: Stop watch; floor mat.

Test procedure: The subject started in the straight press-up position with hands just wider than shoulder width and arms straight. (It is important for the body to remain straight and not to sag or rise at the hips during the movement.) A push-up was counted when the chest was lowered to touch the ground and the arms subsequently straightened to their starting position. The subjects were required to perform as many push-ups as possible in 60 seconds (Jamison, 1994).

Push-up classification (Jamison, 1994; Foster & John, 1989).

Number	Classification
Over 50	Excellent
41–50	Very good
31–40	Good
21–30	Fair
Under 21	Poor

3.3.2.6 Run a three and 505 agility test

The purpose of the run a three and 505 agility test was to evaluate the running speed and the turning speed of a cricketer whilst running a three (Bourdon *et al.*, 2000; Jamison, 1994).

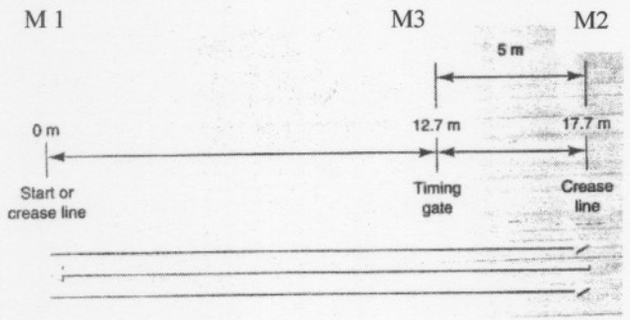
Apparatus: Two stop watches; measuring tape; markers (beacons); cricket bat.

Test procedure: Using the measuring tape and markers, two lines 17,7 m apart were marked out, with a further line marked out 12,7 m from the starting line. The subject assumed the starting position at the starting line with both feet behind the starting line (M1). On the command "go", the stopwatch 1 was activated when the subject's back foot left the ground. The subject then ran as fast as possible to the second marker (M2), turned after sliding the bat over the line and returned to the first marker (M1), thus completing the first run, turned for the second run and,

again after sliding the bat over the line, ran back to the second marker to complete the third run. The stopwatch was stopped on the third run when the bat was over the line at marker 2 (M2). The test was repeated twice and the average was calculated (Bourdon *et al.*, 2000; Jamison, 1994).

In conjunction with the run a three test, the 505 agility test was also performed. The second stopwatch was activated when the subject's hips went past the marker (M3) at 12,7 m and stopped when the hips went past the marker when the subject returned for the second run of the run a three test. The 505 agility test was also done twice and the average running speed was calculated for the two runs. In both tests the times were rounded off the nearest 0,01 sec (Bourdon *et al.*, 2000; Jamison, 1994).

Figure 3.1 Description of run a three test in conjunction with the 505 agility test (Bourdon *et al.*, 2000).



Description of run a three test in conjunction with the 505 agility test (Bourdon *et al.*, 2000).

Run a three classification (Jamison, 1994).

Time (seconds)	**Classification**
Under 9,20	Excellent
9,20–9,69	Very good
9,70–10,19	Good
10,20–10,69	Fair
Over 10,69	Poor

505 test classification (Jamison, 1994).

Time (seconds)	Classification
Under 2,10	Excellent
2,10–2,30	Very good
2,31–2,50	Good
2,51–2,70	Fair
Above 2,70	Poor

3.3.2.7 5-metre multiple shuttle test

The purpose of the 5-metre multiple shuttle test is to evaluate the fitness of the cricketers in a test that is an exercise of short duration and with high intensity, interspersed with periods of recovery (Boddington *et al.*, 2001).

Apparatus: Two stop watches; tape measure; markers (beacons).

Test procedure: The test was completed on a level grass surface. Six beacons were placed 5 m apart in a straight line to cover a total distance of 25 m. The subject began the test in line with the first marker (A); upon the signal "go", the subject sprinted 5 m to the second marker (B), touched the ground adjacent to the marker (B) with the hand and returned to the starting line (marker A), touching the ground adjacent to the marker (A) with the hand. Then the subject turned and sprinted 10 m to the third marker (C) and back to the start (A), etc., until 30 seconds of the exercise had been completed. The distance covered by the subject was recorded to the nearest 5 m during the 30 second shuttle. The subject was then allowed a 35 second recovery, during which the subject walked back to the starting marker (A). Annexure 3.3.4 (p. 376) sets out the calculation of the distance covered in 30 seconds (Boddington *et al.*, 2001).

To complete the test session, the subject was required to repeat the 30 second shuttle and 35 second recovery six times (Boddington *et al.*, 2001).

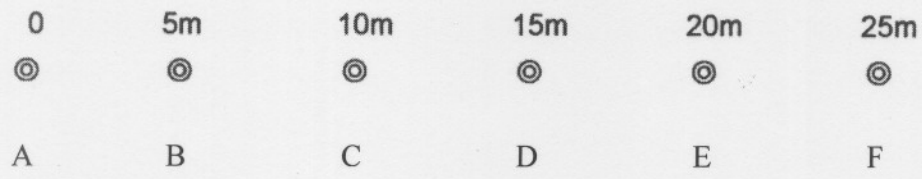


Figure 3.2 Schematics of the 5-metre shuttle run test (see p. 328)

3.3.3 Anthropometric variables

The measuring protocols used in this study were the International Standardrized Protocols as advocated by the International Society for the Advancement of Kinanthropomerty (ISAK) (Carter & Ackland, 1994; Ross & Marfell-Jones, 1991).

3.3.3.1 Terminology

3.3.3.1.1 Anatomical position

The subject stands in an upright position, arms next to the sides, palms facing forward, and feet facing forward (Ross & Marfell-Jones, 1991).

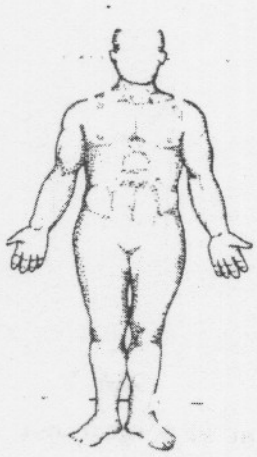
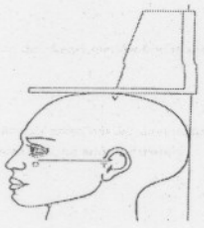


Figure 3.3 Anatomical position

3.3.3.1.2 Frankfort level

On measuring the body length, the head was held in the Frankfort level. The head position in the Frankfort level is when a horizontal line can be drawn from the orbitals to the trachion. The orbital is the inferior border of the eye socket and the trachion is the indentation above the targus of the ear (Norton *et al.*, 2000; Ross & Marfell-Jones, 1991).



V = Vertex
O = Orbital
T = Trachion

Figure 3.4 Frankfort level

3.3.3.1.3 Vertex

The vertex is the highest position on the skull when the head is positioned in the Frankfort level (Norton *et al.*, 2000; Ross & Marfell-Jones, 1991).

3.3.3.1.4 The acromion landmark

The acromion landmark is the highest point on the superior lateral aspect of the acromion when the subject is standing in an upright position with the arms relaxed next to the body (Ross & Marfell-Jones, 1991).

3.3.3.1.5 The radial landmark

This is the point between the upper and lateral border of the head of the radius, the space between the capitulum of the humerus and the head of the radius. The most superior lateral border of the radius is marked (Norton *et al.*, 2000).

3.3.3.1.6 Mid-acromial-radial

The point measured equidistant from the acromial and the radial. The linear distance between the acromial and radial is measured with the arm flexed and extended by the side. A small mark is made at the midpoint between these two

landmarks. This mark is projected around to the posterior and anterior surfaces of the arm as a horizontal line. This line is required for locating the triceps and biceps skinfold sites (Norton *et al.*, 2000).

3.3.3.1.7 Subscapular

The lowermost tip of the inferior angle of the scapula (Norton *et al.*, 2000).

3.3.3.1.8 The iliospinal landmark

The most inferior aspect or lowermost tip of the anterior superior iliac spine (Norton *et al.*, 2000; Ross & Marfell-Jones, 1991).

3.3.3.1.9 Body mass

Apparatus: Calibrated electronic mass meter.

Technique: The subject was measured while dressed in shorts, standing upright with the feet shoulder width apart and weight evenly distributed on the mass meter. The subject was requested to keep his head up and arms relaxed next to the body. Body mass was recorded to the nearest digital tenth of a kilogram (Ross & Marfell-Jones, 1991).

3.3.3.1.10 Body stature (body length)

Apparatus: A portable Holtain stadiometer.

Technique: The maximum distance between the standing surface and the vertex of the skull were obtained. The measurement was taken with the subject standing erect, barefoot with heels together, body weight equally distributed and arms relaxed. The heels, buttocks, upper trunk and back of the skull had to touch the measuring apparatus before measurement. The head was held in the Frankfort level. Before the final measurement was taken, the subject was

requested to inhale and elongate himself without lifting the heels from the platform. Firm contact was made between the index meter and the vertex of the skull for measurement. The body length was recorded to the nearest millimetre (Ross & Marfell-Jones, 1991).

3.3.3.2 Skinfold measurements

Apparatus: Harpen skinfold measuring apparatus with a constant pressure of 10 g/mm^2, tape measure, marker.

Technique: The sites where the measurements had to be taken were clearly identified and marked. The subject was measured on his dominant side. The left hand was used to take the skinfold, which was positioned so that the thumb pointed downward and the back of the hand was in full view of the measurer. The right hand was used to hold the measuring apparatus. For measurement, a double layer of skin with its underlying adipose tissue was firmly gripped on the marked area between the index finger and thumb. In order to eliminate muscle, the finger and thumb rolled the skinfold slightly, thereby also ensuring that there was a sufficiently large grasp of the skinfold. The skinfold was pulled away from the underlying musculature and the mouth of the measuring apparatus was applied 1 cm below the finger of the gripping hand. A firm grip was kept on the skinfold throughout the measurement (Norton *et al.*, 2000; Norton e*t al.*, 1996).

Enough time was allowed (2–3 seconds) throughout the procedure for full pressure measurement to take place. Two measurements of each skinfold were taken and when a discrepancy of more than 1 mm occurred, a third measurement was obtained. The measurements were taken to the nearest 0,2 mm. The seven skinfolds were measured as follows:

3.3.3.2.1 Triceps skinfold

A vertical skinfold was measured on the marked posterior mid-acromial-radial line.

3.3.3.2.2 Biceps skinfold

A vertical skinfold was measured on the marked anterior mid-acromial-radial line.

3.3.3.2.3 Subscapular skinfold

The skinfold was measured at the marked site 2 cm along a line running laterally and obliquely downward from the subscapular landmark at an angle of approximately 45° with the horizontal line.

3.3.3.2.4 Supraspinal skinfold

The skinfold was measured about 7 cm above the iliospinal marked site. It was measured in a line running from the iliospinal landmark to the anterior axillary border. The skinfold was measured at a downward angle of 45° to the horizontal.

3.3.3.2.5 Abdominal skinfold

The skinfold was raised 3–5 cm from the right-hand side of the omphalion. The omphalion is the midpoint of the navel. It was important not to place the fingers or callipers in the navel.

3.3.3.2.6 Thigh skinfold

The skinfold was measured on the anterior surface of the thigh. The landmark was marked parallel to the long axis of the femur at the midpoint of the distance between the inguinal fold and the superior border of the patella (while the leg was bent at an angle of 90°).

3.3.3.2.7 Calf skinfold

The skinfold was measured with the subject sitting with his foot on the box, knee flexed at an angle of 90° and the calf relaxed. The skinfold was raised on the medial aspect of the calf where the calf muscle has its maximal circumference.

3.3.3.3 Breadth measurements

Apparatus: Holtain anthropometer.

Technique: The moving head of the stylus was held in the right hand and the left hand held the non-moving end. With the callipers gripped correctly, the middle fingers were used to palpate the bony points of the epicondyles. The callipers were placed directly on the epicondyles and firm pressure was maintained on the epicondyles with the index fingers. All measurements were taken to the nearest 0,1 cm.

3.3.3.3.1 Humeral breadth

The distance was taken between the medial and lateral epicondyles of the humerus when the arm was raised forward to the horizontal and the forearm was flexed at right angles to the upper arm.

3.3.3.3.2 Femoral breadth

The distance was taken between the medial and lateral epicondyles of the femur when the subject was seated and the leg was flexed at the knee to form a right angle with the thigh.

3.3.3.4 Girth measurements

Apparatus: Flexible steel tape calibrated in centimetres with millimetre gradations.

Technique: The cross-hand technique was used for measuring the girths; the reading was taken from the tape where the zero was located, more laterally than medially on the subject. The tape was held at right angles to the limb or body segment being measured and the tension of the tape kept constant. To achieve the constant tension, it was ensured that there was no indentation on the skin and that the tape was held in position at the designated landmark. All girths were measured to the nearest 0,1 cm.

3.3.3.4.1 Arm (biceps) girth (flexed and tensed)

This is the maximum circumference of the dominant upper arm, raised laterally to the horizontal with the forearm at about 45°. The subject was asked to tighten his biceps to its maximum and the measurement was taken.

3.3.3.4.2 Calf girth

The measurement was taken with the subject standing upright, feet shoulder width apart and the weight distributed on both legs. The measurement was taken on the maximal circumference of the calf muscle.

3.3.3.4.3 Mid-thigh girth

The mid-thigh was measured on the anterior surface of the thigh. The landmark was marked halfway between the trochanterion and the lateral tibial epicondyles. The subject was seated with the knees bent at an angle of 90°.

3.3.3.5 Body composition

3.3.3.5.1 Fat percentage formula

The components of the subjects' body fat was calculated with the use of transformations in Microsoft Office 2000. Body fat percentages were calculated with the formula of Withers *et al.* (1987). This formula also uses the age of the subjects as part of the calculations.

Body Density: (BD) = 1,0326 – 0,00031 x (age) – 0,00036 x (sum of 6 skinfolds)

The six skinfolds were the triceps, subscapular, supraspinal, abdominal, thigh and calf skinfolds.

Fat percentage = (495 / **BD**) – 450

Fat mass (kilograms of fat) was calculated as follows:

Fat mass = $\frac{\text{body weight x fat percentage}}{100}$

Lean body mass was calculated as follows:

Lean body mass = body mass – fat mass

3.3.3.5.2 Somatotyping

For the calculation of somatotypes the Carter-Heath anthropometric somatotype methods were used.

The formula for endomoprhy is as follows (Carter & Heath, 1990):

$$\text{Endomorphy} = -0{,}7182 + 0.1451\,(\text{sum of skinfolds} \times \tfrac{170{,}18}{\text{stature (cm)}}) - 0{,}00068\,(\text{sum of skinfolds} \times \tfrac{170{,}18}{\text{stature (cm)}})^2 + 0{,}0000014\,(\text{sum of skinfolds} \times \tfrac{170{,}18}{\text{stature (cm)}})^3$$

Sum of skinfolds = sum of triceps, subscapular and supraspinal skinfolds

The formula for mesomorphy is as follows (Carter & Heath, 1990):

Mesomorphy = 0,858 X (humeral breadth) + 0,601 X (femur breadth) + 0,188 x (corrected arm girth) + 0,161 (corrected calf girth) – 0, 131 X (stature) + 4,50

Corrected arm girth = arm girth (tensed) – triceps skinfold (mm converted to cm)
Corrected calf girth = calf girth – calf skinfold (mm converted to cm)

The formula for Ectomorphy is as follows (Carter & Heath, 1990):

$$\text{Ectomorphy} = \frac{\text{Stature}}{\sqrt[3]{\text{Body mass}}} = \textbf{HWR}\ (\text{Height-Weight Ratio})$$

If **HWR** greater than or equal to 40,75 then
Ectomorphy = 0,732 X **HWR** – 28<58
If HWR is less than 40,75 and greater than 38,25 then
Ectomorphy = 0,463 x **HWR** – 17,63
If **HWR** is equal to or less than 38,25 then
Ectomorphy = 0,1

3.4 Injury epidemiology

3.4.1 Injury report form

The injury report form used is similar to the injury questionnaire used by Stretch (2003a; 2001a) (annexure 3.4.1, p329).

It was designed to obtain the following information: (1) anatomical site of injury; (2) nature of injury suffered; (3) mechanism of injury; and (4) severity of injury.

Injuries were grouped according to their anatomical location, as follows: 1, head, cervical spine and face; 2, upper limb; 3, thoracic spine, lumbar spine and trunk; and 4, lower limb.

Nature of injury was grouped as follows: 1, fracture; 2, stress fracture; 3, joint; 4, dislocation; 5, muscle; 6, tendon; 7, ligament; 8, fascia; 9, cartilage; 10, nerve; 11, open wound; and 12, other.

Mechanism of injury was grouped as follows: 1, contact/impact; 2, dynamic overload; 3, overuse; 4, structural vulnerability; 5, inflexibility; 6, muscle imbalance; and 7, rapid growth.

The severity of injury was also recorded and was expressed by the number of days missed. The classification was done according to the United States National Athletic Injury Registration System (NAIRS). Injuries were divided into three categories: 1, minor injury (one to seven days); 2, "moderately serious" injury (eight to 21 days); and 3, serious injury (over 21 days) (Van Mechelen, (1997); Van Mechelen *et al.*, 1992). Days missed through medical illness were not considered in this study.

3.4.2 Injury incidence per 10 000 playing hours

The formula used by De Loës *et al.,* (2000), adapted from Chambers (1979), to calculate the injury incidence per 10 000 hours was used. The formula is as follows:

$$\frac{\text{Number of injuries in a sport during a season x 10 000}}{\text{(Number of participants per season) x (Number of hours of participation per season)}}$$

= incidence of injuries per 10 000 hours of play (exposure to) a sport

3.5 Injury prevention and training programme (annexure 3.5, p. 331)

It is stated by Finch *et al.* (1999) that a comprehensive physical conditioning programme before (off-season) and during the cricket season is an important injury prevention strategy. The injury prevention and training programme in this study focused on the off-season and consisted of three six-week gymnasium training programmes (off-season) and one maintenance programme (pre-season to the end of the season) (see Table 3.3). Physiological preparation (aerobic and anaerobic conditioning) programmes were also incorporated into the gymnasium training programmes. Exercises for specific body areas were compiled after an extensive literature study on each of the body areas and their role in causing and preventing injuries. The exercises most suitable for an improvement in the biomechanical evaluation, physical and motor evaluation as well as in the anthropometric evaluation were selected. The injury prevention and training programmes were complied by the fitness trainer of the North-West cricket union. The injury prevention programme and training programme were adjusted accordingly at the end of each of the six biomechanical, physical and motor and anthropometric evaluations to improve on any shortcoming identified by the evaluations done, as well as from the injury list that was compiled at the end of each season.

Table 3.3 Training schedule followed for each season

Active rest	1st 6 week programme	2nd 6 week programme	3rd 6 week programme	Evaluation	Maintenance programme
End of season middle March to start of off-season programme in May	May to middle June	Middle June to end July	Start August to middle September (end of the off-season)	Middle September (end of the off-season training)	Players to do maintenance programme throughout the season

Cricketers were expected to keep a log book, indicating which programmes and which exercises were done on which day. This was done by filling in the date in the space provided for the date on the programme. Training sessions and logs of the cricketers were also monitored by the trainer in a separate log book. This was

done to follow the progress of the cricketers, as well as to adjust the programme accordingly, and to ensure the appropriate training was done before the player progressed to the next level.

3.5.1 The injury prevention and training programme

The first gymnasium programme was divided into the following categories: 1, leg programme; 2, specific shoulder programme; 3, abdominal exercises and lower back (stabilization programme); 4, upper back (scapula stabilizers); and 5, fitness programme. Before the commencement of each programme, players were instructed to complete a ten-minute cycle warm-up as well as specific stretches for the area they were working on that specific day. A total body stretch was expected from the players on each of the days they did programmes 3 and 5. At the end of any three programmes the players were also expected to complete a 20-minute fitness session, e.g. 4000 m rowing after the leg programme or a 20-minute run on the treadmill or 20 minutes on the stepper after any of the other three programmes. Players were allowed to choose the days and the extra running exercises they wanted to do. No running was allowed the day after a hard fitness session or leg session. Players could choose their own order in which to complete the gymnasium programmes.

The second programme was divided into the following categories: 1, leg programme; 2, specific shoulder programme (shoulder ratios); 3, abdominal exercises and lower back (stabilization programme); 4, upper body (chest and scapula stabilizers); and 5, fitness programme. Before the commencement of each programme players were instructed to complete a ten-minute cycle warm-up as well as specific stretches for the area they were working on that specific day. A total body stretch was expected from the players on each of the days they did programmes 3 and 5. At the end of any two programmes the players were also expected to complete a 20-minute fitness session, e.g. 2 x 2000 m rowing after the leg programme or a 20-minute run on the treadmill or 20 minutes on the

stepper after any of the other programmes. Players were allowed to choose the days and the extra running exercise they wanted to do. No running was allowed the day after a hard fitness session or leg session. From the start of the second programme the fitness sessions were done on a specific day of the week by all the players.

The third gymnasium programme was divided into the following categories: 1, leg programme (strength and pliometric work); 2, abdominal exercises and lower back (stabilization programme); 3, upper body (agonist and antagonist (scapula stabilizers)); and 4, fitness programme. Before the commencement of each programme players were instructed to complete a ten-minute cycle warm-up as well as specific stretches for the area they were working on that specific day. A total body stretch was expected from the players on each of the days they did sections two and four. At the end of any two programmes the players were also expected to complete a 20-minute fitness session, e.g. 6 x 300 m rowing (completing 300 m in 60–65 seconds, resting 55 seconds) after the leg programme or a 20-minute run on the treadmill or 20-minutes on the stepper after any of the other programmes. Players were allowed to choose the days and the extra running exercise they wanted to do. No running was allowed the day after a hard fitness session or leg session. From the start of programme 3 the fitness sessions were done on a specific day of the week by all the players.

3.5.2 The maintenance programme

The maintenance programme was done during the playing session season under the supervision of the trainer. The gymnasium exercises given, excluding fitness sessions, could be done as one programme during the week or as a separate programme for each body area, depending on the time available during matches. Fitness sessions were also given to be done once a week, depending on time available during matches. At least one stabilizing session had to be done during

the time off during matches. The programme was not evaluated as part of this study (see annexure 3.5, p.383 for programme).

3.6 Statistical analysis

After consultation with the senior statistician of the North-West University it was recommended the results be reported as done in this study. The statistical analysis was done by means of the SAS statistical program, SAS Institute Inc., 1999 (the SAS system for Windows release 8.02 TS Level 02M0 Copyright 1999-2001 by SAS Institute Inc., Cary, NC, USA (SAS Institute Inc., 1999)). The mean value was calculated, as well as the standard deviation, by means of the SAS statistical program. Furthermore, the SAS statistical program was used to determine significant differences for each of the strategies employed over the six-season period of this study.

Chapter 4. Results and Discussion

4.1 Introduction

The first aim of this study was to evaluate the effectiveness of an injury prevention and training programme on biomechanical, physical and motor and anthropometric variables of elite cricket players during the off-season over a six-season period (1998/1999–2003/2004). A second aim was to monitor the injury epidemiology of the elite cricket players over a six-season period (1998/1999–2003/2004).

To test the effectiveness of an injury prevention and training programme, three different protocols were used to ensure that as many variables as possible were controlled. In the first protocol ("protocol 1") all players were evaluated at the end of the off-season (middle September), irrespective of the number of times they had been exposed to the injury prevention and training programme. The reason for this protocol was that the more cricket players were exposed to the injury prevention and training programme, the more significant the results became.

With this method it was ensured that those cricket players who had previous experience of the injury prevention and training programme, players with no experience, players with serious shortcomings/defects in their biomechanical, physical and motor and anthropometric profiles, players without injury etc. were part of the test . This method also ensured the practical situation experienced in modern-day cricket, the heterogeneity of change among professional cricket players. Also, this protocol was suggested by the senior statistician of the North-West University as most applicable for this study. Several similar studies (Hattingh, 2003; Stretch 2003b; Orchard *et al.*, 2002; Leary & White, 2000) used this type of protocol and obtained results that were useful to the science involving the study of elite sport and talented sportsmen.

A second protocol ("protocol 2") involved dividing players into groups that were exposed to the injury prevention and training programme for the first time, second time, third time and fourth time to evaluate their results. Thus for example if a player was drafted into the North-West professional squad in the 2001/2002 season for the first time and exposed to the injury prevention and training programme for the first time, his results were placed with the players that were exposed to the injury prevention and training programme for the first time (first exposure time) and not with the results of the players in the fourth exposure (players that were evaluated for the fourth time). The same procedure was followed for all the players. One player was exposed to the injury and prevention programme for a fifth time, but the results of this one player will not be discussed in this section

The third protocol ("protocol 3") involved monitoring the results of two different groups of players, each group consisting of the same players, over a three-season period. As a result of the professionalism that exists in the sport, players moved to other provinces or lost their contracts, which made it difficult to monitor the same group of players for longer periods. The numbers in the case studies were small but due to the fact that the study was done on elite cricketers, small numbers are acceptable. The two groups were each evaluated over a period of three seasons, due to the fact that it was not possible to evaluate one group over the period of six seasons for reasons already mentioned.

The results of the different protocols will be discussed under the headings of (1) biomechanical evaluation; (2) physical and motor evaluation; and (3) anthropometric evaluation. The descriptive statistics of each evaluation will be discussed, together with those results with a high practical significance (d-values $\geq$ 0,80). The first section of chapter 4 will focus on the results of the first protocol, namely the biomechanical, physical and motor and anthropometric evaluations for the six off-season periods (1998/1999–2003/2004).

In the second section of chapter 4 (protocol 2) the results of the players were divided into groups that were exposed to the injury prevention and training programme for the first time, the second time, the third time and the fourth time with regard to the biomechanical, physical and motor and anthropometric evaluations will be discussed. The descriptive statistics will be discussed of each evaluation, together with those results with a high practical significance (d-values ≥0,80).

In the third section of Chapter 4 the result of protocol 3 will be discussed, with reference to the two different groups that followed the injury prevention and training programme for three consecutive seasons. The descriptive statistics will be analysed as well as the practical significances (d-values ≥0,80).

The injury epidemiology (second aim) will be discussed after the results of the three protocols in Chapter 4.

The players were all evaluated at the end of the off-season (middle September) before the commencing season. This entails for example that the off-season exposure to the injury prevention and training programme took place from the beginning of May 1998 to middle September 1998. This period, May 1998 to middle September 1998, is thus referred to as the off-season for the 1998/1999 playing season.

Table 4.1 describes the total number of players evaluated per season (at the end of the off-season) over the six off-season periods (1998/1999–2003/2004). It also indicates the total number of players who have been evaluated for the first, second, third, fourth and fifth time. A total of 93 players were evaluated from the 1998/1999 season to the 2003/2004 season.

Table 4.1 Total number of cricketers evaluated per off-season (1998/1999–2003/2004)						
	1998/ 1999	**1999/ 2000**	**2000/ 2001**	**2001/ 2002**	**2002/ 2003**	**2003/ 2004**
Total number of cricketers evaluated per season	**9**	**11**	**18**	**23**	**16**	**16**
First evaluation	9	3	7	12	4	4
Second evaluation		8	4	3	10	2
Third evaluation			7	3	1	9
Fourth evaluation				5	0	1
Fifth evaluation					1	

4.2 Protocol 1

4.2.1 The biomechanical evaluation

The descriptive statistics and the practical significance (d-values ≥ 0,80) for the biomechanical evaluations done (in the off-season) for the six-season period (1998/1999–2003/2004) are discussed below. As a result of more statistics becoming available, owing to the fact that more biomechanical evaluations were introduced, attention will be given to those areas where the practical significance were high. For example if the results from the 1998/1999 off-season (year 1) showed a high practical significance compared to the third off-season 2000/2001 (year 3) for a specific evaluation, the results will be discussed.

Diagram 4.2.1 sets out the corresponding year and off-season used to describe practical significance.

Diagram 4.2.1. Corresponding year and off-season	
Year	**Season**
1	1998/1999
2	1999/2000
3	2000/2001
4	2001/2002
5	2002/2003
6	2003/2004

Table 4.2.1a and Table 4.2.1b display the results of the biomechanical evaluations done (ankle dorsiflexion, Thomas test which evaluates the flexibility of the illiotibial band, quadriceps muscles and iliopsoas muscles and the flexibility of the gluteal muscles). The test for the flexibility of the gluteal muscles was introduced in the 2000/2001 season. This was done to evaluate the cricketer more thoroughly (as stated in the literature by different authors, such as Belle-Jenje (2003) and Agosta (2001)) and to identify more areas of potential injury risks to the cricketer. Also, its purpose was to provide more information regarding the biomechanical profile of the cricketer that could be used by other researchers in their study.

Table 4.2.1a Descriptive statistics of biomechanical variables evaluated (ankle dorsiflexion, Thomas test and gluteus maximus mobility) for the six-season period (1998/1999–2003/2004).													
Variables	**Anatomical Side**	**1998–1999**		**1999–2000**		**2000–2001**		**2001–2002**		**2002–2003**		**2003–-2004**	
		$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**
Ankle dorsiflexion	Left	2,11	0,60	2,00	0,89	1,56	0,70	1,57	0,59	1,69	0,70	1,31	0,48
	Right	2,11	0,60	2,00	0,89	1,50	0,71	1,61	0,66	1,75	0,77	1,31	0,48
Thomas test	**Iliotibial band Mobility**												
	Left	1,67	0,5	1,73	0,47	2,06	0,64	2,26	0,62	1,69	0,60	1,38	0,50
	Right	1,77	0,44	1,73	0,47	2,22	0,65	2,17	0,65	1,63	0,62	1,31	0,48
	Quadriceps mobility												
	Left	1,55	0,53	1,64	0,50	1,89	0,58	1,74	0,62	1,38	0,50	1,44	0,51
	Right	1,56	0,53	1,64	0,50	1,94	0,54	1,74	0,62	1,31	0,48	1,44	0,51
	Iliopsoas Mobility												
	Left	1,67	0,5	1,45	0,52	2,44	0,62	1,96	0,56	1,63	0,51	1,50	0,52
	Right	1,67	0,5	1,45	0,52	2,33	0,69	1,78	0,52	1,44	0,63	1,56	0,51
Gluteus maximus mobility	Left					1,22	0,43	2,26	0,62	1,50	0,63	1,63	0,72
	Right					1,22	0,43	2,30	0,56	1,50	0,52	1,50	0,73

Table 4.2.1b Practically significant differences (d-values) of the biomechanical variables (ankle dorsiflexion, Thomas test and gluteus maximus mobility) evaluated											
Year	Year	Ankle dorsiflexion		Thomas test						Gluteus maximus mobility	
				Iliotibial band mobility		Quadriceps mobility		Iliopsoas mobility			
		Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
1	2	0,12	0,12	0,12	0,11	0,15	0,15	0,41	0,41		
1	3	**0,79**	**0,86**	0,61	0,69	0,57	0,72	**1,26**	**0,97**		
1	4	**0,91**	0,77	**0,96**	0,61	0,30	0,30	0,52	0,22		
1	5	0,60	0,47	0,03	0,25	0,34	0,46	0,07	0,45		
1	6	**1,33**	**1,33**	0,58	**0,97**	0,22	0,22	0,32	0,20		
2	3	0,50	0,56	0,51	0,77	0,43	0,57	**1,61**	**1,28**		
2	4	0,49	0,44	**0,86**	0,69	0,17	0,17	**0,89**	0,63		
2	5	0,35	0,28	0,07	0,17	0,52	0,64	0,28	0,03		
2	6	0,77	0,77	0,70	**0,87**	0,39	0,39	0,09	0,21		
3	4	0,01	0,15	0,32	0,07	0,24	0,33	0,79	**0,80**	**1,68**	**1,94**
3	5	0,19	0,32	0,58	**0,92**	**0,88**	**1,17**	**1,32**	**1,31**	0,44	0,54
3	6	0,34	0,27	**1,06**	**1,41**	0,77	**0,94**	**1,53**	**1,12**	0,56	0,38
4	5	0,17	0,18	**0,93**	**0,84**	0,59	0,69	0,54	0,67	**1,20**	**1,44**
4	6	0,43	0,45	**1,43**	**1,32**	0,49	0,49	**0,81**	0,42	**0,88**	**1,10**
5	6	0,53	0,56	0,52	0,50	0,12	0,24	0,20	0,24	0,17	0,00

The d-values used: d-value < 0,20 = low practical significance, d- value ≥ 0,20 = small practical significance, d-value ≥ 0,50 = medium practical significance and d-value ≥ 0,80 high practical significance.

Table 4.2.1a shows a decrease (positive result) in the mean value for ankle dorsiflexion: left and right anatomical side, illiotibial band mobility: left and right anatomical side, quadriceps mobility: left and right anatomical side, iliopsoas mobility: left and right anatomical side from the 1998/1999 season to the 2003/2004 season. Gluteus maximus mobility: left and right anatomical side in Table 4.2.1a shows an increase in the mean value from the 2000/2001 off-season to the 2003/2004 off-season, a negative result.

Table 4.2.1a shows a decrease (positive) in the mean value for the ankle dorsiflexion test from the 1998/1999 ($\bar{x}$ = 2,11) off-season (year 1) to the 2003/2004 ($\bar{x}$ = 1,31) off-season (year 6) for the left and right anatomical sides. The decrease in the mean value is a positive result for the ankle dorsiflexion test. This is confirmed by the d-value in Table 4.2.1b, indicating a high practical significance of 1,33 for the left and right anatomical sides for the ankle dorsiflexion test.

Table 4.2.1a also indicates a decrease (positive) in the mean value for ankle dorsiflexion from the 1998/1999 off-season ($\bar{x}$ = 2,11, left and right anatomical sides) to the 2000/2001 off-season ($\bar{x}$ = 1,56 for the left anatomical side and $\bar{x}$ = 1,50 for the right anatomical side), with the d-value = 0,79 for the left anatomical side, a medium practical significance, and a d-value = 0,86 for the right anatomical side, a high practical significance (year 1 to year 3, Table 4.2.1b).

Table 4.2.1a further shows a decrease (positive) in the mean value for ankle dorsiflexion from the 1998/1999 off-season ($\bar{x}$ = 2,11, left and right anatomical sides) to the 2001/2002 off-season ($\bar{x}$ = 1,57 for the left anatomical side and $\bar{x}$ = 1,61 for the right anatomical side), with the d-value = 0,91 for the left anatomical side, a medium practical significance, and a d-value = 0,77 for the

right anatomical side, a medium practical significance (year 1 to year 4, Table 4.2.1b).

The mean value for the illiotibial band mobility decreased (positive) from the 1998/1999 off-season ($\bar{x}$ = 1,77 for the right anatomical side) to the 2003/2004 off-season ($\bar{x}$ = 1,31 for the right anatomical side, Table 4.2.1a), a d-value of 0,97 for the right anatomical side (year 1 to year 6 in Table 4.2.1b), a high practical significance for the right anatomical side.

Table 4.2.1a further indicates an increase (a negative result) in the mean value for the left illiotibial band mobility from the 1998/1999 off-season ($\bar{x}$ = 1,67) to the 2001/2002 off-season ($\bar{x}$ = 2,26), with a d-value = 0,96, a high practical significance (year 1 to year 4, Table 4.2.1b). The result for the right illiotibial band mobility (Table 4.2.1a) also showed an increase (a negative result) in the mean value from the 1998/1999 off-season ($\bar{x}$ = 1,77) to the 2001/2002 off-season ($\bar{x}$ = 2,17), with a d-value = 0,61, a medium practical significance (year 1 to year 4, Table 4.2.1b).

Table 4.2.1a then further indicates a decrease (a positive result) in the mean value for the left illiotibial band mobility from the 2001/2002 off-season ($\bar{x}$ = 2,26) to the 2003/2004 off-season ($\bar{x}$ = 1,38), with a d-value = 1,43 a high practical significance (year 4 to year 6, Table 4.2.1b). A similar result was found for the right illiotibial band mobility, with its (Table 4.2.1a) showing a decrease (a positive result) in the mean value from the 2001/2002 off-season ($\bar{x}$ = 2,17) to the 2003/2004 off-season ($\bar{x}$ = 1,31), with a d-value = 1,32, a high practical significance (year 4 to year 6, Table 4.2.1b). Results (Table 4.2.1a) and also indicating a decrease in the mean value from the 2001/2002 off-season to the 2002/2003 off-season for the iliottibial band mobility test, with high practical

significances (Table 4.2.1b) for the left and right anatomical sides. This indicates that the threat of injury that was present in the 2001/2002 off-season, relating to this area, has potentially been decreased in the 2003/2004 off-season.

Table 4.2.1a indicates an increase (negative result) in the mean value of the quadriceps mobility for the left anatomical side from the 1998/1999 off-season ($\bar{x}$ = 1,55) to the 2000/2001 off-season ($\bar{x}$ = 1,89), with a d-value = 0,57, a moderate practical significance (year 1 to year 3 in Table 4.2.1b). There was also an increase (negative result) in the mean value of the quadriceps mobility for the right anatomical side from the 1998/1999 off-season ($\bar{x}$ = 1,56) to 2000/2001 off-season ($\bar{x}$ = 1,94), with a d-value = 0,72, a moderate practical significance (year 1 to year 3 in Table 4.2.1b). An increase in tightness in the quadriceps muscle group may affect the pelvis biomechanics (position), which in turn could potentially lead to muscle injuries and could affect lower limb biomechanics.

Table 4.2.1a indicates a decrease (positive result) in the mean value of the quadriceps mobility for the left anatomical side from the 2000/2001 off-season ($\bar{x}$ = 1,89) to the 2002/2003 off-season ($\bar{x}$ = 1,38), with a d-value = 0,88, a high practical significance (year 3 to year 5 in Table 4.2.1b). There was also a decrease (positive result) in the mean value of the quadriceps mobility for the right anatomical side from the 2000/2001 off-season ($\bar{x}$ = 1,94) to the 2002/2003 off-season ($\bar{x}$ = 1,31), with a d-value = 1,17, a high practical significance (year 3 to year 5 in Table 4.2.1b).

Also a decrease (positive result) is seen in Table 4.2.1a in the mean value of the quadriceps mobility for the left anatomical side from the 2000/2001 off-season ($\bar{x}$ = 1,89) to the 2003/2004 off-season ($\bar{x}$ = 1,44), with a d-value = 0,77, a medium practical significance (year 3 to year 6 in Table 4.2.1b). There was also a decrease (positive result) in the mean value of the quadriceps mobility for the

right anatomical side from the 2000/2001 off-season ($\bar{x}$ = 1,94) to the 2002/2003 off-season ($\bar{x}$ = 1,44), with a d-value = 0,94, a high practical significance (year 3 to year 6 in Table 4.2.1b).

The iliopsoas mobility in Table 4.2.1a indicates an increase (negative result) in the mean value for the left anatomical side of the iliopsoas mobility from the 1998/1999 off-season ($\bar{x}$ = 1,67) to the 2000/2001 off-season ($\bar{x}$ = 2,44), with d-values = 1,26, a high practical significance (year 1 to year 3, Table 4.2b). Similar results (negative) were found for the right anatomical side from the 1998/1999 off-season ($\bar{x}$ = 1,67) to the 2000/2001 off-season ($\bar{x}$ = 2,33), with a d-value = 0,97, a high practical significance (year 1 to year 3, Table 4.2b). A tight iliopsoas muscle could potentially influence the pelvic biomechanics and may lead to potential injuries as a result of this inflexibility.

Table 4.2.1a indicates a decrease (positive result) in the mean value of the left anatomical side for the iliopsoas mobility from the 2000/2001 off-season ($\bar{x}$ = 2,44) to the 2002/2003 off-season ($\bar{x}$ = 1,63), with a d-value = 1,32, a high practical significance (year 3 to year 5, Table 4.2.1b). Similar results in Table 4.2.1a was found for the right anatomical side for the iliopsoas mobility. A decrease (positive result) in the mean value from the 2000/2001 off-season ($\bar{x}$ = 2,33) to the 2002/2003 off-season ($\bar{x}$ = 1,44), with a d-value = 1,31, a small practical significance (year 3 to year 5, Table 4.2b).

Table 4.2.1a further indicates a decrease (positive result) in the mean value of the left anatomical side for the iliopsoas mobility from the 2000/2001 off-season ($\bar{x}$ = 2,44) to the 2003/2004 off-season ($\bar{x}$ = 1,50), with a d-value = 1,53, a high practical significance (year 3 to year 6, Table 4.2.1b). Similar results in Table 4.2.1a was found for the right anatomical side for iliopsoas mobility. A decrease

(positive result) in the mean value from the 2000/2001 off-season ($\bar{x}$ = 2,33) to the 2003/2004 off-season ($\bar{x}$ = 1,56), with a d-value = 1,12, a high practical significance (year 3 to year 6, Table 4.2b).

Table 4.2a indicates a decrease (positive result) in the mean value of the left anatomical side for the iliopsoas mobility from the 2001/2002 off-season ($\bar{x}$ = 1,96) to the 2003/2004 off-season ($\bar{x}$ = 1,50), with a d-value = 0,81, a high practical significance (year 4 to year 6, Table 4.2b). Similar results in Table 4.2a was found for the right anatomical side for the iliopsoas mobility. A decrease (positive result) in the mean value from the 2001/2002 off-season ($\bar{x}$ = 1,78) to the 2003/2004 off-season ($\bar{x}$ = 1,56), with a d-value = 0,42, a small practical significance (year 4 to year 6, Table 4.2b). A tight iliopsoas muscle could potentially influence the pelvic biomechanics and may lead to potential injuries as a result of this inflexibility.

The mean value for the gluteus maximus mobility increased (negative) from the 2000/2001 off-season ($\bar{x}$ = 1,22 for the left and right anatomical sides, Table 4.2.1a) to the 2001/2002 off-season ($\bar{x}$ = 2,26 for the left anatomical side and 2,30 for the right anatomical side, Table 4.2.1a), with a d-value = 1,68 for the left anatomical side (medium practical significance) and a d-value = 1,94 for the right anatomical side (high practical significance) (year 3 to year 4, Table 4.2.1b).

Results in Table 4.2a also indicate that the mean value for the gluteus maximus mobility decreased (positive) from the 2001/2002 off-season ($\bar{x}$ = 2,26 for the left and $\bar{x}$ = 2,30 for the right anatomical side) to the 2002/2003 off-season ($\bar{x}$ = 1,50 for the left anatomical side and $\bar{x}$ = 1,50 for the right anatomical side), with a d-value = 1,20 for the left anatomical side and with a d-value = 1,44 for the right

anatomical side (year 4 to year 5, Table 4.2b). The results of the d-value indicate a high practical significance for the gluteus maximus mobility evaluation for the left and right anatomical sides.

Results in Table 4.2.1a indicate that the mean value for the gluteus maximus mobility decreased (positive) from the 2001/2002 off-season ($\bar{x}$ = 2,26 for the left and $\bar{x}$ = 2,30 for the right anatomical side) to the 2003/2004 off-season ($\bar{x}$ = 1,63 for the left anatomical side and $\bar{x}$ = 1,50 for the right anatomical side), with a d-value = 0,88 for the left anatomical side and a d-value = 1,10 for the right anatomical side (year 4 to year 6, Table 4.2.1b). The results of the d-value indicate a high practical significance for the gluteus maximus mobility evaluation for the left and right anatomical sides.

Next the results of the biomechanical evaluation (Table 4.2.1c.) and practical significances (Table 4.2.1d.) for the adductor mobility, hip internal rotation mobility as well as hip external rotation mobility will be discussed. These tests were only introduced in the 2000/2001 season. This was done to improve the tests that were used previously in order to evaluate the player better and to identify potential areas of injury that could influence the cricketer negatively.

The results in Table 4.2.1c indicate a decrease in the mean value (positive result) of adductor mobility, hip internal rotational mobility: left and right anatomical side and hip external rotational mobility: left and right anatomical side from the 2000/2001 off-season to the 2003/2004 off-season.

Table 4.2.1c Descriptive statistics of biomechanical variables evaluated (hip joint) for the six-season period (1998/1999–2003/2004)									
		2000–2001		2001–2002		2002–2003		2003–2004	
Variables	Anatomical Side	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Adductor Mobility		1,72	0,46	1,70	0,56	1,19	0,40	1,00	0,00
Hip internal rotation mobility	Left	1,83	0,38	1,52	0,67	1,44	0,51	1,00	0,00
	Right	1,89	0,32	1,48	0,67	1,31	0,48	1,00	0,00
Hip external rotation mobility	Left	1,89	0,47	2,09	0,42	1,75	0,58	1,63	0,72
	Right	1,89	0,47	2,04	0,47	1,81	0,66	1,63	0,72

Table 4.2.1d Practically significant differences (d-values) of the biomechanical variables (hip joint) evaluated						
Year	Year	Variables				
		Adductor mobility	Hip internal rotation mobility		Hip external rotation mobility	
			Left	Right	Left	Right
3	4	0,05	0,47	0,62	0,42	0,33
3	5	**1,16**	0,77	**1,20**	0,24	0,12
3	6	**1,57**	**2,17**	**2,75**	0,37	0,37
4	5	**0,91**	0,13	0,25	0,58	0,35
4	6	**1,24**	0,78	0,72	0,64	0,58
5	6	0,47	**0,85**	0,65	0,17	0,26

Table 4.2.1c indicates a decrease (positive result) in the mean value for the adductor mobility from the 2000/2001 off-season ($\bar{x}$ = 1,72) to the 2003/2004 off-season ($\bar{x}$ = 1,00), with a d-value = 1,57, a high practical significance (year 3 to year 6, Table 4.2.1d). As a result of this, the pelvic girdle was relieved from

unnecessary dynamic stress, indicating a decrease in the potential risk of injury for the cricketer.

Table 4.2.1c also indicates a decrease (positive result) in the mean value for the adductor mobility from the 2000/2001 off-season ($\bar{x}$ = 1,72) to the 2002/2003 off-season ($\bar{x}$ = 1,19), with a d-value = 1,16, a high practical significance (year 3 to year 5, Table 4.2.1d) and a decrease (positive result) in the mean value for the adductor mobility from the 2001/2002 off-season ($\bar{x}$ = 1,70) to the 2002/2003 off-season ($\bar{x}$ = 1,00), with a d-value = 0,91, a high practical significance (year 4 to year 5, Table 4.2.1d).

Table 4.2.1c further indicates a decrease in the mean value for adductor mobility from the 2001/2002 off-season ($\bar{x}$ = 1,70) to the 2003/2004 off-season ($\bar{x}$ = 1,00), with a d-value = 1,24, a high practical significance (year 4 to year 6, Table 4.2.1d).

As for the results regarding hip internal rotation mobility, Table 4.2.1c shows a decrease, a positive result for the test, with the mean value for the left anatomical side changing from the 2000/2001 off-season ($\bar{x}$ = 1.83) to the 2003/2004 off-season ($\bar{x}$ = 1.00), with a d-value = 2.17, a high practical significance (year 3 to year 6, Table 4.2.1d). Table 4.2.1c also show a decrease, a positive result, in the mean value for the right anatomical side regarding hip internal rotation mobility from the 2000/2001 off-season ($\bar{x}$ = 1,89) to the 2003/2004 off-season ($\bar{x}$ = 1,00), with a d-value = 2,75, a high practical significance (year 3 to year 6, Table 4.2.1d). This decrease in the mean value, for both the left and right anatomical sides regarding hip internal rotation mobility, might decrease the risk of injury in this area as a result of the hip joint being in a better anatomical position. Tight

internal rotation muscles of the hip joint might change the position of the hip joint, which may influence lower limb biomechanics and lead to lower limb injuries.

Results in Table 4.2.1c indicate that the mean value for hip internal rotation mobility decreased (positive) from the 2000/2001 off-season ($\bar{x}$ = 1,83 for the left and $\bar{x}$ = 1,89 for the right anatomical side) to the 2002/2003 off-season ($\bar{x}$ = 1,44 for the left anatomical side and $\bar{x}$ = 1,31 for the right anatomical side), with a d-value = 0,77, medium practical significance for the left anatomical side and with a d-value = 1,20, high practical significance for the right anatomical side (year 3 to year 5, Table 4.2.1b).

Results in Table 4.2.1c indicate that the mean value for hip internal rotation mobility decreased (positive) from the 2002/2003 off-season ($\bar{x}$ = 1,44 for the left anatomical side) to the 2003/2004 off-season ($\bar{x}$ = 1,00 for the left anatomical side), with a d-value = 0,85, high practical significance for the left anatomical side (year 5 to year 6, Table 4.2.1b).

The next section discusses the results of the biomechanical evaluations (Table 4.2.1e) and the practical significances (Table 4.2.1f) found in the case of the knee (Q-angle, patella squint, patella tilt, and the vastus medialis oblique-lateralis comparison (VMO-L). The patella squint, patella tilt and patella height were only evaluated from the 2000/2001 season. This was done to identify more areas of potential risks factors which could negatively impact on the cricketer's ability to play injury-free cricket.

Table 4.2.1e Descriptive statistics of biomechanical variables evaluated (the knee region) for the six-season period (1998/1999–2003/2004)													
Variables	**Anatomical side**	**1998–1999**		**1999–2000**		**2000–2001**		**2001–2002**		**2002–2003**		**2003–2004**	
		$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**
Q-angle	Left	1,22	0,44	1,18	0,40	1,11	0,32	1,22	0,42	1,13	0,34	1,06	0,25
	Right	1,22	0,44	1,18	0,40	1,11	0,32	1,22	0,42	1,13	0,34	1,06	0,25
Patella squint	Left					1,11	0,32	1,26	0,45	1,13	0,34	1,06	0,25
	Right					1,11	0,32	1,26	0,45	1,13	0,34	1,06	0,25
Patella tilt	Left					1,50	0,51	1,39	0,50	1,25	0,45	1,44	0,51
	Right					1,50	0,51	1,39	0,50	1,25	0,45	1,44	0,51
Vastus medialis oblique-lateralis comparison	Left	1,11	0,33	1,00	0,00	1,06	0,23	1,09	0,29	1,00	0,00	1,06	0,25
	Right	1,11	0,33	1,00	0,00	1,06	0,23	1,13	0,34	1,00	0,00	1,06	0,25

Table 4.2.1f Practically significant differences (d-values) of the biomechanical variables (the knee region) evaluated									
Year	Year	Variables							
		Q-angle		Patella squint		Patella tilt		Vastus medialis obliques-lateralis comparison	
		Left	Right	Left	Right	Left	Right	Left	Right
1	2	0,09	0,09					0,33	0,33
1	3	0,25	0,25					0,17	0,17
1	4	0,01	0,01					0,07	0,07
1	5	0,22	0,22					0,33	0,33
1	6	0,36	0,36					0,15	0,15
2	3	0,17	0,17					0,24	0,24
2	4	0,08	0,08					0,30	0,30
2	5	0,14	0,14						
2	6	0,29	0,29					0,25	0,25
3	4	0,25	0,25	0,33	0,33	0,21	0,21	0,11	0,11
3	5	0,04	0,04	0,04	0,04	0,49	0,49	0,24	0,24
3	6	0,15	0,15	0,15	0,15	0,12	0,12	0,03	0,03
4	5	0,22	0,22	0,30	0,30	0,28	0,28	0,30	0,30
4	6	0,37	0,37	0,44	0,44	0,09	0,09	0,08	0,08
5	6	0,18	0,18	0,18	0,18	0,37	0,37	0,25	0,25

Results regarding the knee complex in Table 4.2.1e indicate a decrease in the mean value for q-angle: left and right anatomical side and vastus medialis oblique-lateralis comparison: left and right anatomical side from the 1998/1999 off-season to the 2003/2004 off-season. Table 4.2.1e also shows a decrease (positive) in the mean value for patella squint: left and right anatomical side and the patella tilt: left and right anatomical side from the 2000/2001 off-season to the 2003/2004 off-season.

The next section discusses the results of the biomechanical evaluations (Table 4.2.1g) and the practical significances (Table 4.2.1h) found for the foot (longitudinal arch status, forefoot positional, rear foot standing, rear foot lying, transverse arch area comparison, foot mobility and toes positional). The forefoot position, rear foot lying, transverse arch area comparison, foot mobility and toes positional were only evaluated from the 2000/2001 off-season, to identify more potential risks areas which could impact on the cricketers' ability to play injury-free cricket.

The results in Table 4.2.1g and Table 4.2.1h indicate the mean value for the longitudinal foot arch: left and right anatomical side increased (positive result, as the norm for this evaluation is two) from the 1998/1999 off-season to the 2003/2004 off-season. The mean value for rear foot position decreased (negative result, as the norm for this evaluation is 2) from the 1998/1999 off-season to the 2003/2004 off-season.

The results in Table 4.2.1g and Table 4.2.1h further indicate a decrease in the mean value (negative result) for forefoot position standing: right anatomical side, rear foot position lying: left and right anatomical side, foot mobility: left and right anatomical side from the 2000/2001 off-season to the 2003/2004 off-season. Forefoot position standing: left anatomical side stayed consistent from the 2000/2001 season to the 2003/2004 season. The mean value for the transverse arch: left and right anatomical side increased (negative result) from the 2000/2001 off-season to the 2003/2004 off-season and the mean value for toes positional decreased (positive result) from the 2000/2001 off-season to the 2003/2004 off-season.

Table 4.2.1g Descriptive statistics of biomechanical variables evaluated (the foot) for the six-season period (1998/1999–2003/2004)													
Variables	**Anatomical side**	**1998–1999**		**1999–2000**		**2000–2001**		**2001–2002**		**2002–2003**		**2003–2004**	
		$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**
Longitudinal arch status	Left	1,33	0,5	1,55	0,52	1,28	0,46	1,17	0,49	1,44	0,51	1,38	0,5
	Right	1,33	0,5	1,55	0,52	1,28	0,46	1,17	0,49	1,44	0,51	1,38	0,5
Forefoot positional	Left					1,44	0,51	1,65	0,49	1,19	0,40	1,44	0,51
	Right					1,39	0,50	1,65	0,49	1,19	0,40	1,50	0,52
Rear foot standing	Left	1,78	0,44	1,54	0,52	1,72	0,46	1,74	0,54	1,19	0,46	1,50	0,52
	Right	1,78	0,44	1,64	0,50	1,67	0,49	1,78	0,51	1,38	0,50	1,50	0,73
Rear foot lying	Left					1,67	0,49	1,65	0,49	1,25	0,45	1,25	0,45
	Right					1,61	0,50	1,61	0,50	1,31	0,48	1,31	0,48
Transverse arch area comparison	Left					1,28	0,46	1,13	0,34	1,13	0,34	1,31	0,48
	Right					1,28	0,46	1,13	0,34	1,13	0,34	1,38	0,5
Foot mobility	Left					1,83	0,79	1,78	0,90	1,56	0,89	1,44	0,63
	Right					1,83	0,79	1,83	0,89	1,56	0,89	1,44	0,63
Toes positional	Left					1,94	0,24	1,87	0,34	1,88	0,34	1,81	0,34
	Right					1,94	0,24	1,87	0,34	1,88	0,34	1,88	0,34

Table 4.2.1h Practically significant differences (d-values) of the biomechanical variables (the foot) evaluated															
Year	Year	Variables													
		Longitudinal arch status		Forefoot positional		Rear foot Standing		Rear foot lying		Transverse arch area comparison		Foot mobility		Toes positional	
		Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
1	2	0,14	0,14			0,44	0,28								
1	3	0,11	0,11			0,12	0,23								
1	4	0,32	0,32			0,07	0,01								
1	5	0,20	0,20			**1,12**	**0,81**								
1	6	0,08	0,08			0,38	0,38								
2	3	0,51	0,51			0,34	0,06								
2	4	0,71	0,71			0,36	0,28								
2	5	0,21	0,21			0,53	0,52								
2	6	0,33	0,33			0,06	0,19								
3	4	0,21	0,21	0,41	0,52	0,03	0,22	0,03	0,00	0,32	0,32	0,06	0,01	0,22	0,22
3	5	0,31	0,31	0,50	0,40	**0,99**	0,58	**0,86**	0,60	0,33	0,33	0,30	0,30	0,20	0,20
3	6	0,19	0,19	0,01	0,22	0,30	0,23	**0,86**	0,60	0,07	0,19	0,50	0,50	0,33	0,20
4	5	0,51	0,51	**0,95**	**0,95**	**0,87**	0,79	**0,83**	0,59	0,02	0,02	0,24	0,30	0,02	0,02
4	6	0,40	0,40	0,42	0,29	0,33	0,39	**0,83**	0,59	0,38	0,49	0,38	0,44	0,14	0,02
5	6	0,12	0,12	0,49	0,61	0,32	0,17	0,00	0,00	0,39	0,50	0,14	0,14	0,16	0,00

Table 4.2.1g indicates a decrease (positive result) in the mean value of the left and right anatomical side for the rear foot lying. The mean value decreased from the 2001/2002 off-season ($\bar{x}$ = 1,65 for the left and right anatomical side) to the 2002/2003 off-season ($\bar{x}$ = 1,19 for the left and right anatomical side), d-value = 0,95 (year 4 to year 5, Table 4.2.1h), a high practical significance for left and right anatomical sides.

Table 4.2.1g further indicates a decrease (negative result) in the mean value of the left and right anatomical sides for the rear foot standing. The mean value decreased from the 1998/1999 off-season ($\bar{x}$ = 1,78 for the left and right anatomical side) to the 2002/2003 off-season ($\bar{x}$ = 1,19 for the left anatomical side and $\bar{x}$ = 1,38 for the right anatomical side), d-value = 1,12 for the left anatomical side and d-value = 0,81 for the right anatomical side (year 1 to year 5, Table 4.2.1h), a high practical significance.

Table 4.2.1g also shows a decrease (negative result) in the mean value of the left anatomical side for rear foot standing. The mean value decreased from the 2000/2001 off-season ($\bar{x}$ = 1,72 for the left anatomical side) to the 2002/2003 off-season ($\bar{x}$ = 1,19 for the left anatomical side), with the d-value = 0,99 for the left anatomical side (year 3 to year 5, Table 4.2.1h), a high practical significance.

Furthermore, Table 4.2.1g shows a decrease (negative result) in the mean value of the left anatomical side for rear foot standing. The mean value decreased from the 2001/2002 off-season ($\bar{x}$ = 1,74 for the left anatomical side) to the 2002/2003 off-season ($\bar{x}$ = 1,19 for the left anatomical side), with the d-value = 0,87 for the left anatomical side (year 4 to year 5, Table 4.2.1h), a high practical significance.

As for rear foot lying, left anatomical side the results are similar for the 2000/2001 off-season to the 2002/2003 off-season and 2000/2001 off-season to the 2003/2004 off-season ($\bar{x}$ = 1,67 for the left anatomical side in the 2000/2001 (year 3) off-season and $\bar{x}$ = 1,25 in the 2002/2003 (years 5) off-season and the 2003/2004 (year 6) off-season, with the d-value = 0,86 a high practical significance).

As regards foot lying, left anatomical side the results are similar for the 2001/2002 off-season to the 2002/2003 off-season and 2001/2002 off-season to the 2003/2004 off-season ($\bar{x}$ = 1,65 for the left anatomical side in the 2001/2002 (year 4) off-season and $\bar{x}$ = 1,25 in the 2002/2003 (year 5) off-season and the 2003/2004 (year 6) off-season, with the d-value = 0,83 a high practical significance).

Next follows a discussion of the results for the biomechanical evaluations (Table 4.2.1i) and the practical significances (Table 4.2.1j) found for the pelvic girdle region (leg-length discrepancy, position of anterior superior iliac crest (ASIS), position of the posterior superior iliac crest (PSIS), pubic tubercle height, the sacroiliac cleft and the bilateral pelvic position). The sacroiliac cleft was only evaluated from the 2000/2001 off-season. This was done to identify more potential areas of injury to the cricketer and to possibly prevent certain injuries from occurring in this area.

Results in Table 4.2.1i show an improvement in the mean value for the pelvic girdle for leg length discrepancy, anterior superior iliac spine, posterior superior iliac spine, pubic tubercle height and bilateral pelvic position from the 1998/1999 off-season to the 2003/2004 off-season. Sacroiliac cleft also showed a decrease in the mean value from the 2000/2001 off-season to the 2003/2004 off-season. Overall, these constitute a positive result for the pelvic girdle region.

Table 4.2.1i Descriptive statistics of biomechanical variables evaluated (pelvic girdle region) for the six-season period (1998/1999–2003/2004)												
Variables	1998–1999		1999–2000		2000–2001		2001–2002		2002–2003		2003–2004	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Pelvic girdle region												
Leg-length discrepancy	1,88	0,33	1,73	0,65	1,50	0,62	1,52	0,59	1,63	0,50	1,19	0,40
ASIS	1,88	0,33	1,64	0,50	1,44	0,51	1,48	0,51	1,63	0,50	1,19	0,40
PSIS	1,88	0,33	1,64	0,50	1,44	0,51	1,48	0,51	1,63	0,50	1,19	0,40
Pubic tubercle height	1,88	0,33	1,64	0,50	1,44	0,51	1,48	0,51	1,63	0,50	1,19	0,40
Sacroiliac cleft					1,44	0,51	1,26	0,45	1,19	0,40	1,00	0,00
Bilateral pelvic position	1,67	0,50	1,73	0,47	1,50	0,62	2,09	0,73	1,75	0,68	1,63	0,72

Results from Table 4.2.1i indicate a decrease (positive result) in the mean value for leg-length discrepancy from the 1998/1999 off-season ($\bar{x}$ = 1,88) to the 2003/2004 off-season ($\bar{x}$ = 1,19), with a d-value = 1,74, a high practical significance (year 1 to year 6 in Table 4.2.1j). Discrepancy in leg length is associated with various types of lower limb injuries. These results indicate that the potential risk of injury due to this aspect has been decreased from the 1998/1999 off-season to the 2003/2004 off-season.

Results from Table 4.2.1i indicate a decrease (positive result) in the mean value for leg-length discrepancy from the 1999/2000 off-season ($\bar{x}$ = 1,73) to the 2003/2004 off-season ($\bar{x}$ = 1,19), with a d-value = 0,83, a high practical significance (year 2 to year 6 in Table 4.2.1j).

Results from Table 4.2.1i indicate a decrease (positive result) in the mean value for leg-length discrepancy from the 2002/2003 off-season ($\bar{x}$ = 1,63) to the 2003/2004 off-season ($\bar{x}$ = 1,19), with a d-value = 0,88, a high practical significance (year 5 to year 6 in Table 4.2.1j).

Table 4.2.1j Practically significant differences (d-values) of the biomechanical variables (pelvic girdle region) evaluated

		Variables					
Year	**Year**	**Leg-length discrepancy**	**ASIS**	**PSIS**	**Pubic tubercle height**	**Sacroiliac cleft**	**Bilateral pelvic position**
1	**2**	0,25	0,50	0,50	0,50		0,12
1	**3**	0,63	**0,87**	**0,87**	**0,87**		0,27
1	**4**	0,62	**0,80**	**0,80**	**0,80**		0,57
1	**5**	0,53	0,53	0,53	0,53		0,12
1	**6**	**1,74**	**1,74**	**1,74**	**1,74**		0,06
2	**3**	0,35	0,38	0,38	0,38		0,37
2	**4**	0,32	0,31	0,31	0,31		0,49
2	**5**	0,16	0,02	0,02	0,02		0,03
2	**6**	**0,83**	**0,89**	**0,89**	**0,89**		0,14
3	**4**	0,04	0,07	0,07	0,07	0,36	**0,80**
3	**5**	0,20	0,35	0,35	0,35	0,50	0,37
3	**6**	0,51	0,50	0,50	0,50	**0,87**	0,17
4	**5**	0,17	0,29	0,29	0,29	0,16	0,46
4	**6**	0,56	0,57	0,57	0,57	0,58	0,63
5	**6**	**0,88**	**0,88**	**0,88**	**0,88**	0,47	0,17

As for the results regarding anterior superior iliac spine (ASIS), posterior superior iliac spine (PSIS) and pubic tubercle height, Table 4.2.1j shows a decrease in the mean value (positive result) from the 1998/1999 off-season ($\bar{x}$ = 1,88) to the 2000/2001 off-season ($\bar{x}$ = 1,44), d-value = 0,87, a high practical significance

(year 1 to year 3, Table 4.2.1i). It (Table 4.2.1j) also indicates that the mean value for the ASIS, PSIS and pubic tubercle height decreased (positive result) from the 1998/1999 off-season ($\bar{x}$ = 1,88) to the 2001/2002 off-season ($\bar{x}$ = 1,48), d-value = 0,80 a high practical significance (year 1 to year 4, Table 4.2.1i).

Furthermore, Table 4.2.1i indicates a decrease (positive result) in the mean value for the ASIS, PSIS and pubic tubercle height from the 1998/1999 off-season ($\bar{x}$ = 1,88) to the 2003/2004 off-season ($\bar{x}$ = 1.19), with a d-value = 1,74, a high practical significance (year 1 to year 6 in Table 4.2.1j), a decrease from the 1999/2000 off-season ($\bar{x}$ = 1,64) to the 2003/2004 off-season ($\bar{x}$ = 1.19), with a d-value = 0,89, a high practical significance (year 2 to year 6 in Table 4.2.1j) and a decrease (positive result) from the 2002/2003 off-season ($\bar{x}$ = 1,63) to the 2003/2004 off-season ($\bar{x}$ = 1.19), with a d-value = 0,88, a high practical significance (year 5 to year 6 in Table 4.2.1j).

Table 4.2.1i indicates a decrease (positive result) in the mean value for the sacroiliac cleft from the 2000/2001 off-season ($\bar{x}$ = 1,44) to the 2003/2004 off-season ($\bar{x}$ = 1.00), with a d-value = 0,87, a high practical significance (year 3 to year 6 in Table 4.2.1j) and the mean value for bilateral pelvic position increased (negative result) from the 2000/2001 off-season ($\bar{x}$ = 1,50) to the 2001/2002 off-season ($\bar{x}$ = 2,09), with a d-value = 0,80, a high practical significance (year 3 to year 4 in Table 4.2.1j).

A discussion follows below of the results of the biomechanical evaluations (Table 4.2.1k) and the practical significances (Table 4.2.1l) found for the spinal region: spinal dynamic mobility (thoraco-lumbar facia mobility (TFL), sacral rhythm, functional extension mobility, functional flexion mobility, rotational mobility and side flexion mobility). All the aforementioned evaluations were done from the

2000/2001 off-season. These were carried out to identify more potential areas of possible injury to the cricketer and to possibly prevent certain injuries from occurring in this area.

Results in Table 4.2.1k indicate an improvement (positive) in the mean values of the thoraco-lumbar facia mobility: left and right anatomical sides, sacral rhythm and functional extension mobility from the 2000/2001 off-season to the 2003/2004 off-season, practical significances varying from low to medium and high practical significances (Table 4.2.1l). Results in Table 4.2k regarding the functional flexion mobility, rotational mobility: left and right anatomical side and side flexion: left and right anatomical side show a decrease (negative result) in the mean values for these areas from the 2000/2001 off-season to the 2003/2004 off-season, with low to practical to small practical significances (Table 4.2.1l).

Table 4.2.1k Descriptive statistics of biomechanical variables evaluated (spinal region: spinal dynamic mobility) for the six-season period (1998/1999–2003/2004)

Variables	Anatomical Side	2000–2001		2001–2002		2002–2003		2003–2004	
		$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Thoraco-lumbar facia mobility	Left	1,61	0,50	1,65	0,57	1,69	0,70	1,44	0,51
	Right	1,61	0,50	1,61	0,58	1,69	0,70	1,44	0,51
Sacral rhythm		1,50	0,51	1,17	0,39	1,06	0,25	1,00	0,00
Functional extension mobility		1,22	0,43	1,48	0,59	1,69	0,70	1,06	0,25
Functional flexion mobility		1,28	0,46	1,43	0,59	1,56	0,81	1,50	0,73
Rotational mobility	Left	1,00	0,00	1,04	0,21	1,06	0,25	1,06	0,25
	Right	1,00	0,00	1,00	0,00	1,06	0,25	1,06	0,25
Side flexion mobility	Left	1,00	0,00	1,13	0,34	1,25	0,45	1,13	0,34
	Right	1,00	0,00	1,13	0,34	1,25	0,45	1,13	0,34

Table 4.2.1l Practically significant differences (d-values) of the biomechanical variables (spinal region: spinal dynamic mobility) evaluated										
Year	Year	Variables								
		Thoraco-lumbar facia mobility		Sacral rhythm	Functional extension mobility	Functional flexion mobility	Rotational mobility		Side flexion mobility	
		Left	Right				Left	Right	Left	Right
3	4	0,07	0,00	0,63	0,43	0,27	0,21		0,38	0,38
3	5	0,11	0,11	**0,85**	0,66	0,35	0,25	0,25	0,56	0,56
3	6	0,34	0,34	**0,97**	0,37	0,30	0,25	0,25	0,37	0,37
4	5	0,05	0,11	0,29	0,30	0,16	0,08	0,25	0,27	0,27
4	6	0,37	0,29	0,45	0,70	0,09	0,08	0,25	0,00	0,00
5	6	0,36	0,36	0,25	**0,89**	0,08	0,00	0,00	0,28	0,28

Results from Table 4.2.1k indicate a decrease (a positive result) in the mean value for the sacral rhythm from the 2000/2001 off-season ($\bar{x}$ = 1,50) to the 2002/2003 off-season ($\bar{x}$ = 1,06), with a d-value = 0,97 a high practical significance (year 3 to year 5, Table 4.2.1l) and a decrease in the mean value (a positive result) from the 2000/2001 off-season ($\bar{x}$ = 1,50) to the 2003/2004 off-season ($\bar{x}$ = 1,00), with a d-value = 0,97, a high practical significance (year 3 to year 6, Table 4.2.1l).

Results from Table 4.2.1k indicate a decrease (a positive result) in the mean value for the functional flexion mobility from the 2002/2003 off-season ($\bar{x}$ = 1,69) to the 2003/2004 off-season ($\bar{x}$ = 1,06), with a d-value = 0,89, a high practical significance (year 5 to year 6, Table 4.2.1l).

Next to be discussed are the results of the biomechanical evaluations (Table 4.2.1m) and the practical significances (Table 4.2.1n) found for the spinal positional alignment: coronal axis evaluation (including the head position,

cervical, thoracic and lumbar), as well as the sagittal axis evaluation (including the head position, cervical, thoracic and lumbar). The sagittal axis evaluation was introduced in the 2000/2001 off-season. This was done to identify more potential areas of possible injury to the cricketer and possibly to prevent certain injuries from occurring in regard to the sagittal axis.

Table 4.2.1m Descriptive statistics of biomechanical variables evaluated (spinal positional alignment: coronal and sagittal axis) for the six-season period (1998/1999–2003/2004).

	1998–1999		1999–2000		2000–2001		2001–2002		2002–2003		2003–2004	
Variables	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**
Coronal Axis												
Head position	1,44	0,53	1,45	0,52	1,33	0,48	1,39	0,50	1,00	0,00	1,00	0,00
Cervical	1,11	0,33	1,27	0,47	1,00	0,00	1,30	0,47	1,06	0,25	1,00	0,00
Thoracic	1,22	0,44	1,36	0,50	1,00	0,00	1,30	0,47	1,25	0,45	1,00	0,00
Lumbar	1,67	0,5	1,54	0,52	1,44	0,51	1,78	0,42	1,25	0,45	1,81	0,40
Sagittal Axis												
Head position					1,00	0,00	1,00	0,00	1,00	0,00	1,00	0,00
Cervical					1,00	0,00	1,00	0,00	1,13	0,34	1,00	0,00
Thoracic					1,72	0,46	1,91	0,29	1,38	0,50	1,75	0,00
Lumbar					1,00	0,00	1,04	0,21	1,06	0,50	1,00	0.00

Results in Table 4.2.1m and Table 4.2.1n indicate an improvement in the head position, cervical spine position and thoracic spine position of the coronal axis evaluation from the 1998/1999 off-season to the 2003/2004 off-season, with small, medium and high practical significances in the improvement. Only in the case of "lumbar" is a decrease indicated from the evaluation of the 1998/1999

off-season to the 2003/2004 off-season, with a low practical significance for the last three off-seasons and a small practical significance for the period of six off-seasons.

Table 4.2.1n Practically significant differences (d–values) of the biomechanical variables (spinal positional alignment: coronal and sagittal axis) evaluated.

Year	Year	Variable							
		Coronal axis				Sagittal axis			
		Head position	Cervical	Thoracic	Lumbar	Head position	Cervical	Thoracic	Lumbar
1	2	0,02	0,35	0,28	0,23				
1	3	0,21	0,33	0,50	0,43				
1	4	0,10	0,41	0,17	0,23				
1	5	**0,84**	0,15	0,54	**0,83**				
1	6	**0,84**	0,33	0,50	0,29				
2	3	0,23	0,58	0,72	0,19				
2	4	0,12	0,07	0,12	0,45				
2	5	**0,87**	0,45	0,26	0,57				
2	6	**0,87**	0,58	0,72	0,51				
3	4	0,12	0,65	0,65	0,66			0,41	0,21
3	5	0,69	0,25	**0,97**	0,38		0,37	0,69	0,25
3	6	0,69			0,72			0,06	
4	5	0,78	0,51	0,38	**1,19**		0,37	**1,08**	0,08
4	6	0,78	0,65	0,65	0,07			0,36	0,21
5	6		0,25	**0,97**	**1,26**		0,37	0,75	0,25

The results from Table 4.2.1m show a decrease (positive result) in the mean value for the coronal axis: head position from the 1998/1999 off-season ($\bar{x}$ = 1,44) to the 2002/2003 off-season ($\bar{x}$ = 1,00), with a d-value = 0,84, a high practical significance (year 1 to year 5, Table 4.2.1n) and a decrease (positive result) in the mean value for the coronal axis: head position from the 1998/1999

off-season ($\bar{x}$ = 1,44) to the 2003/2004 off-season ($\bar{x}$ = 1,00), with a d-value = 0,84, a high practical significance (year 1 to year 6, Table 4.2.1n).

The results from Table 4.2.1m show a decrease (positive result) in the mean value for the coronal axis: head position from the 1999/2000 off-season ($\bar{x}$ = 1,45) to the 2002/2003 off-season ($\bar{x}$ = 1,00), with a d-value = 0,87, a high practical significance (year 1 to year 5, Table 4.2.1n) and a decrease (positive result) in the mean value for the coronal axis: head position from the 1999/2000 off-season ($\bar{x}$ = 1,45) to the 2003/2004 off-season ($\bar{x}$ = 1,00), with a d-value = 0,87, a high practical significance (year 1 to year 6, Table 4.2.1n).

Regarding the coronal axis: lumbar Table 4.2.1m shows a decrease (positive result) in the mean value from the 1998/1999 off-season ($\bar{x}$ = 1,67) to the 2002/2003 off-season ($\bar{x}$ = 1,25), with a d-value = 0,83, a high practical significance (year 1 to year 5, Table 4.2.1n). There is also a decrease (positive result) in the mean value for the coronal axis: lumbar from the 2001/2002 off-season ($\bar{x}$ = 1,78) to the 2002/2003 off-season ($\bar{x}$ = 1,25), with a d-value = 1,19, a high practical significance (year 4 to year 5, Table 4.2.1n) and then an increase in the mean value (negative result) from the 2002/2003 off-season ($\bar{x}$ = 1,25) to the 2003/2004 off-season ($\bar{x}$ = 1,25), with a d-value = 1,26, a high practical significance (year 5 to year 6, Table 4.2.1n).

Next the results of the spinal positional alignment: sagittal axis for head position, cervical, thoracic and lumbar are discussed.

Overall, Table 4.2.1m and Table 4.2.1n show the results in the mean value for the sagittal axis evaluation of the head position, cervical and lumbar to have stayed consistent from the 2000/2001 off-season to the 2003/2004 off-season.

The mean value for the thoracic decreased (negative) over the same period, with low practical significances.

In Table 4.2.1n the mean value for the sagittal axis: thoracic decreased (positive result) from the 2001/2002 off-season ($\bar{x}$ = 1,91) to the 2002/2003 off-season ($\bar{x}$ = 1,38), with a d-value = 1,08, a high practical significance (year 4 to year 5, Table 4.2.1n).

Next follows a discussion of the result of the biomechanical evaluations (Table 4.2.1o) and the practical significances (Table 4.2.1p) found for the upper limb region (hand behind back range of motion (ROM), hand behind neck (ROM), shoulder coronal positional test, winging positional test, shoulder outline composition and throwing position (ROM)). Hand behind back (ROM), hand behind neck (ROM), winging positional test, shoulder outline composition and throwing position (ROM) were evaluated from the 2000/2001 off-season. This was done to identify more potential areas of possible injury to the cricketer and to possibly prevent certain injuries from occurring in this area.

Results in Table 4.2.1o and Table 4.2.1p show a decrease (positive) in the mean value of the upper limb evaluation for the shoulder coronal positional test from the 1998/1999 off-season to the 2003/2004 off-season. Results in Table 4.2.1o and Table 4.2.1p further indicate a decrease in the mean value for the hand behind back (ROM): left and right anatomical side; hand behind neck (ROM): left and right anatomical side; shoulder outline composition from the 2000/2001 off-season to the 2003/2004 off-season, with small to high practical significances. The mean value for winging increased in the same period (negative result), with a small practical significance, and throwing position remained constant.

Table 4.2.1o Descriptive statistics of biomechanical variables evaluated (upper limb region) for the six-season period (1998/1999–2003/2004)

Variables	Anatomical Side	1998–1999		1999–2000		2000–2001		2001–2002		2002–2003		2003–2004	
		$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Hand behind back ROM	Left					1,72	0,46	1,65	0,49	1,50	0,82	1,25	0,45
	Right					1,72	0,46	1,65	0,49	2,00	0,97	1,50	0,63
Hand behind neck ROM	Left					1,39	0,50	1,22	0,42	1,00	0,00	1,00	0,00
	Right					1,39	0,50	1,22	0,42	1,00	0,00	1,13	0,45
Shoulder coronal positional test		2.00	0,00	1,55	0,52	1,17	0,38	1,57	0,51	1,06	0,25	1,25	0,45
Winging positional test						1,06	0,24	1,26	0,45	1,31	0,48	1,13	0,34
Shoulder outline composition						1,22	0,43	1,04	0,21	1,06	0,25	1,06	0,25
Throwing position (ROM)						1,00	0,00	1,04	0,21	1,19	0,40	1,00	0,00

Table 4.2.1p Practically significant differences (d-values) of the biomechanical variables (upper limb region) evaluated									
Year	Year	Variables							
		Hand behind back ROM		Hand behind neck ROM		Shoulder coronal positional test	Winging positional test	Shoulder outline composition	Throwing position (ROM)
		Left	Right	Left	Right				
1	2					**0,87**			
1	3					**2,17**			
1	4					**0,86**			
1	5					**3,75**			
1	6					**1,68**			
2	3					0,73			
2	4					0,04			
2	5					**0,92**			
2	6					0,57			
3	4	0,14	0,14	0,34	0,34	0,79	0,46	0,42	0,21
3	5	0,27	0,29	0,78	0,78	0,27	0,54	0,37	0,47
3	6	**1,02**	0,35	0,78	0,53	0,19	0,20	0,37	
4	5	0,19	0,36	0,52	0,52	**0,99**	0,11	0,08	0,36
4	6	**0,83**	0,24	0,52	0,18	0,62	0,30	0,08	0,21
5	6	0,31	0,52		0,25	0,42	0,39	0,00	0,47

Table 4.2.1o indicates a decrease (positive result) in the mean value for the shoulder coronal positional test from the 1998/1999 off-season ($\bar{x}$ = 2,00) to the 2003/2004 off-season ($\bar{x}$ = 1,25), with a d-value = 1,68, a high practical significance (year 1 to year 6, Table 4.2.1p). It (Table 4.2.1o) shows a decrease from the 1998/1999 off-season ($\bar{x}$ = 2,00) to the 1999/2000 off-season ($\bar{x}$ = 1,55), with a d-value = 0,87, a high practical significance (year 1 to year 2, Table 4.2.1p), a decrease from the 1998/1999 off-season ($\bar{x}$ = 2,00) to the 2000/2001

off-season ($\bar{x}$ = 1,17), with a d-value = 2,17, a high practical significance (year 1 to year 3, Table 4.2.1p), a decrease from the 1998/1999 off-season ($\bar{x}$ = 2,00) to the 2001/2002 off-season ($\bar{x}$ = 1,57), with a d-value = 0,86, a high practical significance (year 1 to year 4, Table 4.2.1p) and a decrease from the 1998/1999 off-season ($\bar{x}$ = 2,00) to the 2002/2003 off-season ($\bar{x}$ = 1,06), with a d-value = 3,75, a high practical significance (year 1 to year 5, Table 4.2.1p).

Table 4.2.1o also shows that the mean value for the coronal shoulder positional test decreased (positive result) from the 1999/2000 off-season ($\bar{x}$ = 1,55) to the 2002/2003 off-season ($\bar{x}$ = 1,06), with a d-value = 0,92, a high practical significance (year 2 to year 5, Table 4.2.1p) and a decrease from the 2001/2002 off-season ($\bar{x}$ = 1,57) to the 2002/2003 off-season ($\bar{x}$ = 1,06), with a d-value = 0,99, a high practical significance (year 4 to year 5, Table 4.2.1p).

Table 4.2.1o further shows the mean value for the hand behind back ROM (left anatomical side) decreased (positive result) from the 2000/2001 off-season ($\bar{x}$ = 1,72) to the 2003/2004 off-season ($\bar{x}$ = 1,25), with a d-value = 1,02, a high practical significance (year 3 to year 6, Table 4.2.1p), and a decrease from the 2002/2003 off-season ($\bar{x}$ = 1,65) to the 2003/2004 off-season ($\bar{x}$ = 1,25), with a d-value = 0,83, a high practical significance (year 4 to year 6, Table 4.2.1p).

The mean value found for the biomechanical evaluations (Table 4.2.1q) and the practical significances (Table 4.2.1r) for the neurodynamics evaluations (straight leg raise, upper limb tension test, prone knee bend (PKB) and slump test) will be discussed next. The upper limb tension test and the slump test were evaluated from the 2000/2001 off-season. This was done to identify more potential areas of injury to the cricketer and to possibly prevent certain injuries from occurring in this area.

Table 4.2.1q Descriptive statistics of biomechanical variables evaluated (neurodynamics) for the six-season period (1998/1999–2003/2004)													
		1998–1999		1999–2000		2000–2001		2001–2002		2002–2003		2003–2004	
Variables	Anatomical Side	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Straight leg raise	Left	2,11	0,60	1,45	0,52	1,67	0,69	2,09	0,60	1,69	0,48	1,25	0,45
	Right	2,11	0,60	1,72	0,48	1,67	0,69	2,13	0,63	1,69	0,48	1,25	0,45
Upper limb tension test	Left					1,06	0,24	1,04	0,21	1,00	0,00	1,00	0,00
	Right					1,06	0,24	1,04	0,21	1,00	0,00	1,00	0,00
Prone knee bend (PKB)	Left	2,00	0,00	1,45	0,52	1,28	0,57	1,30	0,56	1,56	0,63	1,38	0,62
	Right	1,89	0,33	1,45	0,52	1,28	0,57	1,30	0,56	1,75	0,58	1,38	0,62
Slump test	Left					1,11	0,32	1,35	0,49	1,44	0,63	1,00	0,00
	Right					1,11	0,32	1,35	0,49	1,44	0,73	1,00	0,00

Table 4.2.1r Practically significant differences (d-values) of the biomechanical variables (neurodynamics) evaluated									
Year	Year	Variables							
		Straight leg raise		Upper limb tension test		L3,4 prone knee bend (PKB)		Slump test	
		Left	Right	Left	Right	Left	Right	Left	Right
1	2	**1,09**	0,64			**0,83**	**0,83**		
1	3	0,65	0,65			**1,06**	**1,06**		
1	4	0,04	0,03			**1,05**	**1,05**		
1	5	0,70	0,70			0,24	0,24		
1	6	**1,43**	**1,43**			**0,83**	**0,83**		
2	3	0,31	0,09			0,31	0,31		
2	4	**1,06**	0,64			0,27	0,27		
2	5	0,45	0,08			0,51	0,51		
2	6	0,39	1,02			0,13	0,13		
3	4	0,61	0,68	0,05	0,05	0,05	0,05	0,49	0,49
3	5	0,03	0,03	0,24	0,24	0,45	0,82	0,52	0,45
3	6	0,61	0,61	0,24	0,24	0,16	0,16	0,34	0,34
4	5	0,67	0,71	0,21	0,21	0,41	0,77	0,14	0,12
4	6	**1,40**	**1,41**	0,21	0,21	0,11	0,11	0,71	0,71
5	6	**0,91**	**0,91**			0,30	0,61	0,71	0,60

Results in Table 4.2.1q show a decrease (positive result) in the mean value for straight leg raise: left and right anatomical side from the 1998/1999 off-season to the 2003/2004 off-season, as well as a decrease in the mean value for the prone knee bend: left and right anatomical side from the 1998/1999 off-season to the 2003/2004 off-season. Table 4.2.1q further shows a decrease in the mean value (positive result) for upper limb tension test: left and right anatomical side and the

slump test: left and right anatomical side from the 2000/2001 off-season to the 2003/2004 off-season.

The results in Table 4.2.1q show a decrease (positive result) in the mean value of the straight leg raise for the anatomical left and right sides from the 1998/1999 off-season ($\bar{x}$ = 2,11) to the 2003/2004 off-season ($\bar{x}$ = 1,25), with a d-value = 1,43, a high practical significance (year 1 to year 6 in Table 4.2.1r). Furthermore, Table 4.2.1q shows a decrease (positive result) in the mean value of the straight leg raise for the left anatomical sides from the 1998/1999 off-season ($\bar{x}$ = 2,11) to the 1999/2000 off-season ($\bar{x}$ = 1,45), with a d-value = 1,09, a high practical significance (year 1 to year 2 in Table 4.2.1r), an increase in the mean value from the 1999/2000 off-season ($\bar{x}$ = 1,45) to the 2001/2002 off-season ($\bar{x}$ = 2,09), a high practical significance (year 2 to year 4, Table 4.2.1p).

The results for the straight leg raise evaluation in Table 4.2.1q indicate a decrease (positive result) in the mean value from the 2001/2002 off-season ($\bar{x}$ = 2,09 for the left anatomical side and $\bar{x}$ = 2,13 for the right anatomical side) to the 2003/2004 off-season ($\bar{x}$ = 1,25 for the left and right anatomical sides), with a d-value = 1,40 for the left anatomical side, a high practical significance, and with a d-value = 1,41 for the right anatomical side, a high practical significance (year 4 to year 6, Table 4.2.1r). A decrease (positive result) also shows in the mean value from the 2002/2003 off-season ($\bar{x}$ = 1,69 for the left and right anatomical side) to the 2003/2004 off-season ($\bar{x}$ = 1,25 for the left and right anatomical sides), with a d-value = 0,91 for the left and right anatomical side, a high practical significance (year 4 to year 6, Table 4.2.1r).

Furthermore, results in Table 4.2.1q indicate that the mean value for the L3,4 prone knee bend left had decreased (positive result) from the 1998/1999 off-

season ($\bar{x}$ = 2,00) to the 2003/2004 off-season ($\bar{x}$ = 1,38), with a d-value = 0,83, a high practical significance (year 1 to year 6 in Table 4.2.1r). Results for the L3,4 prone knee bend right show a decrease (positive result) in the mean value from the 1998/1999 off-season ($\bar{x}$ = 1,89) to the 2003/2004 off-season ($\bar{x}$ = 1,38), with a d-value = 0,83, a high practical significance (year 1 to year 6, Table 4.2.1r).

The results further indicate (Table 4.2.1q) that the mean value for the L3,4 prone knee bend left anatomical side had decreased (positive result) from the 1998/1999 off-season ($\bar{x}$ = 2,00) to the 1999/2000 off-season ($\bar{x}$ = 1,45), with a d-value = 0,83, a high practical significance (year 1 to year 2 in Table 4.2.1r), while similar results were found for the right anatomical side.

The results additionally indicate (Table 4.2.1q) that the mean value for the L3,4 prone knee bend left anatomical side had decreased (positive result) from the 1998/1999 off-season ($\bar{x}$ = 2,00) to the 2000/2001 off-season ($\bar{x}$ = 1,28), with a d-value = 1,06, a high practical significance (year 1 to year 3 in Table 4.2.1r), while similar results were found for the right anatomical side.

It is also apparent from the results (Table 4.2.1q) that the mean value for the L3,4 prone knee bend left anatomical side had decreased (positive result) from the 1998/1999 off-season ($\bar{x}$ = 2,00) to the 2001/2002 off-season ($\bar{x}$ = 1,30), with a d-value = 1,05, a high practical significance (year 1 to year 4 in Table 4.2.1r), while similar results were found for the right anatomical side.

Conclusion

Decrease in the mean value (positive result) of the biomechanical evaluations done over the six off-seasons (1998/1999-2003/2004)

The results found in the biomechanical evaluations indicate a decrease in the mean value (positive result) in most of the biomechanical evaluations done for the cricketers over the six off-season periods (1998/1999–2003/2004 and 2000/2001–2003/2004) and are:

- ankle dorsiflexion: left and right anatomical side;
- illiotibial band mobility: left and right anatomical side;
- quadriceps mobility: left and right anatomical side; iliopsoas mobility: left and right anatomical side;
- adductor mobility; hip internal rotation mobility: left and right anatomical side;
- hip external rotation mobility: left and right anatomical side; Q-angle: left and right anatomical side; patella squint: left and right anatomical side;
- patella tilt: left and right anatomical side;
- vastus medialis obliques-lateralis comparison: left and right anatomical side;
- longitudinal arch status: left and right anatomical side;
- toes positional: left and right anatomical side;
- leg-length discrepancy; anterior superior iliac crest; posterior iliac crest; pubic tubercle height; sacroiliac cleft;
- bilateral pelvic position; thoraco-lumbar facia mobility: left and right anatomical side;
- sacral rhythm; functional extension mobility;
- functional flexion mobility;
- coronal axis: head position; coronal axis: cervical;
- coronal axis: thoracic; hand behind back ROM: left and right anatomical side;
- hand behind neck ROM: left and right anatomical side;
- shoulder coronal positional test; shoulder outline composition;
- straight leg raise: left and right anatomical side;
- upper limb tension test: left and right anatomical side;
- L3,4 prone knee bend; left and right anatomical side; and
- slump test: left and right anatomical side.

This is an improvement in the biomechanical profile of the cricketer, which means the risk of injury as a result of faulty biomechanics has potentially been decreased over the six off-season periods (1998/1999–2003/2004).

Of the above-mentioned results, (1998/1999–2003/2004 and 2000/2001–2003/2004) where high practical significances (d-value ≥ 0,80) were found for the results (i.e. a decrease in the mean value and a positive result) are:

- ankle dorsiflexion: left and right anatomical side;
- illiotibial band mobility: right anatomical side;
- adductor mobility;
- hip internal rotation mobility: left and right anatomical side;
- leg-length discrepancy; anterior superior iliac spine;
- posterior superior iliac spine; pubic tubercle height;
- sacroiliac cleft; sacral rhythm;
- coronal: head position; coronal shoulder positional test;
- hand behind back: left anatomical side;
- straight leg raise: left and right anatomical side; and
- L3,4 prone knee bend.

Increase in the mean value (negative result) of the biomechanical evaluations done over the six off-seasons (1998/1999-2003/2004)

In the case of the following biomechanical evaluations of the musculoskeletal system, results showed an increase (negative result) in the mean value for 1998/1999–2003/2004 and 2000/2001–2003/2004:

- gluteus maximus mobility: left and right anatomical side;
- forefoot position: right anatomical side;
- rear foot standing: left and right anatomical side;
- rear foot lying: left and right anatomical side;
- transverse arch area comparison: left and right anatomical side;

- foot mobility: left and right anatomical side;
- functional flexion mobility: left and right anatomical side;
- rotational mobility: left and right anatomical side;
- side flexion mobility: left and right anatomical side;
- coronal axis: lumbar; sagittal axis: thoracic; and
- winging positional test.

The practical significances varied from low to small, with a few moderate practical significances. Of these result the only negative high practical significance (d-value ≥ 0,80) was rear foot lying: left anatomical side.

Results also indicate that the injury prevention and training programme did not contribute positively to the feet evaluation. Throughout the six-season period the biomechanical profile of the feet showed in most cases no improvement in the biomechanical profile, a negative result, highlighting an aspect that should receive attention.

The results indicate a decrease in the mean value for the biomechanical evaluation of the musculoskeletal system in the majority of the evaluations done for the six off-season periods (1998/1999-.2003/2004).Therefore the results of the biomechanical evaluations of the musculoskeletal system indicate that the injury prevention and training programme contributed positively to the improved biomechanical profile of the cricketers over the six off-season periods.

4.2.2 Physical and motor evaluations

In the next part of chapter 4 the results found for the physical and motor evaluations will be discussed. The descriptive statistics of each evaluation will be discussed, together with those results with a high practical significance (d-values ≥ 0,80). The tests include: (1) multistage fitness test: shuttle run test; (2) sit-and-reach test; (3) abdominal strength tests; (4) one minute oblique sit-up

test: left and right side; (5) one minute push-up test; (5) run a three test; (6) 505 agility test; and (7) 5 metre multiple shuttle test.

Other forms of the push-up test (2 second push-up test) and sit-up test (2 second sit-up test) had been used previously before the introduction of the fitness standard requirements of the UCBSA (introduced at the beginning of the 2002/2003 off-season). The results of the 2 second push-up and sit-up test were omitted as it would have been difficult to compare these results to the newly introduced test, as the methodology differed. The abdominal strength test, oblique sit-up test: left and right side, push-up test, run a three test and the 505 agility test were introduced in the 2002/2003 season as part of the fitness requirements of the UCB. The 5-metre shuttle run test was introduced in the 2000/2001 off-season.

Results in Table 4.2.2a show an increase in the mean value (positive result) for the physical and motor evaluations in the multistage fitness test; abdominal strength test; one minute oblique sit up test: left and right anatomical side; one minute push up test; and 5-metre multiple shuttle run throughout the six off-season periods (1998/1999-2003/2004). Also a decrease (negative) in the mean value for the sit and reach test; run a three test; and the 505 agility test throughout the six off-season periods (1998/1999-2003/2004).

Table 4.2.2a Descriptive statistics of the physical and motor evaluations done over the six-season period (1998/1999–2003/2004)												
Variables	**1998–1999**		**1999–2000**		**2000–2001**		**2001–2002**		**2002–2003**		**2003–2004**	
	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**
Multistage fitness test												
Shuttle run test	84,4	21,67	94,18	16,82	94,33	12,46	99,39	5,61	105,75	2,11	103,88	6,44
Sit-and-reach test (cm)	41,19	6,10	43,95	4,91	40,72	5,44	39,21	7,87	40,38	6,69	40,75	7,38
Abdominal strength test									4,125	1,02	4,44	0,96
One minute oblique sit-up test												
Left side									63,63	8,54	66,19	3,97
Right side									60,00	10,13	64,56	5,25
One minute push-up test									41,69	7,03	43,63	7,30
Run a three test (sec.)									10,33	0,35	10,38	0,41
505 agility test (sec.)									2,32	0,11	2,35	0,15
5-metre multiple shuttle test (m)					702,22	35,03	720,65	25,19	735,00	12,78	736,56	21,96

Table 4.2.2b. Practically significant differences (d-values) of the physical and motor evaluations.										
Year	Year	Variables								
		Multistage fitness test	Sit-and-reach test	Abdominal strength test	One minute oblique sit-up- test		One minute push-up test	Run a three test	505 agility test	5-metre multiple shuttle test
		Shuttle run test			Left	Right				
1	2	0,45	0,45							
1	3	0,46	0,08							
1	4	0,69	0,25							
1	5	**0,98**	0,12							
1	6	**0,90**	0,06							
2	3	0,01	0,59							
2	4	0,31	0,60							
2	5	0,69	0,53							
2	6	0,58	0,43							
3	4	0,41	0,19							0,53
3	5	**0,92**	0,05							**0,94**
3	6	0,77	0,00							**0,98**
4	5	1,13	0,15							0,57
4	6	0,70	0,19							0,63
5	6	0,29	0,05	0,30	0,30	0,45	0,27	0,14	0,20	0,07

The d-values used: d-value < 0,20 = low practical significance, d-value ≥ 0,20 = small practical significance, d-value ≥ 0,50 = medium practical significance and d-value ≥ 0,80 = high practical significance.

The physical and motor evaluations were done at the end of the off-season (middle September). Comparing the results for the 1998/1999 off-season with the 2003/2004 off-season actually refers to the results at the end of the off-season (middle September) 1998/1999 to the results of the results at the end of the off-season 2003/2004 (middle September).

Table 4.2.2a shows an increase (positive result) for the multistage fitness test from the 1998/1999 off-season ($\bar{x}$ = 84,4, Level 10,04) to the 2003/2004 off-season ($\bar{x}$ = 103,88, Level 11,11), with a d-value = 0,90, a high practical significance (year 1 to year 6, Table 4.2.2b). The result indicates an increase in the aerobic fitness of the cricketers from the first season to the sixth season. This increase in the physical fitness will not only benefit the players in injury prevention but also in their general play as cricketers (as discussed in chapter 2).

Table 4.2.2a shows an increase (positive result) for the multistage fitness test from the 1998/1999 off-season ($\bar{x}$ = 84,4, Level 10,04) to the 2002/2003 off-season ($\bar{x}$ = 105,75, Level 12,01), with a d-value = 0,98, a high practical significance (year 1 to year 5, Table 4.2.2b), as well as an increase (positive result) in the mean value from the 2000/2001 off-season ($\bar{x}$ = 94,33, Level 10,04) to the 2002/2003 off-season ($\bar{x}$ = 105,75, Level 12,01), with a d-value = 0,92, a high practical significance (year 3 to year 5, Table 4.2.2b).

As for the 5-metre multiple shuttle test (testing the anaerobic capacity of the cricketers), Table 4.2.2a indicates an increase (positive result) in the mean value for the 2000/2001 off-season ($\bar{x}$ = 702,22) to the 2003/2004 off-season ($\bar{x}$ = 736,56), with a d-value = 0,98, a high practical significance (year 3 to year 6, Table 4.2.2b) as well as an increase from the 2000/2001 off-season ($\bar{x}$ = 702,22) to the 2002/2003 off-season ($\bar{x}$ = 735,00), with a d-value = 0,94, a high

practical significance (year 3 to year 5, Table 4.2.2b) The result can only benefit the cricketers, as it indicates an improvement in their anaerobic capacity.

Conclusion

Improvement in the aerobic fitness (multistage fitness test: shuttle run test) was found from the 1998/1999 off-season (84,4 shuttles, level 10,04) to the 2003/2004 off-season (103,88 shuttles, level 11,11) indicating the players were aerobically more prepared at the end of the sixth off-season season (2003/2004) than at the end of the first off-season (1998/1999). An improvement in the anaerobic fitness (5-metre multiple shuttle test) was found at the end of the 2003/2004 off-season (736,56m) compared to the end of the 2000/2001 off-season (702,22 meters). The results indicate that the players were better prepared anaerobically for the game of cricket at the end of the sixth off-season (2003/2004) than at the end of the 2000/2001 off-season, when the test was introduced.

The increase in the abdominal strength (4,125 at the end of the 2002/2003 off-season to 4,44 at the end of the 2003/2004 off-season), the increase in the oblique sit-up: left and right (63,63 for the left anatomical side at the end of the 2002/2003 off-season to 66,19 for the left anatomical side at the end of the 2003/2004 off-season and 60,00 for the right anatomical side at the end of the 2002/2003 off-season to 64,56 for the right anatomical side at the end of the 2003/2004 off-season) and the increase in the push-ups (41,69 at the end of the 2002/2003 off-season to 46,63 at the end of the 2003/2004 off-season) also indicate that the players were better prepared physically at the end of the 2003/2004 off-season.

The decrease in the sit-and-reach test is a negative result, which impacts negatively on the physical profile of the cricketers. The decrease in the running speed of the run a three test as well as the 505 agility test also impacts

negatively on the physical fitness of the players, although the decrease was of small practical significance.

Overall, the cricketers' physical fitness profile was better at the end of the off-season before the 2003/2004 season than was experienced at the end of the off-season in the 1998/1999 season and in the 2002/2003 season (when the new evaluations were introduced).

The anthropometric results will be discussed next.

4.2.3 Anthropometric evaluations

In this section the results of the anthropometric evaluations are discussed. The descriptive statistics of each evaluation are discussed, together with those results with a high practical significance (d-values ≥ 0,80). This includes the following: body weight, fat percentage, kilograms of body fat and kilograms of lean muscle. Also, the results of the somatotype evaluations will be discussed, which include endomorphy, mesomorphy and ectomorphy calculations.

Table 4.2.3a and Table 4.2.3b showed an improvement in the fat percentage, fat mass and lean body mass from the 1998/1999 off-season to the 2003/2004 off-season. Improvements also occurred in the mean values of the endomorphy and ectomorphy somatotype components over the six off-season periods and a decrease in the mean value for the mesomorphy component. The results in Table 4.2.3a and Table 4.2.3b indicate that the mean values stayed relatively consistent for the last three seasons for fat percentage, fat mass, lean body mass, endomorphy, ectomorphy and mesomorphy.

Table 4.2.3a Descriptive statistics of the anthropometric evaluations done over the six-season period (1998/1999–2003/2004)												
	1998–1999		1999–2000		2000 - 2001		2001–2002		2002– 2003		2003–2004	
Variables	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Body mass	84,48	15,42	81,76	8,710	84,94	13,46	84,02	12,94	82,98	8,84	82,98	11,53
Fat percentage	16,30	6,66	13,60	4,99	13,48	5,83	13,37	4,91	12,07	3,53	13,51	5,33
Fat mass	14,52	8,78	11,52	5,23	12,00	7,61	11,55	5,97	10,00	2,90	11,55	5,20
Lean body mass	69,95	7,82	70,43	6,31	72,87	7,73	72,47	9,31	73,11	8,39	71,53	9,00
Somatotype												
Endomorphy	3,62	1,70	3,25	1,29	3,24	1,41	3,17	1,29	2,91	1,03	3,25	1,53
Mesomorphy	4,88	1,41	4,95	1,02	4,50	1,35	4,48	1,05	4,30	0,85	4,43	1,00
Ectomorphy	1,89	1,32	1,98	0,89	2,37	1,26	2,57	0,99	2,83	0,84	2,61	0,91

Table 4.2.3b. Practically significant differences (d-values) of the anthropometric evaluations								
Year	Year	Variables						
		Body mass	Fat percentage	Fat mass	Lean body mass	Somatotype		
						Endomorphy	Mesomorphy	Ectomorphy
1	2	0,18	0,41	0,34	0,06	0,22	0,05	0,07
1	3	0,03	0,42	0,29	0,37	0,22	0,27	0,36
1	4	0,03	0,44	0,34	0,27	0,27	0,28	0,52
1	5	0,10	0,64	0,51	0,38	0,42	0,41	0,71
1	6	0,10	0,42	0,34	0,17	0,22	0,31	0,54
2	3	0,24	0,02	0,06	0,32	0,01	0,33	0,30
2	4	0,17	0,04	0,00	0,22	0,07	0,44	0,60
2	5	0,14	0,31	0,29	0,32	0,27	0,64	**0,95**
2	6	0,11	0,02	0,01	0,12	0,00	0,50	0,69
3	4	0,07	0,02	0,06	0,04	0,05	0,01	0,16
3	5	0,15	0,24	0,26	0,03	0,24	0,15	0,37
3	6	0,15	0,00	0,06	0,15	0,00	0,05	0,19
4	5	0,08	0,27	0,26	0,07	0,20	0,18	0,27
4	6	0,08	0,03	0,00	0,10	0,05	0,04	0,04
5	6	0,00	0,27	0,30	0,18	0,22	0,14	0,25

The d-values (practical significance) used: d-value < 0,20 = low practical significance, d-value ≥ 0,20 = small practical significance, d-value ≥ 0,50 = medium practical significance and d-value ≥ 0,80 high practical significance.

The anthropometric evaluations were done at the end of the off-season (middle September). A comparison of the results for the 1998/1999 season with the 2003/2004 season actually refers to the results at the end of the off-season (middle September) 1998/1999 to the results of the results at the end of the off-season (middle September) 2003/2004.

Ectomorphy shows an increase (positive) in the mean value (Table 4.2.3a) from the 1999/2000 off-season ($\bar{x}$ = 1,98) to the 2002/2003 off-season ($\bar{x}$ = 2,83), with a d-value = 0,95 (year 2 to year 5, Table 4.4b), a high practical significance.

Conclusion

The results show the cricketers to have a better anthropometric profile at the end of the off-season of the 2003/2004 season compared to the end of the off-season of the 1998/1999 season. The decrease in the mean body weight from the 1998/1999 off-season (84,48 kg) to the 2003/2004 off-season (82,98 kg), the decrease in the body fat percentage from 16,30% in the 1998/1999 off-season to 13,51% in the 2003/2004 off-season, the decrease in kilograms of body fat from 14,52 kg in the 1998/1999 off-season to 11,54 kg in the 2003/2004 off-season and the increase in the lean muscle mass from 69,95 kg in the 1998/1999 off-season to 71,53 kg in the 2003/2004 off-season supports the statement that the cricketers had a better anthropometric profile in the 2003/2004 off-season than in the 1998/1999 off-season.

The improvement of the endomorphic component from 3,62 at the end of the off-season of the 1998/1999 season to 3,25 at the end of the off-season of the 2003/2004 season also indicates a better anthropometric profile for the cricketers. The improvement of the ectomorphy component from 1,89 at the end of the off-season of the 1998/1999 season to 2,61 at the end of the off-season of the 2003/2004 season also indicates a better anthropometric profile for cricketers. The decrease in the mesomorphic component from 4,88 at the end of

the off-season in the 1998/1999 season to 4,43 at the end of the off-season in the 2003/2004 season impacts negatively on the improvement in the anthropometric profile of the cricketers. Overall the somatotype score of 3,25–4,43–2,61 is a better score at the end of the off-season of the 2003/2004 season than the somatotype score of 3,62–4,88–1,89 at the end of the off-season of the 1998/1999 season.

4.3. Protocol 2

4.3.1 Introduction

In this section of Chapter 4 the players were divided into groups that were exposed to the training and prevention programme for the first time, second time, third time and fourth time. There was one player who was exposed to the training and prevention programme for a fifth time. Only the results for the first four exposures will be discussed in this section.

Table 4.3.1 Number of players exposed to the injury prevention and training programme per exposure

Table 4.3.1 Number of players exposed to the injury prevention and training programme per exposure	
Exposure	**Number of players**
First time	39
Second time	27
Third time	20
Fourth time	6
Fifth time	1
Total exposures	**93**

The descriptive statistics of each evaluation (biomechanical, physical and motor and anthropometric evaluation) will be discussed, together with those results with a high practical significance (d-value ≥ 0,80) for the first to the fourth exposure, together with high practical significances for the first second, third and fourth exposure. The biomechanical evaluations of the musculoskeletal system will be discussed in the next section.

4.3.2 The biomechanical evaluation

The results of the biomechanical variables evaluated (ankle dorsiflexion, Thomas test and gluteus maximus mobility) are discussed next (Table 4.3.2a biomechanical evaluations and Table 4.3.2b practical significances).

A decrease in the mean value in Table 4.3.2a was found for ankle dorsiflexion: left and right anatomical side; illiotibial band mobility: left anatomical side; quadriceps mobility: left and right anatomical side: iliopsoas mobility: left and right anatomical side; and gluteus maximus mobility: left and right anatomical side from the first exposure to the fourth exposure. Practical significances varied from low to high practical significances (Table 4.3.2b). An increase (negative) in the mean value for the right anatomical side of the illiotibial band mobility was found from exposure one to the fourth exposure, a small practical significance.

Table 4.3.2a indicates a decrease (positive result) in the mean value for the iliopsoas mobility from the first exposure ($\bar{x}$ = 1,90 for the right anatomical side) to the fourth exposure ($\bar{x}$ = 1,33 for the right anatomical side), with a d-value = 0,94, a high practical significance for the right anatomical side (exposure 3 to exposure 4, Table 4.3.2b), as well as from the third exposure ($\bar{x}$ = 2,05 for the left anatomical side and $\bar{x}$ = 1,90 for the right anatomical side) to the fourth exposure ($\bar{x}$ = 1,90 for the left anatomical side and $\bar{x}$ = 1,33 for the right anatomical side), with a d-value = 0,80 for the left anatomical side and 0,88 for the right anatomical side, a high practical significance (exposure 3 to exposure 4, Table 4.3.2b)

Table 4.3.2a Descriptive statistics of biomechanical variables evaluated (ankle dorsiflexion, Thomas test and gluteus maximus mobility) for the four exposures (1998/1999–2003/2004)									
Variables	**Anatomical side**	**1st time**		**2nd time**		**3rd time**		**4th time**	
		$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**
Ankle dorsiflexion	Left	1,74	0,64	1,74	0,71	1,40	0,68	1,50	0,84
	Right	1,72	0,65	1,78	0,75	1,40	0,68	1,67	1,03
Thomas test	**Illiotibial band mobility**								
	Left	1,95	0,60	1,74	0,66	1,80	0,70	2,16	0,75
	Right	1,95	0,60	1,78	0,64	1,85	0,81	1,83	0,75
	Quadriceps mobility								
	Left	1,69	0,57	1,52	0,51	1,70	0,57	1,50	0,84
	Right	1,74	0,55	1,52	0,51	1,65	0,59	1,33	0,82
	Iliopsoas mobility								
	Left	1,92	0,62	1,63	0,69	2,05	0,69	1,50	0,54
	Right	1,90	0,60	1,56	0,64	1,90	0,64	1,33	0,52
Gluteal maximus mobility	Left	1,96	0,81	1,63	0,76	1,30	0,47	1,83	0,41
	Right	1,96	0,76	1,53	0,70	1,35	0,59	1,83	0,41

Results in Table 4.3.2a show the mean value for the gluteus maximus mobility to decrease (positive result) from the first exposure ($\bar{x}$ = 1,96 for the left anatomical side and $\bar{x}$ = 1,96 for the right anatomical side) to the third exposure ($\bar{x}$ = 1,30 for the left anatomical side and $\bar{x}$ = 1,35 for the right anatomical side), with a d-value = 0,82 for the left anatomical side and a d-value = 0,81 for the right

anatomical side (exposure 1 to exposure 3, Table 4.3.2b), a high practical significance for the left and right anatomical sides. The mean value increased (negative) from the third exposure ($\bar{x}$ = 1,30 for the left anatomical side and $\bar{x}$ = 1,35 for the right anatomical side) to the fourth exposure ($\bar{x}$ = 1,83 for the left and the right anatomical side), with a d-value = 1,13 for the left anatomical side and a d-value = 0,82 for the right anatomical side (exposure 3 to exposure 4, Table 4.3.2b), a high practical significance for the left and right anatomical sides.

Table 4.3.2b Practically significant differences (d-values) of the biomechanical variables (ankle dorsiflexion, Thomas test and gluteus maximus mobility) evaluated

Exposure	Exposure	Variables									
		Ankle dorsiflexion		Thomas test						Gluteus maximus mobility	
				Illiotibial band mobility		Quadriceps mobility		Iliopsoas mobility			
		Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
1	2	0,04	0,08	0,32	0,27	0,31	0,41	0,43	0,53	0,41	0,58
1	3	0,50	0,48	0,21	0,12	0,01	0,16	0,18	0,04	**0,82**	**0,81**
1	4	0,29	0,05	0,29	0,15	0,26	0,50	0,69	**0,94**	0,16	0,17
2	3	0,48	0,50	0,09	0,09	0,32	0,22	0,61	0,54	0,44	0,25
2	4	0,29	0,11	0,57	0,07	0,02	0,23	0,19	0,35	0,27	0,44
3	4	0,12	0,26	0,49	0,02	0,24	0,39	**0,80**	**0,88**	**1,13**	**0,82**

The d-values used to describe the practical significance: d-value < 0,20 = low practical significance, d-value ≥ 0,20 = small practical significance, d-value ≥ 0,50 = medium practical significance and d-value ≥ 0,80 high practical significance.

The results found for the biomechanical evaluation of the hip joint (adductor mobility, hip internal rotation mobility and hip external rotation mobility) are discussed in the next section (Table 4.3.2c biomechanical evaluations and Table 4.3.2d practical significances).

The results in Table 4.3.2c indicate a decrease (positive) in the mean value for hip internal rotation: left anatomical side, small practical significance (Table 4.3.2d), as well as an increase (negative) in the mean value for adductor mobility, hip internal rotation: right anatomical side and hip external rotation mobility: left and right anatomical side from the first exposure to the fourth exposure, with low to small practical significances (Table 4.3.2d).

Table 4.3.2c Descriptive statistics of biomechanical variables evaluated (hip joint) for the four exposures (1998/1999–2003/2004)

Variables	Anatomical side	1st time		2nd time		3rd time		4th time	
		$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Adductor Mobility		1,52	0,51	1,39	0,50	1,30	0,47	1,83	0,75
Hip internal rotation mobility	Left	1,48	0,58	1,63	0,60	1,40	0,50	1,33	0,52
	Right	1,44	0,58	1,58	0,61	1,35	0,49	1,50	0,55
Hip external rotation mobility	Left	1,93	0,55	1,84	0,60	1,75	0,55	2,00	0,63
	Right	1,89	0,58	1,89	0,66	1,75	0,55	2,00	0,63

Table 4.3.2d Practically significant differences (d-values) of the biomechanical variables (hip joint) evaluated

Exposure	Exposure	Variables				
		Adductor mobility	Hip internal rotation mobility		Hip external rotation mobility	
			Left	Right	Left	Right
1	2	0,29	0,25	0,22	0,14	0,01
1	3	0,43	0,14	0,16	0,32	0,24
1	4	0,42	0,26	0,10	0,12	0,18
2	3	0,14	0,39	0,38	0,15	0,22
2	4	0,62	0,50	0,13	0,25	0,16
3	4	0,71	0,13	0,27	0,40	0,40

A decrease (positive result) in the mean value of adductor mobility, hip internal rotation (left and right anatomical sides) and hip external rotation mobility (left and right anatomical side) from the first exposure to the third exposure are shown in Table 4.3.2c, practical significances varied from low to small practical significances (Table 4.3.2d).

The next discussion (Table 4.3.2e biomechanical evaluation and Table 4.3.2f practical significances) is of the results of the biomechanical evaluation of the knee (Q-angle, patella squint, patella tilt and vastus medialis obliques-lateralis comparison (VMO-L)).

Table 4.3.2e Descriptive statistics of biomechanical variables evaluated (the knee region) for the four exposures (1998/1999–2003/2004)

Variables	Anatomical side	1st time		2nd time		3rd time		4th time	
		$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Q-angle	Left	1,15	0,37	1,11	0,32	1,15	0,37	1,17	0,41
	Right	1,15	0,37	1,11	0,32	1,15	0,37	1,17	0,41
Patella squint	Left	1,15	0,36	1,21	0,42	1,10	0,31	1,17	0,41
	Right	1,15	0,36	1,21	0,42	1,10	0,31	1,17	0,41
Patella tilt	Left	1,48	0,51	1,32	0,48	1,40	0,50	1,17	0,41
	Right	1,48	0,51	1,32	0,48	1,40	0,50	1,17	0,41
Vastus medialis obliques-lateralis comparison	Left	1,08	0,27	1,04	0,19	1,05	0,22	1,17	0,41
	Right	1,08	0,27	1,04	0,19	1,10	0,31	1,17	0,41

Table 4.3.2f Practically significant differences (d-values) of the biomechanical variables (the knee region) evaluated									
Exposure	**Exposure**	**Variables**							
		Q–angle		**Patella squint**		**Patella tilt**		**Vastus medialis obliques – lateralis comparison**	
		Left	Right	Left	Right	Left	Right	Left	Right
1	**2**	0,12	0,12	0,15	0,15	0,33	0,33	0,15	0,15
1	**3**	0,01	0,01	0,13	0,13	0,16	0,16	0,10	0,07
1	**4**	0,03	0,03	0,05	0,05	0,62	0,62	0,22	0,22
2	**3**	0,11	0,11	0,26	0,26	0,17	0,17	0,06	0,20
2	**4**	0,14	0,14	0,10	0,10	0,31	0,31	0,32	0,32
3	**4**	0,04	0,04	0,16	0,16	0,46	0,46	0,29	0,16

Table 4.3.2e shows the mean value for the q-angle (left and right anatomical sides), patella squint (left and right anatomical sides), vastus medialis obliques-lateralis comparison (left and right anatomical sides) decreased from the first exposure to the fourth exposure, with practical significances being low to small (Table 4.3.2f). Improvement was found for patella tilt from the first exposure to the fourth exposure, with a medium practical significance.

The next discussion (Table 4.3.2g biomechanical evaluation and Table 4.3.2h practical significances) is of the results of the biomechanical evaluation of the foot (longitudinal arch status, forefoot positional, rear foot standing, rear foot lying, transverse arch area comparison, foot mobility and toes positional).

Table 4.3.2g Descriptive statistics of biomechanical variables evaluated (the foot) for the four exposures (1998/1999–2003/2004)									
Variables	**Anatomical side**	**1st time**		**2nd time**		**3rd time**		**4th time**	
		$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**
Longitudinal arch status	Left	1,23	0,43	1,48	0,58	1,35	0,49	1,33	0,52
	Right	1,23	0,43	1,48	0,58	1,35	0,49	1,33	0,52
Forefoot positional	Left	1,37	0,49	1,37	0,50	1,65	0,49	1,50	0,55
	Right	1,37	0,49	1,37	0,50	1,60	0,50	1,67	0,52
Rear foot standing	Left	1,67	0,53	1,33	0,50	1,70	0,66	1,67	0,52
	Right	1,64	0,54	1,48	0,51	1,70	0,66	1,67	0,52
Rear foot lying	Left	1,56	0,50	1,21	0,42	1,55	0,51	1,50	0,55
	Right	1,52	0,51	1,26	0,45	1,55	0,51	1,67	0,52
Transverse arch area comparison	Left	1,19	0,40	1,26	0,45	1,20	0,41	1,33	0,52
	Right	1,19	0,40	1,26	0,45	1,25	0,44	1,33	0,52
Foot mobility	Left	1,48	0,75	1,68	0,95	1,85	0,81	2,00	0,89
	Right	1,52	0,75	1,68	0,95	1,85	0,81	2,00	0,89
Toes positional	Left	1,89	0,32	1,89	0,32	1,90	0,31	1,67	0,52
	Right	1,89	0,32	1,89	0,32	1,90	0,31	1,67	0,52

Table 4.3.2h Practically significant differences (d-values) of the biomechanical variables (the foot) evaluated															
Exposure	Exposure	Variables													
		Longitudinal arch status		Forefoot positional		Rear foot standing		Rear foot lying		Transverse arch area comparison		Foot mobility		Toes positional	
		Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
1	2	0,43	0,43	0,00	0,00	0,53	0,30	0,68	0,50	0,17	0,17	0,21	0,18	0,02	0,02
1	3	0,24	0,24	0,57	0,46	0,05	0,09	0,01	0,06	0,04	0,15	0,45	0,41	0,03	0,03
1	4	0,20	0,20	0,24	0,57	0,00	0,05	0,10	0,29	0,29	0,29	0,58	0,54	0,43	0,14
2	3	0,23	0,23	0,57	0,46	0,48	0,33	0,67	0,56	0,14	0,03	0,17	0,18	0,02	0,02
2	4	0,26	0,26	0,24	0,58	0,55	0,36	0,53	0,78	0,14	0,14	0,33	0,33	0,44	0,15
3	4	0,32	0,32	0,27	0,13	0,05	0,05	0,09	0,23	0,26	0,16	0,17	0,17	0,45	0,16

Table 4.3.2g indicates improvements in the mean values from the first exposure to the fourth exposure for the longitudinal arch status (left and right anatomical sides), foot mobility (left and right anatomical sides) and toes positional (left and right anatomical sides), with the practical significance being small to medium practical significance (Table 4.3.2h). A decrease in the mean value from the first exposure to the fourth exposure was found for forefoot positional (left and right anatomical sides), rear foot lying (left and right anatomical sides), transverse arch area comparison (left and right anatomical sides), with low to small practical significances.

To follow a discussion of the results of the biomechanical evaluations done for the four exposures for pelvic girdle region (leg-length discrepancy, anterior superior iliac spine (ASIS), posterior superior iliac spine (PSIS), pubic tubercle height, sacroiliac cleft and bilateral pelvic position). Table 4.3.2i describes the biomechanical evaluation and Table 4.3.2j the practical significances.

Table 4.3.2i Descriptive statistics of biomechanical variables evaluated (pelvic girdle region) for the four exposures (1998/1999–2003/2004)

Variables	1st time		2nd time		3rd time		4th time	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Pelvic girdle region								
Leg-length discrepancy	1,64	0,58	1,59	0,57	1,25	0,44	1,33	0,52
ASIS	1,59	0,49	1,56	0,51	1,25	0,44	1,33	0,52
PSIS	1,59	0,49	1,56	0,51	1,25	0,44	1,33	0,52
Pubic tubercle height	1,59	0,49	1,56	0,51	1,25	0,44	1,33	0,52
Sacroiliac cleft	1,33	0,48	1,21	0,42	1,10	0,31	1,33	0,52
Bilateral pelvic position	1,89	0,72	1,67	0,55	1,25	0,67	1,67	0,82

Table 4.3.2j Practically significant differences (d-values) of the biomechanical variables (pelvic girdle region) evaluated							
Exposure	Exposure	Variables					
		Leg-length discrepancy	ASIS	PSIS	Pubic tubercle height	Sacroiliac cleft	Bilateral pelvic position
1	2	0,08	0,07	0,07	0,07	0,26	0,32
1	3	0,66	0,68	0,68	0,68	0,49	0,34
1	4	0,52	0,50	0,50	0,50	0,00	0,28
2	3	0,59	0,60	0,60	0,60	0,26	0,02
2	4	0,45	0,43	0,43	0,43	0,23	0,00
3	4	0,16	0,16	0,16	0,16	0,45	0,02

Results for the pelvic girdle region in Table 4.3.2i indicate an improvement in the mean value for leg length discrepancy, ASIS, PSIS, pubic tubercle height and bilateral pelvic position from the first exposure to the fourth exposure, of medium practical significance (Table 4.3.2j). The sacroiliac cleft stayed consistent from exposure one to exposure four.

A discussion of the results of the biomechanical evaluation (Table 4.3.2k) and practical significance (Table 4.3.2l) for the spinal region: spinal dynamic mobility (thoraco-lumbar facia mobility, sacral rhythm, functional extension mobility, functional flexion mobility, rotational mobility and side flexion mobility) follows next.

The results in Table 4.3.2k indicate a decrease in the mean value (positive) for the thoraco-lumbar facia mobility (left and right anatomical sides), functional flexion mobility and rotational mobility (left anatomical side) from the first exposure to the fourth exposure, with practical significances low to medium (Table 4.3.2l). An increase in the mean value (negative result) was found for

sacral rhythm, functional extension mobility and side flexion mobility (left and right anatomical sides), with small practical significances.

Table 4.3.2k Descriptive statistics of biomechanical variables evaluated (spinal region: spinal dynamic mobility) for the four exposures (1998/1999–2003/2004)

Variables	Anatomical side	1st time		2nd time		3rd time		4th time	
		$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Thoraco-lumbar facia mobility	Left	1,74	0,59	1,53	0,61	1,55	0,51	1,50	0,55
	Right	1,78	0,57	1,42	0,60	1,55	0,51	1,50	0,55
Sacral rhythm		1.22	0,42	1,16	0,37	1,20	0,41	1,33	0,52
Functional extension mobility		1.26	0,53	1,68	0,67	1,15	0,37	1,50	0,55
Functional flexion mobility		1.44	0,58	1,57	0,77	1,35	0,67	1,33	0,52
Rotational mobility	Left	1,04	0,19	1,05	0,23	1,05	0,22	1,00	0,00
	Right	1,00	0,00	1,05	0,23	1,05	0,22	1,00	0,00
Side flexion mobility	Left	1,11	0,32	1,16	0,37	1,05	0,22	1,33	0,52
	Right	1,11	0,32	1,16	0,37	1,05	0,22	1,33	0,52

Results in Table 4.3.2k show the mean value for functional extension mobility decreased (positive result) from the second exposure ($\bar{x}$ = 1,96) to the third exposure ($\bar{x}$ = 1,15), d-value = 0,80 (exposure 2 to exposure 3, Table 4.3.2l), a high practical significance.

Table 4.3.2l Practically significant differences (d-values) of the biomechanical variables (spinal region: spinal dynamic mobility) evaluated										
Exposure	Exposure	Variables								
		Thoraco-lumbar facia mobility		Sacral rhythm	Functional extension mobility	Functional flexion mobility	Rotational mobility		Side flexion mobility	
		Left	Right				Left	Right	Left	Right
1	2	0,35	0,59	0,15	0,63	0,18	0,07	0,23	0,12	0,12
1	3	0,32	0,39	0,05	0,21	0,14	0,06	0,22	0,19	0,19
1	4	0,41	0,48	0,21	0,44	0,19	0,19		0,43	0,43
2	3	0,03	0,21	0,10	**0,80**	0,30	0,11	0,11	0,29	0,29
2	4	0,04	0,13	0,34	0,27	0,32	0,22	0,23	0,34	0,34
3	4	0,09	0,09	0,26	0,64	0,02	0,22	0,22	0,55	0,55

The next discussion will deal with the biomechanical results (Table 4.3.7m) and practical significance (Table 4.3.2n) for the spinal positional alignment: coronal axis and sagittal axis (head position, cervical, thoracic and lumbar). The first discussion will focus on the results for the spinal positional alignment: coronal axis and then the sagittal axis will follow.

Table 4.3.2m Descriptive statistics of biomechanical variables evaluated (spinal positional alignment: coronal axis and sagittal axis) for the four exposures (1998/1999–2003/2004)

Variables	1st time		2nd time		3rd time		4th time	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Coronal axis								
Head position	1,31	0,47	1,19	0,40	1,25	0,44	1,33	0,52
Cervical	1,10	0,31	1,15	0,36	1,05	0,22	1,33	0,52
Thoracic	1,15	0,37	1,41	0,50	1,05	0,22	1,33	0,52
Lumbar	1,64	0,48	1,33	0,48	1,70	0,47	1,67	0,52
Sagittal axis								
Head position	1,00	0,00	1,00	0,00	1,00	0,00	1,00	0,00
Cervical	1,00	0,00	1,11	0,32	1,00	0,00	1,00	0,00
Thoracic	1,74	0,45	1,63	0,50	1,75	0,44	1,67	0,52
Lumbar	1,04	0,19	1,05	0,23	1,00	0,00	1,00	0,00

The results in Table 4.3.2m show an increase in the mean value (negative result) of the head position, cervical, thoracic and lumbar evaluations of the coronal axis for spinal alignment position from the first exposure to the fourth exposure, with the practical significances being low to medium practical significance (Table 4.3.2n).

Table 4.3.2n Practically significant differences (d-values) of the biomechanical variables (spinal positional alignment: coronal axis and sagittal axis evaluation) evaluated									
Exposure	Exposure time	Variable							
		Coronal axis				Sagittal axis			
		Head position	Cervical	Thoracic	Lumbar	Head position	Cervical	Thoracic	Lumbar
1	2	0,26	0,13	0,51	0,63		0,33	0,22	0,07
1	3	0,12	0,17	0,28	0,12			0,02	0,19
1	4	0,04	0,45	0,35	0,05			0,14	0,19
2	3	0,15	0,27	0,71	0,76		0,33	0,24	0,23
2	4	0,29	0,36	0,14	0,65		0,33	0,06	0,23
3	4	0,16	0,55	0,55	0,06			0,16	

Results of the spinal alignment for the sagittal axis show the head position, cervical to have stayed consistent from the first exposure to the fourth exposure (Table 4.3.2m). Table 4.3.2m further indicates an improvement (positive result) in the thoracic and lumbar spinal position alignment, practical significances being low (Table 4.3.2n).

The biomechanical evaluation (Table 4.3.2o) and practical significance (Table 4.3.2p) for the upper limb region (hand behind back range of motion ROM, hand behind neck ROM, shoulder coronal positional test, winging positional test, shoulder outline composition and throwing position ROM) are discussed in the next section.

Table 4.3.2o Descriptive statistics of biomechanical variables evaluated (upper limb region) for the four exposures (1998/1999–2003/2004)

Variables	Anatomical side	1st time		2nd time		3rd time		4th time	
		$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Hand behind back ROM	Left	1,48	0,58	1,58	0,69	1,60	0,50	1,67	0.51
	Right	1,59	0,64	1,89	0,81	1,75	0,55	1,67	0.51
Hand behind neck ROM	Left	1,19	0,40	1,11	0,32	1,20	0,41	1,17	0.41
	Right	1,19	0,40	1,11	0,32	1,30	0,57	1,17	0.41
Shoulder coronal positional test		1.59	0,50	1,29	0,47	1,20	0,41	1,17	0,41
Winging positional test		1.19	0,40	1,21	0,42	1,15	0,37	1,17	0,41
Shoulder outline composition		1.19	0,40	1,05	0,23	1,05	0,22	1,00	0,00
Throwing position (ROM)		1.07	0,27	1,11	0,32	1,00	0,00	1,00	0,00

Table 4.3.2p Practically significant differences (d-values) of the biomechanical variables (upper limb region) evaluated									
Exposure	Exposure	Variables							
		Hand behind back ROM		Hand behind neck ROM		Shoulder coronal positional test	Winging positional test	Shoulder outline composition	Throwing position (ROM)
		Left	Right	Left	Right				
1	2	0,14	0,37	0,20	0,20	0,59	0,06	0,33	0,09
1	3	0,20	0,25	0,04	0,21	0,78	0,09	0,34	0,28
1	4	0,32	0,12	0,05	0,05	**0,84**	0,05	0,48	0,28
2	3	0,03	0,18	0,23	0,34	0,21	0,14	0,11	0,33
2	4	0,13	0,28	0,15	0,15	0,28	0,10	0,23	0,33
3	4	0,13	0,15	0,08	0,23	0,08	0,04	0,22	

The results in Table 4.3.2o show that the mean value for hand behind back ROM (left and right anatomical side) increased (negative result) from the first exposure to the fourth exposure, with practical significances low to small (Table 4.3.2p). The mean value for hand behind neck ROM (left and right anatomical sides), shoulder coronal positional test, winging positional test, shoulder outline composition and throwing position decreased (positive result) from the first exposure to the fourth exposure, with practical significances low, small, medium and high.

The results of the mean value in Table 4.3.2o indicate a decrease (positive result) in the mean value for the shoulder coronal positional test from the first exposure ($\bar{x}$ = 1.59) to the fourth exposure ($\bar{x}$ = 1.17), with a d-value = 0,84, a high practical significance (exposure 1 to exposure 4, Table 4.3.2p).

The next discussion will deal with the results for the biomechanical evaluations (Table 4.3.2q) and practical significances (Table 4.3.2r) of the neurodynamics (straight leg raise, upper limb tension test, L3,4 prone knee bend and slump test).

Table 4.3.2q shows a decrease (negative result) in the mean value for the straight leg raise (left and right anatomical side), upper limb tension test (left and right anatomical side) and L3,4 prone knee bend (left and right anatomical sides), with practical significances being small (Table 4.3.2r). An improvement in the slump test (positive result) was present from the first exposure to the fourth exposure, with small practical significance.

Table 4.3.2q Descriptive statistics of biomechanical variables evaluated (neurodynamics) for the four exposures (1998/1999–2003/2004)									
Variables	**Anatomical side**	**1st time**		**2nd time**		**3rd time**		**4th time**	
		$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**
Straight leg raise	Left	1,79	0,70	1,67	0,48	1,50	0,61	2,17	0,75
	Right	1,85	0,71	1,74	0,45	1,50	0,61	2,17	0,75
Upper limb tension test	Left	1,00	0,00	1,00	0,00	1,05	0,22	1,16	0,41
	Right	1,00	0,00	1,00	0,00	1,05	0,22	1,16	0,41
L3,4 prone knee bend (PKB)	Left	1,38	0,48	1,56	0,64	1,35	0,59	1,50	0,84
	Right	1,36	0,49	1,63	0,63	1,40	0,60	1,50	0,84
Slump test	Left	1,26	0,45	1,39	0,60	1,05	0,22	1,16	0,41
	Right	1,30	0,54	1,39	0,60	1,05	0,22	1,16	0,41

Table 4.3.2r Practically significant differences (d-values) of the biomechanical variables (neurodynamics) evaluated									
Exposure	**Exposure**	**Variables**							
		Straight leg raise		**Upper limb tension test**		**L3,4 prone knee band (PKB)**		**Slump test**	
		Left	Right	Left	Right	Left	Right	Left	Right
1	**2**	0,18	0,15			0,27	0,43	0,18	0,12
1	**3**	0,42	0,49	0,22	0,22	0,06	0,07	0,47	0,45
1	**4**	0,49	0,43	0,41	0,41	0,14	0,17	0,20	0,24
2	**3**	0,27	0,40	0,22	0,22	0,32	0,36	0,53	0,53
2	**4**	0,66	0,57	0,41	0,41	0,07	0,15	0,34	0,34
3	**4**	0,88	0,89	0,29	0,29	0,18	0,12	0,29	0,29

Conclusion

The results of the biomechanical evaluation for the second protocol show an increase (negative) in the mean value from the first exposure to the fourth exposure for the following biomechanical evaluations which were done: illiotibial band mobility: left anatomical side; adductor mobility; hip external rotation mobility; Q-angle; patella squint; vastus medialis oblique-lateralis comparison: left and right anatomical side; forefoot positional: left and right anatomical side; rear foot lying: left and right anatomical side; transverse arch area comparison: left and right anatomical side; sacral rhythm; functional extension mobility; side flexion mobility: left and right anatomical side; coronal axis: head position; coronal: cervical; coronal axis: thoracic; coronal axis: lumbar; hand behind back ROM: left and right anatomical side; straight leg raise: left and right anatomical side; upper limb tension test: left and right anatomical side; and L3,4 prone knee bend, with practical significances varying from low to medium.

The results of the biomechanical evaluations done for the second protocol show a decrease in the mean value from the first exposure to the fourth exposure for the following evaluations:

- ankle dorsiflexion: left and right anatomical side;
- illiotibial mobility: right anatomical side;
- quadriceps mobility:left and right anatomical side;
- iliopsoas mobility: left and right anatomical side;
- gluteus maximus mobility: left and right anatomical side;
- hip internal mobility: left anatomical side;
- patella tilt: left and right anatomical side;
- longitudinal arch status: left and right anatomical side;
- foot mobility: left and right anatomical side;
- toes positional: left and right anatomical side;
- leg-length discrepancy;

- ASIS;
- PSIS;
- pubic tubercle height;
- sacroiliac cleft;
- bilateral pelvic position;
- thoraco-lumbar facia mobility: left and right anatomical side;
- functional flexion mobility;
- sagittal axis: thoracic; hand behind neck ROM: left and right anatomical side;
- coronal shoulder positional test;
- winging positional test;
- shoulder outline composition;
- throwing position (ROM);
- slump test: left and right anatomical side,

Practical significances varied from low to high, but mostly between low to small.

High practical significance was found for the coronal shoulder positional test and iliopsoas mobility: right anatomical side from the first exposure to the fourth exposure, which is a positive result.

4.3.3. Physical and motor evaluations

The next part of chapter 4 will discuss the results found for the physical and motor evaluations for the four exposures. The descriptive statistics of each evaluation will be discussed, together with those results with a high practical significance (d-values ≥ 0,80). The tests included: (1) multi-stage fitness test: shuttle run test; (2) sit-and-reach test; (3) abdominal strength test; (4) one minute oblique sit-up test: left and right anatomical sides; (5) one-minute push-up test; (5) run a three test; (6) 505 agility test; and (7) 5-metre multiple shuttle test.

Table 4.3.3a Descriptive statistics of the physical and motor evaluations done for the four exposures (1998/1999–2003/2004)								
Variables	**1st time**		**2nd time**		**3rd time**		**4th time**	
	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**
Multistage fitness test								
Shuttle run test	95,56	13,27	99,67	13,55	99,65	10,57	101,6	2,58
Sit-and-reach test (cm)	41,25	6,79	41,19	7,32	39,15	5,98	39,33	5,27
Abdominal strength test	4,88	0,35	3,83	1,03	4,20	1,14		
One minute oblique sit-up test								
Left side	68,63	5,85	61,50	7,78	65,50	3,30		
Right side	68,38	6,09	57,00	8,22	63,90	3,17		
One minute push-up test	42,50	5,98	42,58	8,26	41,90	6,66		
Run a three test (sec.)	10,48	0,38	10,27	0,32	10,29	0,43		
505 agility test (sec.)	2,37	0,60	2,33	0,13	2,32	0,17		
5-metre multiple shuttle test (m)	716,48	29,41	732,63	25,68	719,75	30,19	724,17	20,84

The results in Table 4.3.3a for the physical and motor evaluation for the four exposures show an improvement (positive) in the multistage fitness test, the 5-metre multiple shuttle test, with small practical significances (Table 4.3.3b). Results for run the three test and the 505 agility test showed improvement from the first exposure to the third exposure (Table 4.3.3a), with small practical

significances (Table 4.3.3b). The results indicate that the injury prevention and training programme contributed to the (positive) improvement of the results of the multistage fitness test, the 5-metre multiple shuttle test, run a three test and the 505 agility test.

The decrease (negative) in the abdominal strength, sit-and-reach test, oblique sit-up test: left and right anatomical sides and push-up from the first exposure to the third exposure (Table 4.3.3a) is a negative result. Practical significances varied from low, small to medium practical significance (Table 4.3.3b).

Table 4.3.3b Practically significant differences (d-values) of the physical and motor evaluations										
Exposure	**Exposure**	**Variables**								
		Multistage fitness test	**Sit-and-reach test**	**Abdominal strength test**	**One minute oblique sit-up test**		**One minute push-up test**	**Run a three test**	**505 agility test**	**5-metre multiple shuttle test**
		Shuttle run test			Left	Right				
1	**2**	0,30	0,01	**1,01**	**0,91**	**1,38**	0,01	0,51	0,30	0,55
1	**3**	0,31	0,31	0,59	0,53	0,73	0,09	0,42	0,29	0,11
1	**4**	0,46	0,28							0,26
2	**3**	0,00	0,28	0,32	0,51	0,84	0,08	0,04	0,06	0,43
2	**4**	0,15	0,25							0,33
3	**4**	0,19	0,31							0,15

The d-values used: d-value < 0,20 = low practical significance, d-value ≥ 0,20 = small practical significance, d-value ≥ 0,50 = medium practical significance and d-value ≥ 0,80 high practical significance.

4.3.4. Anthropometric evaluations

In the next part of Chapter 4 the result of the anthropometric evaluations will be discussed. The descriptive statistics of each evaluation will be discussed, together with those results with a high practical significance (d-values ≥ 0,80). This includes the following: body mass, fat percentage, fat mass and lean body mass. The results for the somatotype evaluations, which include endomorphy, mesomorphy and ectomorphy calculations, will also be included.

Table 4.3.4a Descriptive statistics of the anthropometric evaluations done for the four exposures (1998/1999–2003/2004)

Variables	1st time		2nd time		3rd time		4th time	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Body mass	82,11	11,19	83,78	13,30	87,32	11,55	82,13	7,84
Fat percentage	13,12	5,36	13,22	5,29	14,42	5,20	15,51	3,64
Fat mass	11,13	5,94	11,48	6,53	13,05	6,36	12,72	3,13
Lean body mass	71,04	8,11	72,38	9,20	74,28	7,38	69,37	7,31
Somatotype								
Endomorphy	3,15	1,45	3,14	1,29	3,39	1,34	3,40	1,00
Mesomorphy	4,48	1,03	4,67	1,10	4,69	1,29	4,11	0,81
Ectomorphy	2,50	1,07	2,35	1,04	2,27	1,05	2,77	0,97

Table 4.3.4b Practically significant differences (d-values) of the anthropometric evaluations								
Exposure	Exposure	Variables						
		Body mass	Fat percentage	Fat mass	Lean body mass	Somatotype		
						Endomorphy	Mesomorphy	Ectomorphy
1	2	0,13	0,02	0,05	0,15	0,01	0,17	0,14
1	3	0,45	0,24	0,30	0,40	0,16	0,16	0,22
1	4	0,00	0,45	0,27	0,20	0,17	0,36	0,26
2	3	0,27	0,23	0,24	0,21	0,18	0,02	0,08
2	4	0,12	0,43	0,19	0,33	0,20	0,50	0,41
3	4	0,45	0,21	0,05	0,67	0,01	0,44	0,48

The d-values used: d-value < 0,20 = low practical significance, d-value ≥ 0,20 = small practical significance, d-value ≥ 0,50 = medium practical significance and d-value ≥ 0,80 high practical significance.

The results in Table 4.3.4a shows an increase (negative result) in the mean value for fat percentage, fat mass, lean body mass and endomorphy from the first exposure to the fourth exposure, with small practical significances (Table 4.3.4b). The decrease in the mean value for mesomorphy from the first exposure to the fourth exposure is also negative, with small practical significance. The increase of the ectomorphy from the first exposure to the fourth exposure is a positive result, a small practical significance.

The result for the anthropometric evaluation shows that the anthropometric profile did not improve (negative result) over the four exposures. The only slight improvement was to somatotype: ectomorphy. It increased from the first exposure (2,50) to the fourth exposure (2,77), a positive result.

Conclusion

The results for protocol 2 show similarities with protocol 1. This includes results where a decrease (positive result) in the mean value was present, as well as an increase in the mean value (negative result). Also, evaluations were done where a decrease was present in the mean value for an evaluation in a protocol and an increase in the mean value for the same evaluation was present in the other protocol.

The results in protocol 2 for the biomechanical evaluation of the musculoskeletal evaluation show similar positive trends (decrease in the mean value) to those found in protocol 1. Similar results are found for ankle dorsiflexion: left and right anatomical side; illiotibial band mobility: right anatomical side; quadriceps mobility: left and right anatomical side; iliopsoas mobility: left and right anatomical side; hip internal mobility: right anatomical side; patella tilt: left and right anatomical side; longitudinal arch status: left and right anatomical side; toes positional: left and right anatomical side; leg-length discrepancy; anterior superior iliac spine; posterior superior iliac spine; pubic tubercle height; pelvis bilateral

position; thoraco lumbar facia mobility: left and right anatomical side; hand behind neck: left and right anatomical side; coronal shoulder positional test; shoulder outline composition; slump test: left and right anatomical side.

The mean value for throwing position (ROM) decreased to the ideal mean value for protocol 2 and stayed consistent for protocol 1 at the ideal mean value, thus a positive similarity between both groups. The same occurred for sagittal axis. The mean value decreased for protocol 2 to the ideal mean value and stayed consistent at the ideal mean value for protocol 1. Sagittal axis: head position, cervical also stayed consistent at the mean value for protocol 2 and one.

The results in protocol 2 for the biomechanical evaluation of the musculoskeletal system show similar negative trends (increase in the mean value) to those found in protocol 1. Similar results were found for transverse arch: left and right anatomical side; rear foot lying: left anatomical side; forefoot position: left and right anatomical side; side flexion mobility: left and right anatomical side; coronal axis: lumbar; and winging positional.

Similarities for the physical and motor evaluation between protocol 1and protocol 2 are the multistage fitness test, sit and reach test and the 5-metre multiple shuttle test. Anthropometric similarities are body mass; somatotype: endomorphy; somatotype: mesomorphy; and somatotype: ectomorphy.

Although similarities are present between protocol 1 and protocol 2 the results in protocol 2 are of such a nature that it is difficult to compare with the other results. Therefore the results in protocol 2 will not be used for further comparisons.

4.4 Protocol 3

4.4.1 Introduction

In this section of the study the players were divided into two groups. Each group consisted of players who remained constant for thee consecutive seasons and who were exposed to a injury prevention and training programme over three seasons. This protocol was carried out to investigate the effect of an injury prevention and training programme on two different groups of players over two different time periods. Group 1 consisted of seven players evaluated from the 1998/1999 season to the 2000/2001 season, nine players were evaluated for the first time in the 1998/1999 season (see p.67). Group 2 consisted of nine players evaluated from the 2001/2002 season to the 2003/2004 season, 12 players were evaluated for the first time in the 2001/2002 season (see p.67). The starting group of nine players could unfortunately not be monitored over the six-season period (1998/1999–2003/2004) due to the nature of professional cricket (players moving provinces, players losing their professional contracts or players retiring from playing professional cricket).

Table 4.4.1 Number of players per group	
Group and seasons	**Number of players per group**
Group 1: 1998/1999 season to 2000/2001 season	7
Group 2: 2001/2002 season to 2003/2004 season	9

The descriptive statistics of each evaluation (biomechanical, physical and motor and anthropometric evaluation) will be discussed for group 1 and group 2, as well as practical significances (d-value ≥0,80). The biomechanical evaluations done will be discussed in the next section. In certain instances new biomechanical

evaluations were introduced in the 2000/2001 season. This was done to improve the tests that were used previously in order to evaluate the player more thoroughly and to identify potential areas of injury that could influence the cricketer negatively, as stated by Belle-Jenje (2003) and Agosta (2001). Therefore in certain cases no information will be available to compare the results of the new tests in the 2000/2001 season to the results of the 1998/1999 season.

4.4.2. Biomechanical evaluation of the musculoskeletal system for group 1 (1998/1999-2000/2001) and group 2 (2001/2002-2003/2004)

The results of the biomechanical variables evaluated (ankle dorsiflexion, Thomas test and gluteus maximus mobility) will be discussed next (Table 4.4.2a descriptive statistics and Table 4.4.2b practical significances). The results compared for each group will be the result at the end of the off-season (middle September) for each season.

Results in Table 4.4.2a show a decrease (positive result) in the mean value for ankle dorsiflexion (left and right anatomical sides) for group 1 from the end of the 1998/1999 off-season to the end of the 200/2001 off-season. An increase (negative result) is shown for illiotibial band mobility: left and right anatomical side, quadriceps mobility: left and right anatomical side; and iliopsoas mobility: left and right anatomical side for group 1 from the end of the 1998/1999 off-season to the end of the 200/2001 off-season. Gluteus maximus mobility was only evaluated for the first time in the third evaluation (2000/2001 off-season) for the first group of cricketers and therefore no results were available from the end of the 1998/1999 off-season for purposes of comparison, with practical significances being small to medium (Table 4.4.2b).

The results for the last three seasons 2001/2002 off-season to the 2003/2004 off-season (group 2) show a decrease (positive result) in the mean value for ankle dorsiflexion: left and right anatomical side; illiotibial band mobility: left and right

anatomical side; quadriceps mobility: left and right anatomical sides; iliopsoas mobility: left and right anatomical side; and gluteus maximus mobility: left and right anatomical side.

Table 4.4.2a Descriptive statistics of biomechanical variables evaluated (ankle dorsiflexion, Thomas test and gluteus maximus mobility) for the three-season periods (1998/1999–2003/2004)

Variables	Anatomical Side	Group 1: n = 7						Group 2: n = 9					
		1998–1999		1999–2000		2000–2001		2001–2002		2002–2003		2003–2004	
		$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Ankle dorsiflexion	Left	2,00	0,58	2,00	1,00	1,71	0,95	1,78	0,44	1,78	0,67	1,22	0,44
	Right	2,00	0,58	2,00	1,00	1,71	0,95	1,67	0,50	1,89	0,78	1,22	0,44
Thomas test	**Illiotibial band Mobility**												
	Left	1,71	0,49	1,57	0,54	1,86	0,69	2,44	0,53	1,78	0,67	1,44	0,53
	Right	1,86	0,38	1,57	0,54	2,29	0,76	2,44	0,53	1,67	0,50	1,22	0,44
	Quadriceps Mobility												
	Left	1,57	0,54	1,57	0,54	1,88	0,69	2,00	0,50	1,44	0,53	1,56	0,53
	Right	1,57	0,54	1,57	0,54	2,00	0,58	2,00	0,50	1,44	0,53	1,44	0,53
	Iliopsoas Mobility												
	Left	1,71	0,49	1,29	0,49	2,29	0,76	2,11	0,60	1,57	0,73	1,67	0,50
	Right	1,71	0,49	1,29	0,49	2,00	0,82	2,00	0,50	1,44	0,53	1,78	0,44
Gluteus maximus mobility	Left					1,14	0,38	2,33	0,71	1,57	0,73	1,33	0,50
	Right					1,14	0,38	2,22	0,67	1,33	0,50	1,33	0,50

Table 4.4.2b shows the practical significances for group 2 for ankle dorsiflexion: left (d-value = 1,27) and right (d-value = 0.90) anatomical side: illiotibial band mobility: left (d-value = 1,89) and right (d-value = 2,30) anatomical side; quadriceps mobility: left (d-value = 0,83) and right (d-value = 1,06) anatomical side and gluteus maximus mobility: left (d-value = 1,41) and right (d-value = 1,33) anatomical side to be of high practical significance. The results for the iliopsoas mobility indicate a medium practical significance (d-value = 0,73) for the left

anatomical side and a small practical significance (d-value = 0,44) for the right anatomical side.

Table 4.4.2b Practically significant differences (d-values) of the biomechanical variables (ankle dorsiflexion, Thomas test and gluteus maximus mobility) evaluated for the three-season periods (1998/1999–2003/2004)			
Variables	**Anatomical Side**	**Group 1: n = 7** **d-value: 1998/1999–2000/2001**	**Group 2: n = 9** **d-value: 2001/2002-2003/2004**
Ankle dorsiflexion	Left	0,31	**1,27**
	Right	0,31	**0,90**
Thomas test	**Illiotibial band Mobility**		
	Left	0,22	**1,89**
	Right	0,57	**2,30**
	Quadriceps Mobility		
	Left	0,45	**0,83**
	Right	0,74	**1,06**
	Iliopsoas Mobility		
	Left	0,76	0,73
	Right	0,35	0,44
Gluteus maximus mobility	Left		**1,41**
	Right		**1,33**

The d-values used: d-value < 0,20 = low practical significance, d- value ≥ 0,20 = small practical significance, d-value ≥ 0,50 = medium practical significance and d-value ≥ 0,80 high practical significance.

Next follows a discussion of the results of the biomechanical evaluation (Table 4.4.2c.) for the adductor mobility, hip internal rotation mobility as well as hip external rotation mobility. These tests were only introduced at the end of the 2000/2001 off-season, and therefore no results are available for the first group to compare with results from the end of the 1998/1999 off-season. This was done to improve the tests that were used previously in order to evaluate the player more thorough and to identify potential areas of injury that could influence the cricketer negatively as stated by Belle-Jenje (2003) and Agosta (2001).

Table 4.4.2c Descriptive statistics of biomechanical variables evaluated (hip joint) for the three-season periods (1998/1999–2003/2004)

Variables	Anatomical Side	Group 1: N = 7		Group 2: n = 9					
		2000–2001		2001–2002		2002–2003		2003–2004	
		$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Adductor Mobility		1,71	0,49	1,78	0,44	1,22	0,44	1,00	0,00
Hip internal rotation mobility	Left	1,86	0,38	1,78	0,67	1,67	0,50	1,00	0,00
	Right	1,86	0,38	1,57	0,73	1,56	0,53	1,00	0,00
Hip external rotation mobility	Left	2,14	0,38	1,89	0,60	1,67	0,71	1,33	0,50
	Right	2,14	0,38	1,89	0,60	1,78	0,67	1,44	0,53

Results in Table 4.4.2c and Table 4.4.2d show an improvement in the mean value for group 2 from the end of the 2001/2002 off-season to the end of the 2003/2004 off-season in adductor mobility, hip internal rotation mobility: left and right anatomical side as well as hip external rotation mobility: left and right anatomical side, with high practical significances: d-value = 1,77 for adductor mobility; d-value = 1,16 for hip internal rotation mobility: left anatomical side; d-value = 0,93 for hip external mobility: left anatomical side (Table 4.4.2d). Table 4.4.2d also indicates the practical significance (d-value) for hip internal rotation mobility: right anatomical side of 0,78 (medium practical significance) for group 2

and the a practical significance (d-value) for hip external rotation mobility of 0,75 for group 2, a medium practical significance.

Table 4.4.2d Practically significant differences (d-values) of the biomechanical variables (hip joint) evaluated for the three-season periods (1998/1999–2003/2004)			
		Group 1: n = 7	**Group 2: n = 9**
Variables	**Anatomical Side**	**d-value: 1998/1999–2000/2001**	**d-value: 2001/2002-2003/2004**
Adductor mobility			**1,77**
Hip internal rotation mobility	**Left**		**1,16**
	Right		**0,78**
Hip external rotation mobility	**Left**		**0,93**
	Right		**0,75**

The next section discusses the results of the biomechanical evaluations (Table 4.4.2e) found in the case of the knee (Q-angle, patella squint, patella tilt, and the vastus medialis oblique-lateralis comparison (VMO-L). The patella squint, patella tilt and patella height were only evaluated from the end of the 2000/2001 off-season.

Results in Table 4.4.2e indicate an increase (negative result) in the mean value for group 1 (end of the 1998/1999 off-season to end of the 2000/2001 off-season) for q-angle: left and right anatomical side and a decrease in the mean value (positive result) for vastus medialis oblique-lateralis comparison: left and right anatomical side, low practical significances (Table 4.4.2f).

Table 4.4.2e Descriptive statistics of biomechanical variables evaluated (the knee region) for the three-season periods (1998/1999–2003/2004)													
Variables	**Anatomical side**	**Group 1: n = 7**						**Group 2: n = 9**					
		1998–1999		**1999–2000**		**2000–2001**		**2001–2002**		**2002–2003**		**2003–2004**	
		$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**
Q-angle	Left	1,14	0,38	1,14	0,38	1,29	0,49	1,22	0,44	1,11	0,33	1,11	0,33
	Right	1,14	0,38	1,14	0,38	1,29	0,49	1,22	0,44	1,11	0,33	1,11	0,33
Patella squint	Left					1,00	0,00	1,22	0,44	1,11	0,33	1,11	0,33
	Right					1,00	0,00	1,22	0,44	1,11	0,33	1,11	0,33
Patella tilt	Left					1,14	0,38	1,33	0,50	1,22	0,44	1,67	0,50
	Right					1,14	0,38	1,33	0,50	1,22	0,44	1,67	0,50
Vastus medialis oblique-lateralis comparison	Left	1,14	0,38	1,00	0,00	1,00	0,00	1,11	0,33	1,00	0,00	1,00	0,00
	Right	1,14	0,38	1,00	0,00	1,00	0,00	1,11	0,33	1,00	0,00	1,00	0,00

Table 4.4.2f Practically significant differences (d-values) of the biomechanical variables (the knee region) evaluated for the three-season periods (1998/1999–2003/2004)			
Variables	**Anatomical Side**	**Group 1: n = 7** **d-value: 1998/1999–2000/2001**	**Group 2: n = 9** **d-value: 2001/2002-2003/2004**
Q-angle	Left	0,31	0,25
	Right	0,31	0,25
Patella squint	Left		0,25
	Right		0,25
Patella tilt	Left		0,68
	Right		0,68
Vastus medialis oblique-lateralis comparison	Left	0,36	0,33
	Right	0,36	0,33

Table 4.4.2e further indicates a decrease in the mean value (positive result) for group 2 (end of the 2001/2002 off-season to the end of the 2003/2004 off-season) in q-angle: left and right anatomical side; patella squint: left and right anatomical side; and vastus medialis oblique-lateralis comparison: left and right anatomical side, low practical significances (Table 4.4.2f). The only negative result in this section for group 2 were the results for patella tilt: left and right anatomical side, an increase in the mean value from the end of the 2001/2002 off-season to the end of the 2003/2004 off-season, a medium practical significance (d-value = 0,68 left and right anatomical side, Table 4.4.2f).

The next section discusses the results of the biomechanical evaluations (Table 4.4.2d) found for the foot (longitudinal arch status, forefoot positional, rear foot standing, rear foot lying, transverse arch area comparison, foot mobility and toes positional). The forefoot position, rear foot lying, transverse arch area

comparison, foot mobility and toes positional were only evaluated from the end of the 2000/2001 off-season, to identify more potential risks areas that could impact on the cricketers' ability to play injury-free cricket. No results are therefore available for comparison of the 2000/2001 off-season to the 1998/1999 off-season for group 1.

The results in Table 4.4.2g show the mean value for the longitudinal arch status: left and right anatomical side stayed constant from the end of the 1998/1999 off-season to the end of the 2000/2001 off-season for group 1. Table 4.4.2g also indicates an increase (positive) in the mean value for the rear foot standing position: left and right anatomical side for the first group (ideal norm for this evaluation is 2), small practical significance (Table 4.4.2h).

As for group 2 (end of the 2001/2002 off-season to the end of the 2003/2004 off-season) the results in Table 4.4.2g show an improvement (positive result) for longitudinal arch status: left and right anatomical side (d-value = 0,64, medium practical significance in Table 4.4.2h); fore foot positional: left and right anatomical side; foot mobility: left anatomical side, small practical significances (table 4.4.2h).

Foot mobility: right anatomical side; toes positional: left and right anatomical side stayed constant through the period for group 2 (Table 4.4.2g). Areas where no improvement (negative results) occurred was rear foot standing: left and right anatomical side; rear foot lying: left and right anatomical side; and transverse arch comparison: left and right anatomical side (Table 4.4.2g), low to small practical significances (Table 4.4.2h).

Table 4.4.2g Descriptive statistics of biomechanical variables evaluated (the foot) for the three-season periods (1998/1999–2003/2004)													
Variables	**Anatomical side**	**Group 1: n = 7**						**Group 2: n = 9**					
		1998–1999		**1999–2000**		**2000–2001**		**2001–2002**		**2002–2003**		**2003–2004**	
		$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**
Longitudinal arch status	Left	1,14	0,38	1,57	0,54	1,14	0,38	1,22	0,44	1,44	0,53	1,56	0,53
	Right	1,14	0,38	1,57	0,54	1,14	0,38	1,22	0,44	1,44	0,53	1,56	0,53
Forefoot positional	Left					1,57	0,54	1,78	0,44	1,33	0,50	1,67	0,50
	Right					1,43	0,54	1,78	0,44	1,33	0,50	1,50	0,52
Rear foot standing	Left	1,86	0,38	1,71	0,49	2,00	0,00	2,00	0,50	1,11	0,46	1,67	0,87
	Right	1,86	0,38	1,86	0,38	2,00	0,00	1,89	0,60	1,33	0,50	1,67	0,87
Rear foot lying	Left					2,00	0,00	1,89	0,33	1,22	0,44	1,33	0,50
	Right					2,00	0,00	1,78	0,44	1,22	0,44	1,33	0,48
Transverse arch area comparison	Left					1,14	0,38	1,11	0,33	1,11	0,33	1,22	0,44
	Right					1,14	0,38	1,11	0,33	1,11	0,33	1,33	0,50
Foot mobility	Left					1,86	0,69	1,22	0,44	1,22	0,67	1,33	0,60
	Right					1,86	0,69	1,33	0,50	1,22	0,67	1,33	0,50
Toes positional	Left					2,00	0,00	1,89	0,33	1,89	0,33	1,89	0,33
	Right					2,00	0,00	1,89	0,33	1,89	0,33	1,89	0,33

Table 4.4.2h Practically significant differences (d-values) of the biomechanical variables (the foot) evaluated for the three-season periods (1998/1999–2003/2004)			
Variables	**Anatomical Side**	**Group 1: n = 7** **d-value: 1998/1999–2000/2001**	**Group 2: n = 9** **d-value: 2001/2002–2003/2004**
Longitudinal arch status	Left	0,00	0,64
	Right	0,00	0,64
Forefoot positional	Left		0,22
	Right		0,53
Rear foot standing	Left	0,37	0,38
	Right	0,37	0,25
Rear foot lying	Left		1,12
	Right		0,93
Transverse arch area comparison	Left		0,25
	Right		0,44
Foot mobility	Left		0,18
	Right		0,00
Toes positional	Left		0,00
	Right		0,00

Next follows a discussion of the results for the biomechanical evaluations (Table 4.4.2i) found for the pelvic girdle region (leg-length discrepancy, position of anterior superior iliac crest (ASIS), position of the posterior superior iliac crest (PSIS), position of pubic tubercle height, the sacroiliac cleft and the bilateral pelvic position). The sacroiliac cleft was only evaluated from the end of the

2000/2001 off-season. This was done to identify more potential areas of injury to the cricketer and to possibly prevent certain injuries from occurring in this area.

A consistent decrease in the mean value (positive result) was found for group 1 (end of the 1998/1999 off-season to the end of the 2000/2001 off-season) in Table 4.4.2i regarding leg length discrepancy, ASIS, PSIS and pubic tubercle height over the three seasons. Pelvic bilateral position stayed constant for group 1 throughout the three seasons. Table 4.4.2j indicates the practical significance (d-value) as high practical significances for leg length discrepancy (d-value = 1,16), ASIS (d-value = 1,16), PSIS (d-value = 1,16) and pubic tubercle height (d-value = 1,16) over the three seasons.

Table 4.4.2i Descriptive statistics of biomechanical variables evaluated (pelvic girdle region) for the three-season periods (1998/1999–2003/2004)

Variables	Group 1: n = 7						Group 2: n = 9					
	1998–1999		1999–2000		2000–2001		2001–2002		2002–2003		2003–2004	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Pelvic girdle region												
Leg-length discrepancy	1,86	0,38	1,71	0,76	1,29	0,49	1,56	0,73	1,78	0,44	1,22	0,44
ASIS	1,86	0,38	1,57	0,54	1,29	0,49	1,44	0,58	1,78	0,44	1,22	0,44
PSIS	1,86	0,38	1,57	0,54	1,29	0,49	1,44	0,58	1,78	0,44	1,22	0,44
Pubic tubercle height	1,86	0,38	1,57	0,54	1,29	0,49	1,44	0,58	1,78	0,44	1,22	0,44
Sacroiliac cleft					1,29	0,49	1,22	0,44	1,22	0,44	1,00	0,00
Bilateral pelvic position	1,71	0,49	1,71	0,49	1,71	0,76	2,44	0,73	1,89	0,60	1,67	0,71

Table 4.4.2j Practically significant differences (d-values) of the biomechanical variables (pelvic girdle region) evaluated for the three-season periods (1998/1999–2003/2004)			
Variables	Anatomical Side	Group 1: n = 7 d-value: 1998/1999–2000/2001	Group 2: n = 9 d-value: 2001/2002-2003/2004
Pelvic girdle region			
Leg-length discrepancy		1,16	0,46
ASIS		1,16	0,37
PSIS		1,16	0,37
Pubic tubercle height		1,16	0,37
Sacroiliac cleft			0,50
Bilateral pelvic position		0,00	1,05

As for group 2 (end of the 2001/2002 off-season to the end of the 2003/2004 off-season) a decrease (positive result) in the mean value for leg length discrepancy, ASIS, PSIS, pubic tubercle height, sacroiliac cleft and bilateral pelvic position were found in Table 4.4.2i over the last three seasons. Small practical significances for length discrepancy, ASIS, PSIS, pubic tubercle height, medium practical significance for sacroiliac cleft and a high practical significance for bilateral pelvis position (d-value = 1,05, Table 4.4.2j).

A discussion follows now of the results of the biomechanical evaluations (Table 4.4.2k) and practical significances (Table 4.4.2l) found for the spinal region: spinal dynamic mobility (thoraco-lumbar facia mobility (TFL), sacral rhythm, functional extension mobility, functional flexion mobility, rotational mobility and side flexion mobility). All the aforementioned evaluations were evaluated from the end of the 2000/2001 off-season. This was done to identify more potential areas of possible injury to the cricketer and to possibly prevent certain injuries from occurring in this area.

Table 4.4.2k shows a decrease in the mean value (positive result) for thoraco-lumbar facia mobility: left and right anatomical side, sacral rhythm and functional extension mobility for group 2 (end of the 2001/2002 off-season to the end of the 2003/2004 off-season), medium practical significances (Table 4.4.2l). The functional flexion mobility stayed constant, as well as the rotational mobility: left anatomical side; and side flexion mobility: left and right anatomical side. Rotational mobility for the right anatomical side increased (negative result) from the end of the 2001/2002 off-season to the end of the 2003/2004 off-season, with a small practical significance.

Table 4.4.2k Descriptive statistics of biomechanical variables evaluated (spinal region: spinal dynamic mobility) for the three-season periods (1998/1999–2003/2004)

Variables	Anatomical side	Group 1: n = 7		Group 2: n = 9					
		2000–2001		2001–2002		2002–2003		2003–2004	
		$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Thoraco-lumbar facia mobility	Left	1,71	0,49	1,78	0,67	1,67	0,71	1,44	0,53
	Right	1,71	0,49	1,78	0,67	1,56	0,73	1,44	0,53
Sacral rhythm		1.43	0,54	1,33	0,50	1,11	0,33	1,00	0,00
Functional extension mobility		1.14	0,38	1,44	0,73	1,89	0,78	1,00	0,00
Functional flexion mobility		1.14	0,38	1,67	0,71	1,78	0,97	1,67	0,87
Rotational mobility	Left	1,00	0,00	1,11	0,33	1,11	0,33	1,11	0,33
	Right	1,00	0,00	1,00	0,00	1,11	0,33	1,11	0,33
Side flexion mobility	Left	1,00	0,00	1,11	0,33	1,33	0,50	1,11	0,33
	Right	1,00	0,00	1,11	0,33	1,33	0,50	1,11	0,33

Table 4.4.2j Practically significant differences (d-values) of the biomechanical variables (the spinal region: spinal dynamic mobility) evaluated for the three-season periods (1998/1999–2003/2004)			
		Group 1: n = 7	Group 2: n = 9
Variables	**Anatomical Side**	**d-value: 1998/1999–2000/2001**	**d-value: 2001/2002-2003/2004**
Thoraco-lumbar facia mobility	Left		0,51
	Right		0,51
Sacral rhythm			0,66
Functional extension mobility			0,60
Functional flexion mobility			0,00
Rotational mobility	Left		0,00
	Right		0,33
Side flexion mobility	Left		0,00
	Right		0,00

Next to be discussed are the results of the biomechanical evaluations (Table 4.4.2m) for the spinal positional alignment: coronal axis evaluation (including the head position, cervical, thoracic and lumbar), as well as the sagittal axis evaluation (including the head position, cervical, thoracic and lumbar). The sagittal axis evaluation was introduced at the end of the 2000/2001 off-season. This was done to identify more potential areas of possible injury to the cricketer and possibly to prevent certain injuries from occurring in regard to the sagittal axis.

The results in Table 4.4.2m indicate the mean value for the coronal axis: head position to have stayed constant for group 1 from the end of the 1998/1999 off-season to the end of the 2000/2001 off-season, as well as the mean value for lumbar. Table 4.4.2m further indicates the mean value for coronal axis: cervical

and thoracic decreased (positive result) from the 1998/1999 season to the 2000/2001 season, a small practical significance (d-value = 0,37) and medium practical significance (d-value = 0,59) respectively (Table 4.4.2n).

Table 4.4.2m Descriptive statistics of biomechanical variables evaluated (spinal positional alignment: coronal and sagittal axis) for the three-season periods (1998/1999–2003/2004)

Variables	Group 1: n = 7						Group 2: n = 9					
	1998–1999		1999–2000		2000–2001		2001–2002		2002–2003		2003–2004	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Coronal Axis												
Head position	1,43	0,54	1,29	0,49	1,43	0,54	1,33	0,50	1,00	0,00	1,00	0,00
Cervical	1,14	0,38	1,29	0,49	1,00	0,00	1,22	0,44	1,11	0,33	1,00	0,00
Thoracic	1,29	0,49	1,43	0,54	1,00	0,00	1,22	0,44	1,67	0,50	1,00	0,00
Lumbar	1,57	0,54	1,29	0,52	1,57	0,54	1,78	0,44	1,11	0,33	1,89	0,33
Sagittal Axis												
Head position					1,00	0,00	1,00	0,00	1,00	0,00	1,00	0,00
Cervical					1,00	0,00	1,00	0,00	1,11	0,33	1,00	0,00
Thoracic					1,57	0,54	1,89	0,33	1,44	0,53	1,78	0,44
Lumbar					1,00	0,00	1,11	0,33	1,11	0,33	1,00	0.00

The results in Table 4.4.2m show the mean value for group 2 (end of the 2001/2002 off-season to the end of the 2003/2004 off-season) for coronal axis: head position (medium practical significance, d-value = 0,66), cervical and thoracic (medium practical significance) (Table 4.4.2n) decreased (positive result), but the mean value for coronal axis: lumbar increased (negative result), with low practical significance (Table 4.4.2n)

Table 4.4.2n Practically significant differences (d-values) of the biomechanical variables (spinal positional alignment: coronal and sagittal axis) evaluated for the three-season periods (1998/1999–2003/2004)		
	Group 1: n = 7	Group 2: n = 9
Variables	d-value: 1998/1999–2000/2001	d-value: 2001/2002-2003/2004
Coronal axis		
Head position	0,00	0,66
Cervical	0,37	0,50
Thoracic	0,59	0,50
Lumbar	0,00	0,25
Sagittal axis		
Head position		0,00
Cervical		0,00
Thoracic		0,25
Lumbar		0,33

Results regarding the sagittal axis in Table 4.4.2m show head position and cervical stayed constant from the end of the 2001/2002 off-season to the end of the 2003/2004 off-season for group 2. A decrease in the mean value (positive result) for sagittal axis: thoracic and lumbar is shown in Table 4.4.2m, with small practical significances (Table 4.4.2n).

Next follows a discussion of the result of the biomechanical evaluations (Table 4.4.2p) found for the upper limb region (hand behind back range of motion (ROM), hand behind neck ROM, shoulder coronal positional test, winging positional test, shoulder outline composition and throwing position (ROM)). Hand behind back ROM, hand behind neck ROM, winging positional test, shoulder outline composition and throwing position (ROM) were evaluated from the end of

the 2000/2001 off-season. This was done to identify more potential areas of possible injury to the cricketer and to possibly prevent certain injuries from occurring in this area.

Shoulder coronal positional test in Table 4.4.2o shows a decrease (positive result) in the mean value for group 1 from the end of the 1998/1999 off-season to the end of the 2000/2001 off-season, a high practical significance (d-value = 1,44, Table 4.4.2p). The shoulder coronal positional test also shows a decrease (positive result) in the mean value for group 2 (end of the 2001/2002 off-season to the end of the 2003/2004 off-season), also a high practical significance (d-value = 1,12, Table 4.4.2p).

Result for the evaluations of the upper limb region: shoulder show a decrease (positive result) in the mean value for hand behind back (ROM): left anatomical side (medium practical significance, Table 4.4.2p); hand behind neck ROM: left and right anatomical side (medium and small practical significance, Table 4.4.2p); winging positional test; and throwing position ROM (small practical significance, Table 4.4.2p) for group 2 (end of the 2001/2002 off-season to the end of the 2003/2004 off-season). Shoulder outline composition and hand behind back ROM: right anatomical side stayed constant for group 2 over the three seasons (end of the 2001/2002 off-season to the end of the 2003/2004 off-season).

Table 4.4.2o Descriptive statistics of biomechanical variables evaluated (upper limb region) for the three-season periods (1998/1999–2003/2004)													
Variables	Anatomical Side	Group 1: n = 7						Group 2: n = 9					
		1998–1999		1999–2000		2000–2001		2001–2002		2002–2003		2003–2004	
		$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Hand behind back ROM	Left					1,86	0,38	1,78	0,44	1,67	0,82	1,44	0,53
	Right					1,86	0,38	1,78	0,44	2,33	0,87	1,78	0,67
Hand behind neck ROM	Left					1,57	0,54	1,33	0,50	1,00	0,00	1,00	0,00
	Right					1,57	0,54	1,33	0,50	1,00	0,00	1,22	0,67
Shoulder coronal positional test		2.00	0,00	1,57	0,54	1,29	0,49	1,67	0,50	1,00	0,00	1,11	0,33
Winging positional test						1,14	0,38	1,33	0,50	1,33	0,50	1,11	0,33
Shoulder outline composition						1,14	0,38	1,00	0,00	1,11	0,33	1,00	0,00
Throwing position (ROM)						1,00	0,00	1,11	0,33	1,22	0,44	1,00	0,00

Table 4.4.2p Practically significant differences (d-values) of the biomechanical variables (upper limb region) evaluated for the three-season periods (1998/1999–2003/2004)			
Variables	**Anatomical Side**	**Group 1: n = 7** **d-value: 1998/1999–2000/2001**	**Group 2: n = 9** **d-value: 2001/2002-2003/2004**
Hand behind back ROM	Left		0,64
	Right		0,00
Hand behind neck ROM	Left		0,66
	Right		0,30
Shoulder coronal positional test		1,44	1,12
Winging positional test			0,44
Shoulder outline composition			0,00
Throwing position (ROM)			0,34

The mean value found for the biomechanical evaluations (Table 4.4.2q) for the neurodynamics evaluations (straight leg raise, upper limb tension test, prone knee bend (PKB) and slump test) will be discussed next. The upper limb tension test and the slump test were evaluated from the end of the 2000/2001 off-season. This was done to identify more potential areas of injury to the cricketer and to possibly prevent certain injuries from occurring in this area.

Results regarding the mean value for straight leg raise and L3,4 prone knee bend in Table 4.4.2q show a decrease (positive result) in the mean value from the end of the 1998/1999 off-season to the end of the 2000/2001 off-season for group 1, with small to medium practical significances (Table 4.4.2r).

Table 4.4.2q Descriptive statistics of biomechanical variables evaluated (neurodynamics) for the three-season periods (1998/1999–2003/2004)													
Variables	Anatomical Side	Group 1: n = 7						Group 2: n = 9					
		1998–1999		1999–2000		2000–2001		2001–2002		2002–2003		2003–2004	
		$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Straight leg raise	Left	2,00	0,58	1,43	0,54	1,71	0,76	2,22	0,44	2,00	0,00	1,33	0,50
	Right	2,00	0,58	1,71	0,49	1,71	0,76	2,33	0,50	2,00	0,00	1,33	0,50
Upper limb tension test	Left					1,14	0,38	1,00	0,00	1,00	0,00	1,00	0,00
	Right					1,14	0,38	1,00	0,00	1,00	0,00	1,00	0,00
Prone knee bend (PKB)	Left	2,00	0,00	1,57	0,54	1,57	0,79	1,22	0,44	1,67	0,71	1,33	0,50
	Right	1,86	0,38	1,57	0,54	1,57	0,79	1,22	0,44	1,89	0,60	1,33	0,50
Slump test	Left					1,14	0,38	1,00	0,00	1,56	0,73	1,00	0,00
	Right					1,14	0,38	1,00	0,00	1,56	0,73	1,00	0,00

Table 4.4.2r Practically significant differences (d-values) of the biomechanical variables (neurodynamics) evaluated for the three-season periods (1998/1999–2003/2004)			
Variables	**Anatomical Side**	**Group 1: n = 7** **d-value: 1998/1999–2000/2001**	**Group 2: n = 9** **d-value: 2001/2002-2003/2004**
Straight leg raise	Left	0,38	1,78
	Right	0,38	2,00
Upper limb tension test	Left	0,36	0,00
	Right	0,36	0,00
Prone knee bend (PKB)	Left	0,54	0,22
	Right	0,37	0,22
Slump test	Left	0,37	0,00
	Right	0,37	0,00

Results for group 2 in Table 4.4.2q show the mean value for straight leg raise to have decreased (positive result) from the end of the 2001/2002 off-season to the end of the 2003/2004 off-season, with a high practical significance (d-value = 1,78 for the left anatomical side and 2,00 for the right anatomical side, Table 4.4.2r), an increase in the mean value (negative result) for L3,4 prone knee bend (small practical significances, Table 4.4.2r) and with the mean value for upper limb tension test (left and right anatomical sides) and slump test (left and right anatomical side) staying constant from the end of the 2001/2002 off-season to the end of the 2003/2004 off-season.

The decrease (positive result) in the mean value for group 1 (end of the 1998/1999 off-season to the end of the 2000/2001 off-season) includes the following: ankle dorsiflexion: left and right anatomical side; vastus medialis qblique-lateralis comparison: left and right anatomical side; rear foot standing: left

and right anatomical side; leg length discrepancy; anterior superior iliac spine; posterior superior iliac spine; pubic tubercle height; coronal axis: cervical; coronal axis: thoracic; shoulder coronal positional test; straight leg raise: left and right anatomical side and L3,4 prone knee bend: left and right anatomical side.

An increase (negative result) in the mean value for group 1 (end of the 1998/1999 off-season to the end of the 2000/2001 off-season) includes the following: illiotibial band mobility: left and right anatomical side; quadriceps mobility: left and right anatomical side; iliopsoas mobility: left and right anatomical side; and q-angle: left and right anatomical side.

Areas for group 1 where the mean value stayed constant for the three seasons are as follows: longitudinal arch status: left and right anatomical side; bilateral pelvic position; coronal axis: head position; and coronal axis: lumbar.

Results indicate that 30 evaluations had data available from the first evaluation at the end of the 1998/1999 off-season to the end of the 2000/2001 off-season. 17 (56,67%) of these evaluations showed an improvement in the mean value from the first evaluation at the end of the 1998/1999 off-season to the end of the 2000/2001 off-season, eight evaluations (26,67%) showed a decrease in the mean value and five evaluations (16,66) stayed constant throughout. Of the five evaluations that stayed constant, two (40%) were close to the mean value and three (60%) were not close to the mean value. This indicates that the training and prevention programme contributed to improving the biomechanical profile of these players for the 30 identified areas, with an improvement in the biomechanical profile in 19 (63,33%) of the 30 evaluations done and a worse biomechanical profile in 11 (36.67%) of the 30 evaluations done.

The results of the biomechanical evaluation for group 2 (end of the 2001/2002 off-season to the end of the 2003/2004 off-season) indicate improvements in the following:

- ankle dorsiflexion: left and right anatomical side;
- illiotibial band mobility: left and right anatomical side;
- quadriceps mobility: left and right anatomical side;
- iliopsoas mobility: left and right anatomical side;
- gluteus maximus mobility: left and right anatomical side;
- adductor mobility;
- hip internal rotation mobility: left and right anatomical side;
- hip external rotation mobility: left and right anatomical side;
- q-angle: left and right anatomical side;
- patella squint: left and right anatomical side;
- vastus medialis oblique-lateralis comparison: left and right anatomical side;
- longitudinal arch status: left and right anatomical side;
- forefoot positional: left and right anatomical side;
- foot mobility: left anatomical side;
- leg length discrepancy;
- anterior superior iliac spine;
- posterior superior iliac spine;
- pubic tubercle height;
- sacroiliac cleft;
- bilateral pelvic position;
- thoraco-lumbar facia mobility: left and right anatomical side;
- sacral rhythm;
- functional extension mobility;
- coronal axis: head position;
- coronal axis: cervical;
- coronal axis: thoracic;
- sagittal axis: thoracic;
- sagittal axis: lumbar;
- hand behind back ROM: left anatomical side;
- hand behind neck ROM: left and right anatomical side;

- shoulder coronal positional test;
- winging positional test; and
- throwing position (ROM); and straight leg raise: left and right anatomical side.

Areas where a decrease in the mean value occurred for group 2 are as follows:

- patella tilt: left and right anatomical side;
- rear foot standing: left and right anatomical side;
- rear foot lying: left and right anatomical side;
- transverse arch area comparison: left and right anatomical side;
- rotational mobility: right anatomical side;
- coronal axis: lumbar; and
- L3,4 prone knee bend: left and right anatomical side.

Areas that stayed constant for the three seasons for group 2 are:

- foot mobility: right anatomical side;
- toes positional: left and right anatomical side;
- functional flexion mobility;
- rotational mobility: left anatomical side;
- side flexion mobility: left and right anatomical side;
- sagittal axis: head position;
- sagittal axis: cervical, hand behind back ROM: right anatomical side;
- shoulder outline composition;
- upper limb tension test: left and right anatomical side; and
- slump test: left and right anatomical side.

Results of the 76 evaluations done from at the end of the 2001/2002 off-season to the end of the 2003/2004 off-season for group 2 indicate an improvement in 49 (64,47%) of the evaluations done, 12 (15,79%) where no improvement occurred and 15 (19,74%) evaluations that stayed constant. Of the 15 evaluations that stayed constant 12 (80%) stayed close to the ideal mean value and three (20%)

did not stay close to the ideal mean value. Of the 12 no improvements, six (50%) involved the feet. Overall the results for group 2 indicate an improvement in 61 (80,26%) of the 76 biomechanical evaluations done, and 15 (19,74%) no improvements. This indicates that the training and prevention programme contributed to the improvement of the biomechanical profile of the players for the last three seasons.

Conclusion

The results regarding the biomechanical evaluation for group 1 (seven players, end of the 1998/1999 off-season to the end of the 200/2001 off-season) indicate improvement in the results for the biomechanical evaluation in certain aspects, as well as no improvement in other aspects. The introduction of new biomechanical evaluations in the 2000/2001 season made it difficult to compare results in these areas to the 1998/1999 season as no results were available in this season. However, these new evaluations in the 2000/2001 season played an important role as it identified shortcomings in the injury prevention and training programme the players were exposed to in this period and allowed for adjustments to be made. The biomechanical evaluation of group 2 (nine players, end of the 2001/2002 off-season to the end of the 2003/2004 off-season) indicates improvement in most of the areas.

High practical significances (d-value ≥0,80) for group 1 were: adductor mobility; hip internal rotational mobility: left and right anatomical side; hip external mobility: left and right anatomical side; leg length discrepancy; anterior superior iliac spine; posterior superior iliac spine; pubic tubercle height; and shoulder coronal positional test. Negative practical significance was found in the case of the patella tilt: left and right anatomical side.

High practical significances (d-value ≥0,80) for group 2 were: ankle dorsiflexion: left and right anatomical side; illiotibial band mobility: left and right anatomical

side; quadriceps mobility: left and right anatomical side; gluteus maximus mobility: left and right anatomical side; adductor mobility: hip internal rotation mobility: left anatomical side; hip external rotation mobility: left anatomical side; pelvis bilateral position; shoulder coronal positional test; and straight leg raise: left and right anatomical side.

The injury prevention and training programme group 2 was exposed to in the off-season period contributed more positively to improving the biomechanical profile of these cricketers than the injury prevention programme in the case of the first group.

4.4.3 Physical and motor evaluations

In the next part of chapter 4 the results of the physical and motor evaluations are discussed. The descriptive statistics of each evaluation will be discussed. The tests included: (1) multistage fitness test: shuttle run test; (2) sit-and-reach test; (3) abdominal strength tests; (4) one minute oblique sit-up test: left and right side; (5) one minute push-up test; (5) run a three test; (6) 505 agility test; and (7) 5-metre multiple shuttle test.

Other forms of the push-up test (2 second push-up test) and sit-up tests (2 second sit-up test) had been used previously before the introduction of the fitness standard requirements of the UCBSA (introduced at the beginning of the 2002/2003 season). The abdominal strength test, oblique sit-up test: left and right side, push-up test, run a three test and 505 agility test were introduced in the 2002/2003 season as part of the fitness requirements of the UCB. The 5-metre shuttle run test was introduced in the 2000/2001 season.

Table 4.4.3a Descriptive statistics of the physical and motor evaluations done over the three-season periods (1998/1999–2003/2004)												
Variables	**Group 1: n = 7**						**Group 2: n = 9**					
	1998–1999		**1999–2000**		**2000–2001**		**2001–2002**		**2002–2003**		**2003–2004**	
	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**
Multistage fitness test												
Shuttle run test	85,43	22,42	93,71	20,11	94,71	14,76	97,89	6,47	105,89	1,54	105,00	0,00
Sit-and-reach test (cm)	42,88	5,04	44,24	5,40	39,28	4,11	36,11	7,57	37,22	6,04	37,44	5,98
Abdominal strength test									3,67	1,12	4,11	1,17
One minute oblique sit-up test												
Left side									59,89	9,13	65,56	3,50
Right side									55,89	9,13	63,78	3,35
One minute push-up test									42,11	7,06	41,78	7,05
Run a three test (sec.)									10,16	0,25	10,24	0,41
505 agility test (sec.)									2,30	0,12	2,31	0,18
5-metre multiple shuttle test (m)					702,22	35,03	717.22	23.33	737,78	9,05	739,44	10,44

Table 4.4.3b Practically significant differences (d-values) of physical and motor evaluations done over the three-season periods (1998/1999–2003/2004)		
Variables	**Group 1: n = 7**	**Group 2: n = 9**
	d-value: 1998/1999–2000/2001	**d-value: 2001/2002-2003/2004**
Multistage fitness test		
Shuttle run test	0,41	1,09
Sit-and-reach test (cm)	0,71	0,17
Abdominal strength test		0,37
One minute oblique sit-up test		
Left side		0,62
Right side		0,86
One minute push-up test		0,04
Run a three test (sec.)		0,20
505 agility test (sec.)		0,06
5-metre multiple shuttle test (m)		0,95

The results in Table 4.4.3a indicate an increase in the mean value (positive result) for the multistage fitness test for group 1 from the end of the 1998/1999 off-season to the end of the 2000/2001 off-season, small practical significances (d-value = 0,41, Table 4.4.3b). The results in Table 4.4.3a also show the mean value for the sit and reach test decreased (negative result) from the end of the 1998/1999 off-season to the end of the 2000/2001 off-season, with a medium practical significance (d-value = 0,71, Table 4.4.3b).

Table 4.4.3a indicates an improvement in the multistage fitness test; sit and reach test; one minute oblique sit-up test: left and right anatomical side; and the

5-metre multiple shuttle test for group 2, with high practically significant improvements for the multiple shuttle run test (d-value = 1,09, Table 4.4.3b); one minute oblique sit-up test: left anatomical side (d-value = 1,09, Table 4.4.3b); and 5-metre multiple shuttle test (d-value = 0,95, Table 4.4.3b). Also shown are increases for the sit and reach test, of low practical significance (d-value = 0,17, Table 4.4.3b), and one minute oblique sit-up test: left anatomical side for group 2, of medium practical significance (d-value = 0,62, Table 4.4.3b).

A decrease in the mean value for group 2 is shown in Table 4.4.3b for the one-minute push up test; run a three test; and 505 agility test, with practical significances low (d-value = 0,04, Table 4.4.3b) for the one minute push-up test, low practical significance (d-value = 0,06, Table 4.4.3b) for 505 agility test and small practical significance (d-value = 0,20, Table 4.4.3b) for run a three test.

Conclusion

The injury prevention and training programme contributed positively to the improvement of mean value for the multistage fitness test for group 1 and group 2. Results for the sit and reach test differed for the two groups. Group 1 showed a decrease in the mean value for the test whereas group 2 showed an increase in the mean value for the sit and reach test.

The injury prevention programme contributed to the improvement of the multistage fitness test; sit and reach test; oblique sit-up test: left and right anatomical side; and the 5-metre shuttle test for group 2. Three of the four improvements were of high practical significance (d-value = 0 ≥ 0,80) as described earlier.

4.4.4 Anthropometric evaluations

In the next part of Chapter 4 the results of the anthropometric evaluations will be discussed. The descriptive statistics of each evaluation will be discussed. This includes the following: body weight, fat percentage, kilograms of body fat and kilograms of lean muscle. Also, the results of the somatotype evaluations will be discussed, which include endomorphy, mesomorphy and ectomorphy calculations.

Table 4.4.4a Descriptive statistics of the anthropometric evaluations done over the three-season periods (1998/1999–2003/2004)												
Variables	**Group 1: n = 7**						**Group 2: n = 9**					
	1998–1999		**1999–2000**		**2000–2001**		**2001–2002**		**2002–2003**		**2003–2004**	
	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**	$\bar{x}$	**s**
Body mass	78,69	8,55	79,34	10,30	82,71	9,07	82,45	9,58	84,30	10,05	87,14	9,73
Fat percentage	14,41	5,61	14,02	5,87	15,10	5,73	10,63	2,22	11,56	2,24	13,57	3,60
Fat mass	11,61	5,72	11,49	6,27	12,91	6,23	8,86	2,26	9,76	2,12	12,05	3,43
Lean body mass	67,08	5,29	67,85	6,38	69,66	4,96	73,65	8,24	74,78	8,84	75,23	7,90
Somatotype												
Endomorphy	3,20	1,53	3,37	1,57	3,54	1,51	2,55	0,60	2,76	0,69	3,20	1,02
Mesomorphy	4,69	1,40	4,85	1,28	4,79	1,53	4,10	1,00	4,53	0,93	4,46	0,98
Ectomorphy	2,23	1,27	2,17	1,06	2,00	1,20	3,03	0,71	2,66	0,71	2,45	0,69

Table 4.4.4b Practically significant differences (d-values) of anthropometric evaluations done over the three-season periods (1998/1999–2003/2004)		
Variables	**Group 1: n = 7**	**Group 2: n = 9**
	d-value: 1998/1999–2000/2001	**d-value: 2001/2002-2003/2004**
Body mass	0,44	0,51
Fat percentage	0,12	0,81
Fat mass	0,21	0,93
Lean body mass	0,48	0,19
Somatotype		
Endomorphy	0,23	0,64
Mesomorphy	0,07	0,46
Ectomorphy	0,18	0,82

Table 4.4.4a showed an increase (negative result) in the mean value of fat percentage and fat mass for group 1 from the end of the 1998/1999 off-season to the end of the 2000/2001 off-season, with low practical significance for fat percentage (d-value = 0,12, Table 4.4.3b) and small practical significance for fat mass (d-value = 0,21, Table 4.4.3b). The results in Table 4.4.4a for group 1 also indicate an increase (negative) in the mean value for endomorphy of somatotype from the end of the 1998/1999 off-season to the end of the 2000/2001 off-season, an increase in the mean value for mesomorphy (positive result) and a decrease in ectomorphy (negative result). Low to small practical significances are found in Table 4.4.4b for group 1.

The results in Table 4.4.4a for group 2 (2001/2002 off-season to the 2003/2004 off-season) indicate an increase in the mean value for fat percentage and fat mass. Both with high practical significances (d-value = 0,81 for fat percentage and d-value = 0,93 for fat mass, Table 4.4.4b). Table 4.4.4a also shows an

increase (negative) in the mean value for endomorphy for group 2, of medium practical significance (d-value = 0,64, Table 4.4.4b), and an increase in the mean value for mesomorphy, of small practical significance (d-value = 0,46, Table 4.4.4b), and an decrease in the mean value (negative result) for ectomorphy, high practical significance (d-value = 0,82, Table 4.4.4b).

Conclusion

The results indicate that the injury prevention and training programme had similar effects on the anthropometric evaluations done for group 1 and group 2.

Next follows a discussion on the comparison made between protocol 1 (last three seasons, 2001/2002 off-season to 2003/2004 off-season) to protocol 3 (group 2) (last three seasons, 2001/2002 off-season to 2003/2004 off-season). As not all the results of group 1 (7 players) of the biomechanical evaluation of the musculoskeletal system were available, this comparison has been made to evaluate how the effectiveness of the injury prevention and training programme was influenced by the introduction of new players during a three off-season period (protocol 1, 2001/2002 off-season to 2003/2004 off-season), as compared to when the players stayed the same for a three off-season period (protocol 3, group 2).

4.4.5. Comparison protocol 1 and protocol 3 (group 2)

The comparison of these two groups comprises the same three off-seasons (end of the 2001/2002 off-season to the end of the 2003/2004 off-season, year 4 to year 6). The subjects in protocol 1 consisted of 55 players and for protocol 3 the results of the same nine players (see Chapter 3, p.67). This comparison is done to evaluate how the effectiveness of the injury prevention and training programme were influenced by the introduction of new players during a three off-season period (protocol 1), as compared to when the players stayed the same for a three off-season period.

The results of the Tables (Protocol 1: Table 4.2.1b; Table 4.2.1d; Table 4.2.1f; Table 4.2.1h; Table 4.2.1j; Table 4.2.1l; Table 4.2.1n; Table 4.2.1p; Table 4.2.1r;, Table 4.2.2 b; and Table 4.2.3b; and Protocol 3 (group 2): Table 4.4.2b; Table 4.4.2d; Table 4.4.2f; Table 4.4.2h; Table 4.4.2j; Table 4.4.2l; Table 4.4.2n; Table 4.2.2p; Table 4.4.2r; Table 4.4.3b; and Table 4.4.4b) describing changes in the practical significances (d-values) for protocol 1 and protocol 3 (group 2) will be used to provide a summary. Table 4.4.5c indicates the practical significances between protocol 1 and protocol 3 (group 2), (end of the off-season 2001/2002–2003/2004), as well as the practical significances between the start mean value for protocol 1 and protocol 3 (group 2), (end of the off-season, 2001/2002), and the end mean value for each of the two protocols, (end of the 2003/2004 off-season).

Next will follow a discussion of the comparison of practical significances (d-values) for protocol 1 (2001/2002–2003/2004) and protocol 3 (group 2, 2001/2002–2003/2004) for the biomechanical evaluation.

4.4.5.1 Comparison of practical significances (d-values) for protocol 1 (2001/2002-2003/2004) and protocol 3 (group 2, 2001/2002-2003/2004) for the biomechanical evaluation

Table 4.4.5.1 Comparison of practical significances (d-values) for protocol 1 (2001/2002-2003/2004) and protocol 3 (group 2, 2001/2002-2003/2004) for the biomechanical evaluation							
Variables	**Anatomical side**	**Protocol 1**		**Protocol 3 (group 2)**		**d-value: start *** protocol 1 versus protocol 3**	**d-value: end **** protocol 1 versus protocol 3**
		*** d-value**	**Improvement Yes or no**	**** d-value**	**Improvement Yes or no**		
Ankle dorsiflexion	Left	0,43	Yes	1,27	Yes	0,36	0,19
	Right	0,45	Yes	0,90	Yes	0,09	0,19
Illiotibial band mobility	Left	1,43	Yes	1,89	Yes	0,29	0,11
	Right	1,32	Yes	2,30	Yes	0,41	0,19
Quadriceps mobility	Left	0,49	Yes	0,83	Yes	0,42	0,23
	Right	0,49	Yes	1,06	Yes	0,42	0,23
Iliopsoas mobility	Left	0,81	Yes	0,73	Yes	0,25	0,33
	Right	0,42	Yes	0,44	Yes	0,42	0,43
Gluteus maximus mobility	Left	0,88	Yes	1,41	Yes	0,10	0,42
	Right	1,10	Yes	1,33	Yes	0,12	0,23
Aductor mobility		1,24	Yes	1,77	Yes	0,14	0,00
Hip internal rotation mobility	Left	0,78	Yes	1,16	Yes	0,39	0,00
	Right	0,72	Yes	0,78	Yes	0,12	0,00

* d-value from the end of the off-season 2001/2002 to the end of the off-season 2003/2004 for protocol 1

** d-value from the end of the off-season 2001/2002 to the end of the off-season 2003/2004 for protocol 3 (group 2)

*** d-value between protocol 1 and protocol 3 (group 2) for the end of the off-season 2001/2002

**** d-value between protocol 1 and protocol 3 (group 2) for the end of the off-season 2003/2004

Table 4.4.5.1 (continue) Comparison of practical significances (d-values) for protocol 1 (2001/2002-2003/2004) to protocol 3 (group 2, 2001/2002-2003/2004) for the biomechanical evaluation							
Variables	**Anatomical side**	**Protocol 1**		**Protocol 3 (group 2)**		**d-value: *** start protocol 1 versus protocol 3**	**d-value: **** end protocol 1 versus protocol 3**
		*** d-value**	**Improvement Yes or no**	**** d-value**	**Improvement Yes or no**		
Hip external rotation mobility	Left	0,64	Yes	0,93	Yes	0,33	0,42
	Right	0,58	Yes	0,75	Yes	0,25	0,26
Q-angle	Left	0,37	Yes	0,25	Yes	0,00	0,15
	Right	0,37	Yes	0,25	Yes	0,00	0,15
Patella squint	Left	0,44	Yes	0,25	Yes	0,09	0,15
	Right	0,44	Yes	0,25	Yes	0,09	0,15
Patella tilt	Left	0,09	No	0,68	No	0,12	0,45
	Right	0,09	No	0,68	No	0,12	0,45
Vastus medialis obliques-comparison test	Left	0,08	Yes	0,33	Yes	0,06	0,24
	Right	0,08	Yes	0,33	Yes	0,06	0,24
Longitudinal arch status	Left	0,40	Yes	0,64	Yes	0,10	0,34
	Right	0,40	Yes	0,64	Yes	0,10	0,34
Forefoot positional	Left	0,42	Yes	0,22	Yes	0,27	0,45
	Right	0,29	Yes	0,53	Yes	0,27	0,00
Rear foot standing	Left	0,33	No	0,38	No	0,48	0,20
	Right	0,39	No	0,25	No	0,18	0,20

* d-value from the end of the off-season 2001/2002 to the end of the off-season 2003/2004 for protocol 1

** d-value from the end of the off-season 2001/2002 to the end of the off-season 2003/2004 for protocol 3 (group 2)

*** d-value between protocol 1 and protocol 3 (group 2) for the end of the off-season 2001/2002

**** d-value between protocol 1 and protocol 3 (group 2) for the end of the off-season 2003/2004

Table 4.4.5.1 (continue) Comparison of practical significances (d-values) protocol 1 (2001/2002-2003/2004) to protocol 3 (group 2, 2001/2002-2003/2004) for the biomechanical evaluation							
Variables	Anatomical side	Protocol 1		Protocol 3 (group 2)		d-value: *** start protocol 1 versus protocol 3	d-value: **** end protocol 1 versus protocol 3
		* d-value	Improvement Yes or no	** d-value	Improvement Yes or no		
Rear foot lying	Left	0,83	No	1,12	No	0,49	0,16
	Right	0,59	No	0,93	No	0,34	0,04
Transverse arch area comparison	Left	0,38	No	0,25	No	0,06	0,19
	Right	0,49	No	0,44	No	0,06	0,10
Foot mobility	Left	0,38	No	0,18	Yes	0,62	0,17
	Right	0,44	No	0,00	No	0,56	0,17
Toes positional	Left	0,14	Yes	0,00	No	0,06	0,24
	Right	0,02	Yes	0,00	No	0,06	0,03
Leg-length discrepancy		0,56	Yes	0,46	Yes	0,05	0,07
Anterior superior iliac spine		0,57	Yes	0,37	Yes	0,07	0,07
Posterior iliac spine		0,57	Yes	0,37	Yes	0,07	0,07
Pubic tubercle height		0,57	Yes	0,37	Yes	0,07	0,07

* d-value from the end of the off-season 2001/2002 to the end of the off-season 2003/2004 for protocol 1
** d-value from the end of the off-season 2001/2002 to the end of the off-season 2003/2004 for protocol 3 (group 2)
*** d-value between protocol 1 and protocol 3 (group 2) for the end of the off-season 2001/2002
**** d-value between protocol 1 and protocol 3 (group 2) for the end of the off-season 2003/2004

Table 4.4.5.1 (continue) Comparison of practical significances (d-values) for protocol 1 (2001/2002-2003/2004) to protocol 3 (group 2, 2001/2002-2003/2004) for the biomechanical evaluation							
Variables	Anatomical side	Protocol 1		Protocol 3 (group 2)		*** d-value: start protocol 1 versus protocol 3	**** d-value: end protocol 1 versus protocol 3
		* d-value	Improvement Yes or no	** d-value	Improvement Yes or no		
Sacroiliac cleft		0,58	Yes	0,50	Yes	0,09	0,00
Bilateral pelvic position		0,63	Yes	1,05	Yes	0,48	0,05
Thoraco-lumbar facia mobility	Left	0,37	Yes	0,51	Yes	0,19	0,00
	Right	0,37	Yes	0,51	Yes	0,25	0,00
Sacral rhythm		0,45	Yes	0,66	Yes	0,32	0,00
Functional extension mobility		0,70	Yes	0,60	Yes	0,05	0,24
Functional flexion mobility		0,09	No	0,00	No	0,34	0,20
Rotational mobility	Left	0,08	No	0,00	No	0,21	0,15
	Right	0,25	No	0,33	No	0,00	0,15

* d-value from the end of the off-season 2001/2002t o the end of the off-season 2003/2004 for protocol 1
** d-value from the end of the off-season 2001/2002 to the end of the off-season 2003/2004 for protocol 3 (group 2)
*** d-value between protocol 1 and protocol 3 (group 2) for the end of the off-season 2001/2002
**** d-value between protocol 1 and protocol 3 (group 2) for the end of the off-season 2003/2004

Table 4.4.5.1 (continue) Comparison of practical significances (d-values) protocol 1 (2001/2002-2003/2004) to protocol 3 (group 2, 2001/2002-2003/2004) for the biomechanical evaluation							
Variables	**Anatomical side**	**Protocol 1**		**Protocol 3 (group 2)**		***** d-value: start protocol 1 versus protocol 3**	****** d-value: end protocol 1 versus protocol 3**
		*** d-value**	**Improvement Yes or no**	*** d-value**	**Improvement Yes or no**		
Side flexion mobility	Left	0,00	Yes	0,00	Yes	0,06	0,06
	Right	0,00	Yes	0.00	Yes	0,06	0,06
Coronal axis							
Head position		0,78	Yes	0,66	Yes	0,12	0,00
Cervical		0,65	Yes	0,50	Yes	0,17	0,00
Thoracic		0,65	Yes	0,50	Yes	0,17	0,00
Lumbar		0,07	No	0,25	No	0,00	0,20
Sagittal axis							
Head position		0,00	Yes	0,00	Yes	0,00	0,00
Cervical		0,00	Yes	0,00	Yes	0,00	0,00
Thoracic		0,36	Yes	0,25	Yes	0,06	0,07
Lumbar		0,21	Yes	0,33	Yes	0,21	0,00

* d-value from the end of the off-season 2001/2002 to the end of the off-season 2003/2004 for protocol 1
** d-value from the end of the off-season 2001/2002 to the end of the off-season 2003/2004 for protocol 3 (group 2)
*** d-value between protocol 1 and protocol 3 (group 2) for the end of the off-season 2001/2002
**** d-value between protocol 1 and protocol 3 (group 2) for the end of the off-season 2003/2004

Table 4.4.5.1 (continue) Comparison of practical significances (d-values) protocol 1 (2001/2002-2003/2004) to protocol 3 (group 2, 2001/2002-2003/2004) for the biomechanical evaluation							
Variables	**Anatomical side**	**Protocol 1**		**Protocol 3 (group 2)**		***** d-value: start protocol 1 versus protocol 3**	****** d-value: end protocol 1 versus protocol 3**
		*** d-value**	**Improvement Yes or no**	*** d-value**	**Improvement Yes or no**		
Hand behind back ROM	Left	0,83	Yes	0,64	Yes	0,27	0,36
	Right	0,24	Yes	0,00	No	0,27	0,41
Hand behind neck ROM	Left	0,52	Yes	0,66	Yes	0,22	0,00
	Right	0,18	Yes	0,30	Yes	0,22	0,13
Shoulder coronal positional test		0,62	Yes	1,12	Yes	0,19	0,31
Winging positional test		0,30	Yes	0,44	Yes	0,14	0,06
Shoulder outline composition		0,08	No	0,00	Yes	0,19	0,24
Throwing position (ROM)		0,21	Yes	0,34	Yes	0,21	0,00

* d-value from the end of the off-season 2001/2002 to the end of the off-season 2003/2004 for protocol 1
** d-value from the end of the off-season 2001/2002 to the end of the off-season 2003/2004 for protocol 3 (group 2)
*** d-value between protocol 1 and protocol 3 (group 2) for the end of the off-season 2001/2002
**** d-value between protocol 1 and protocol 3 (group 2) for the end of the off-season 2003/2004

Table 4.4.5.1 (continue) Comparison of practical significances (d-values) protocol 1 (2001/2002-2003/2004) to protocol 3 (group 2, 2001/2002-2003/2004) for the biomechanical evaluation							
Variables	**Anatomical side**	**Protocol 1**		**Protocol 3 (group 2)**		***** d-value: start protocol 1 versus protocol 3**	****** d-value: end protocol 1 versus protocol 3**
		*** d-value**	**Improvement Yes or no**	*** d-value**	**Improvement Yes or no**		
Straight leg raise	Left	1,40	Yes	1,78	Yes	0,22	0,16
	Right	1,41	Yes	2,00	Yes	0,27	0,16
Upper limb tension test	Left	0,21	Yes	0,00	Yes	0,19	0,00
	Right	0,21	Yes	0,00	Yes	0,19	0,00
L3,4 prone knee bend	Left	0,11	No	0,22	No	0,14	0,08
	Right	0,11	No	0,22	No	0,14	0,08
Slump test	Left	0,71	Yes	0,00	Yes	0,71	0,00
	Right	0,71	Yes	0,00	Yes	0,71	0,00

* d-value from the end of the off-season 2001/2002 to the end of the off-season 2003/2004 for protocol 1
** d-value from the end of the off-season 2001/2002 to the end of the off-season 2003/2004 for protocol 3 (group 2)
*** d-value between protocol 1 and protocol 3 (group 2) for the end of the off-season 2001/2002
**** d-value between protocol 1 and protocol 3 (group 2) for the end of the off-season 2003/2004

The results in Table 4.4.5.1 show clearly that the mean value for the evaluations did not differ with high practical significance (d-value ≥ 0,80) in respect of all the biomechanical evaluations of the musculoskeletal system done at the start of the off-season in the 2001/2002 season between the two groups (protocol 1 and protocol 3 (group 2). This indicates that the two groups monitored were relatively homogeneous. The results found for the two groups (protocol 1 and protocol 3 (group 2)) at the end of the three off-season period (2003/2004) also indicate that the two groups did not differ with high practical significance in respect of any of the biomechanical evaluations done.

The effect of the injury prevention and training programme for the two groups (protocol 1 and protocol 3 (group 2) over the last three off-seasons (2001/2002-2003/2004) were investigated. Only the high practical significances will be highlighted (d-value ≥ 0,80). The first important conclusion that can be drawn is that the injury and prevention programme to a great extent had the same effect on both the groups. Both groups show an improvement in 56 of the evaluations done, although not with high practical significances (d-value ≥ 0,80). Both groups also showed 15 evaluations where no improvement (negative results) occurred, although not with high practical significances (d-value ≥ 0,80). Five instances were recorded where the results were positive for one protocol and then negative for the other protocol. For example, in the case of hand behind back ROM: right anatomical side for protocol 1 an improvement (positive result) was found, and no improvement was found for protocol 3 (group 2).

The improvements, although all not of high practical significance (d-value ≥ 0,80), for the 56 evaluations are:

- ankle dorsiflexion: left and right anatomical side;
- illiotibial band mobility: left and right anatomical side;
- quadriceps mobility: left and right anatomical side;
- iliopsoas mobility: left and right anatomical side;
- gluteus maximus mobility: left and right anatomical side;

- aductor mobility;
- hip internal rotation mobility: left and right anatomical side;
- hip external mobility: left and right anatomical side;
- q-angle: left and right anatomical side;
- patella squint: left and right anatomical side;
- vastus medialis oblique- lateralis comparison test: left and right anatomical side;
- longitudinal arch status: left and right anatomical side;
- forefoot positional: left and right anatomical side;
- leg-length discrepancy;
- anterior superior iliac spine;
- posterior superior iliac spine; pubic tubercle height;
- sacroiliac cleft; bilateral pelvic position;
- thoraco-lumbar facia mobility: left and right anatomical side;
- sacral rhythm; functional extension mobility;
- side flexion: left and right anatomical side;
- coronal axis: head position;
- coronal axis: cervical;
- coronal axis: thoracic;
- sagittal axis: head position;
- sagittal axis: cervical;
- sagittal axis: thoracic;
- sagittal axis: lumbar;
- hand behind back ROM; left anatomical side;
- hand behind neck: left and right anatomical side;
- shoulder coronal positional test;
- winging positional test;
- throwing position (ROM);
- straight leg raise: left and right anatomical side;
- upper limb tension test: left and right anatomical side;

- slump test; and
- left and right anatomical side.

The 15 evaluations where no improvement (negative result) were found (practical significances not high) are:
patella tilt: left and right anatomical side;
rear foot standing: left and right anatomical side;
rear foot lying left and right anatomical side;
transverse arch area comparison: left and right anatomical side;
foot mobility: right anatomical side;
functional flexion mobility;
rotational mobility: left and right anatomical side;
coronal axis: lumbar; and
L3,4 prone knee bend: left and right anatomical side.

The five areas where an improvement in one protocol was found and no improvement in the other protocol (practical significances were not high) are:
- foot mobility: left anatomical side;
- toes positional: left and right anatomical side;
- hand behind back ROM:
- right anatomical side; and
- shoulder outline composition

Table 4.4.5.1 also shows an improvement in seven of the same biomechanical evaluations on both groups (protocol 1 and protocol 3 (group 2)) where high practical significances (d-value ≥ 0,80) occurred. These are illiotibial band mobility: left and right anatomical side; gluteus maximus mobility: left and right anatomical side; adductor mobility; and straight leg raise: left and right anatomical side.

The reasons for this could be that the starting mean value for both groups was relatively high when evaluated for the first time and that the injury and prevention programme was compiled to improve on these specific areas.

Table 4.4.5.1 further also indicates two instances where high practical significances were present in protocol 1 but not in protocol 3 (group 2) and are: iliopsoas mobility: left anatomical side and hand behind back ROM: left anatomical side. The results for these areas in protocol 3 (group 2) also show an improvement in this area, although only of medium practical significances.

Table 4.4.5.1 also shows nine biomechanical evaluations with high practical significances present for protocol 3 (group 2) but not for protocol 1, namely: ankle dorsiflexion: left and right anatomical side; quadriceps mobility: left and right anatomical side; hip internal rotation mobility: left anatomical side; hip external rotation mobility: left anatomical side; pelvic bilateral position; and shoulder coronal positional test. All the above were positive results.

One result with a high practical significance, a negative result, was present in protocol 3 (group 2) and not in protocol 1, namely: rear foot lying: right anatomical side. The results for protocol 1 also show a medium practical significance for the rear foot lying right anatomical side (negative result). The injury prevention and training programme therefore had a similar effect for the two protocols for this evaluation.

The purpose of this comparison was to compare the results of protocol 1 and protocol 3 (group 2) with each other to identify if the injury prevention and training programme provided different results for the two groups. Results in Table 4.4.5.1 indicate that in the majority of the biomechanical evaluations (71 out of 76, 93,42%) the injury prevention and training programme had the same effect on the two groups. Including positive and negative results, as shown in Table 4.4.5.1, the positive results occurred in the case of the same biomechanical

evaluations in protocol 1 and protocol 3 (group 2) and the negative results were to the same biomechanical evaluations in protocol 1 and protocol 3 (group 2). As a result of this similarity found between the two groups, the conclusion can be drawn that the conclusions from protocol 1 are valid and can be accepted. This aspect will be discussed further in the next chapter.

4.4.5.2 Comparison of practical significances (d-values) for protocol 1 (2001/2002-2003/2004) with those for protocol 3 (group 2, 2001/2002-2003/2004) for the physical and motor evaluation

Table 4.4.5.2 indicate the practical significances between protocol 1 and protocol 3 (group 2), as well as the practical significances between the start mean value for protocol 1 and protocol 3 (group 2) and the end mean value for each of the two protocols for the physical and motor evaluation.

The results in Table 4.4.5.1 show clearly that the mean values for the physical and motor evaluations did not differ with high practical significance (d-value ≥ 0,80) for the physical and motor evaluations done at the start of the 2001/2002 off-season between the two groups (protocol 1 and protocol 3 (group 2). Indicating the two groups monitored were relatively homogeneous. The results found for the two groups (protocol 1 and protocol 3 (group 2)) at the end of the third off-season period (2003/2004) also indicate that the two groups did not differ with high practical significance in any of the physical and motor evaluations.

Table 4.4.5.2 Comparison of practical significances (d-values) for protocol 1 (2001/2002–2003/2004) to protocol 3 (group 2, 2001/2002-2003/2004) for the physical and motor evaluation

Variables	Protocol 1		Protocol 3 (group 2)		*** d-value: start protocol 1 versus protocol 3	****d-value: end protocol 1 versus protocol 3
	* d-value	Improvement Yes or no	** d-value	Improvement Yes or no		
Multistage fitness test	0,70	Yes	1,09	Yes	0,23	0,17
Sit and reach test	0.19	No	0,17	Yes	0,39	0,44
Abdominal strength test	0,30	Yes	0,37	Yes	0,39	0,28
One minute oblique sit-up test						
Left side	0,30	Yes	0,62	Yes	0,41	0,15
Right side	0,42	Yes	0,86	Yes	0,40	0,15
One minute push-up test	0,26	Yes	0,04	No	0,06	0,25
Run a three test	0,12	No	0,20	No	0,48	0,34
505 agility test	0,20	No	0,06	No	0,17	0,22
5-metre multiple shuttle test	0,63	Yes	0,95	Yes	0,13	0,13

* d-value from the end of the off-season 2001/2002 to the end of the off-season 2003/2004 for protocol 1

** d-value from the end of the off-season 2001/2002 to the end of the off-season 2003/2004 for protocol 3 (group 2)

*** d-value between protocol 1 and protocol 3 (group 2) for the end of the off-season 2001/2002

**** d-value between protocol 1 and protocol 3 (group 2) for the end of the off-season 2003/2004

The effect of the injury prevention and training programme on the physical and motor evaluations done on the two groups (protocol 1 and protocol 3 (group 2) for the last three off-seasons (2001/2002-2003/2004) was investigated. Only the high practical significances will be highlighted (d-value ≥ 0,80). The first important deduction that can be made is that the injury and prevention programme to a great extent had the same effect on both groups. Both groups showed an improvement (positive result) in five of the physical and motor evaluations done, although not with high practical significances (d-value ≥ 0,80). Both groups showed two physical and motor evaluations where a negative result occurred, although not with high practical significances (d-value ≥ 0,80). Two instances were recorded where the results were positive for one protocol, then negative for the other protocol. For example, the sit and reach test did not improve for protocol 1 (negative result) and did improve for protocol 3 (group 2).

The improvements, although not all of high practical significance (d-value ≥ 0,80) for the five physical and motor evaluations, were: multistage fitness test; abdominal strength test, oblique sit-up test: left and right anatomical side; and 5-metre multiple shuttle test.

The two physical and motor evaluations done where no improvement occurred (negative result) were the run a three test and 505 agility test. The two tests where different results were found for the two groups were the sit and reach test and push-up test.

No high practical significances were found for the physical and motor evaluations for the two groups. High practical significances were present in protocol 3 (group 2) but not in protocol 1, namely: multistage fitness test, oblique sit-up test: right anatomical side; and 5-metre multiple shuttle test. This could be that the injury and prevention programme contributed to the improvement of these results.

The purpose of this comparison on the physical and motor evaluations was to compare the results of protocol 1 and protocol 3 (group 2) with each other to identify if the injury prevention and training programme provided different results for the two groups during the off-season. The results in Table 4.4.5.2 indicate that in the majority of the physical and motor evaluations (seven out of nine, 77,78%) the injury prevention and training programme had the same effect on the two groups, including positive and negative results, as it is shown in Table 4.4.5.2 that the positive results were in regard to the same physical and motor evaluations in protocol 1 and protocol 3 (group 2), and the negative results were in regard to the same physical and motor evaluations in protocol 1 and protocol 3 (group 2). As a result of this similarity between the two groups, the conclusion can be drawn that the conclusions from protocol 1 are valid and can be accepted. This aspect will be discussed further in the next chapter.

4.4.5.3 Comparison of practical significances (d-values) for protocol 1 (2001/2002-2003/2004) to those for protocol 3 (group 2, 2001/2002-2003/2004) for the anthropometric evaluation

Table 4.4.5.3 indicates the practical significances between protocol 1 and protocol 3 (group 2), as well as the practical significances between the start mean value for protocol 1 and protocol 3 (group 2) and the end mean value for each of the two protocols for the anthropometric evaluation

The results in Table 4.4.5.3 show clearly that the level of performance did not differ in regard to practical significance (d-value ≥ 0,80) for the anthropometric evaluations done at the start of the in the 2001/2002 off-season between the two groups (protocol 1 and protocol 3 (group 2). Thus, indicating the two groups monitored were relatively homogeneous. The results found for the two groups (protocol 1 and protocol 3 (group 2)) at the end of the three off-season period (2003/2004) also indicate that the two groups did not differ with high practical significance (d-value ≥ 0,80) in any of the anthropometric evaluations.

Table 4.4.5.3 Comparison of practical significances (d-values) for protocol 1 (2001/2002-2003/2004) to protocol 3 (group 2, 2001/2002-2003/2004) for the anthropometric evaluation						
Variables	**Protocol 1**		**Protocol 3 (group 2)**		**d-value: start protocol 1 versus protocol 3**	**d-value: end protocol 1 versus protocol 3**
	*** d-value**	**Improvement Yes or no**	**** d-value**	**Improvement Yes or no**		
Body mass	0,08		0,51		0,12	0,36
Fat percentage	0,03	No	0,81	No	0,55	0,11
Fat mass	0,00	No	0,93	No	0,46	0,09
Lean body mass	0,10		0,19		0,12	0,41
Somatotype						
Endomorphy	0,05	No	0,64	No	0,48	0,14
Mesomorphy	0,04	No	0,46	Yes	0,45	0,03
Ectomorphy	0,04	Yes	0,82	No	0,46	0,17

* d-value from the end of the off-season 2001/2002 to the end of the off-season 2003/2004 for protocol 1,

** d-value from the end of the off-season 2001/2002 to the end of the off-season 2003/2004 for protocol 3 (group 2)

*** d-value between protocol 1 and protocol 3 (group 2) for the end of the off-season 2001/2002

**** d-value between protocol 1 and protocol 3 (group 2) for the end of the off-season 2003/2004

The effect of the injury prevention and training programme on the anthropometric evaluations was investigated on the two groups (protocol 1 and protocol 3 (group 2) for the last three off-seasons (2001/2002-2003/2004). Only the high practical significances will be highlighted (d-value ≥ 0,80). The first important deduction that can be made is that the injury and prevention programme had a similar effect on both the groups. Both groups showed three anthropometric evaluations where a negative result occurred, although not with high practical significances (d-value

≥ 0,80). Two instances were recorded where the results were positive and then negative for both groups.

The three anthropometric evaluations where no improvement (negative result) occurred in both groups are fat percentage, fat mass and endomorphy. The two anthropometric evaluations where a improvement occurred (positive result) and then no improvement (a negative result) are mesomorphy and ectomorphy.

The results in Table 4.4.5.3 indicate three high practical significances for the anthropometric evaluation (all negative) for protocol 3 (group 2) and not in protocol 1. They are fat percentage, fat mass and ectomorphy. This could be due to the fact that the players in protocol 3 (group 2) had a longer than six week period off from playing cricket. The cricketing season ended earlier (middle December) in the 2002/2003 season as a result of the World Cup of cricket that took place in South Africa. Therefore in stead of having a six week rest period the players normally had they had a rest period of approximately sixteen weeks. Affecting their anthropometric evaluation results negatively. Although not reported as it is not part of this study, the starting mean value for fat percentage was 14.98% for protocol 3 (group 2) at the start of the 2003/2004 off-season injury prevention and training programme.

4.4.5.4 Injury epidemiology comparison between protocol 1 and protocol 3 (group 2)

In this section only the injury epidemiology trend between protocol 1 (2001/2002 - 2003/2004) and protocol 3 (group 2) will be looked at.

Table 4.4.5.4 Injury epidemiology comparison between protocol 1 (2001/2002-2003/2004) and protocol 3 (group 2) (2001/2002-2003/2004)		
Variables	**Protocol 1**	**Protocol 3 (group 2)**
Number of injuries	44	22
Anatomical site of injury		
Head, cervical spine and face	2	0
Upper limb	16	8
Thoracic spine, lumbar spine and trunk	14	7
Lower limb	12	7
Nature of injury suffered		
Fracture	2	0
Stress fracture	2	1
Joint	7	3
Muscle	14	6
Tendon	15	9
Cartilage	1	1
Nerve	2	1
Other	1	1
Mechanism of injury		
Contact or impact	13	6
Dynamic overload	3	2
Overuse	17	8
Structural vulnerability	10	6
Inflexibility	1	0
Severity of injury		
1–3 days	21	13
4–21 days	15	4
21+ days	8	5

This comparison between the two groups is only aimed at identifying similarities or similar trends between protocol 1 and protocol 3 (group 2) for injury epidemiology. Table 4.4.5.4 indicates similar trends regarding the epidemiology of injury for protocol 1 and protocol 3 (group 2). Regarding the anatomical site of injury it is shown in Table 4.4.5.4 that most injuries suffered by protocol 3 (group 2) were to the upper limb region (eight injuries), similar to group 1 (16 injuries).

Similar trends are seen regarding the nature of injuries between protocol 1 and protocol 3 (group 2). Most injuries suffered were to the tendon complex, in the case of protocol 3 (group 2), with nine injuries. This area was also shown to have suffered most injuries for protocol 1, with 15 tendon injuries. Muscle injuries also are shown in Table 4.4.5.4 to be the second-most injuries for protocol 1 and protocol 3 (group 2), with 14 injuries for protocol 1 and six injuries for protocol 3 (group 2) respectively. The third-most injuries occurred to joints in the case of both groups. The tendency (results) for nature of injury indicates similarities for protocol 1 and protocol 3 (group 2).

Mechanism of injury in Table 4.4.5.4 also shows a similar tendency between protocol 1 and protocol 3 (group 2), with overuse injuries occurring most in both groups.

In terms of severity of injury it is also indicated in Table 4.4.5.4 that most injuries were injuries of 1–3 days for protocol 1, with 21 injuries, and protocol 3 (group 2), with 13 injuries.

As a result of there being so many similarities present between the results (trends) regarding injury epidemiology between protocol 1 and protocol 3 (group 2), the focus will be on the results of injury epidemiology of protocol 1 during conclusions in the next chapter. The fact that more numbers are involved in protocol 1 makes the results valid and reliable for research.

4.5 Injury epidemiology

4.5.1 Protocol 1: Injury epidemiology over the six-season period (1998/1999–2003/2004)

This section of this chapter will focus on the injury epidemiology of the cricketers over the six-season period (1998/1999–2003/2004) and the last three seasons (2001/2002–2003/2004). Attention will be given to the following: (1) days of cricket played (Diagram 4.5.1); (2) injury suffered per season and anatomical site of injury (Table 4.5.1a); (3) nature of injury suffered (Table 4.5.1b); (4) mechanism of injury (Table 4.5.1c); (5) the severity of the injuries suffered (Table 4.5.1d); and (6) injury incidence per 10 000 hours of play (Table 4.5.7d).

4.5.2 Days of cricket played

In the 1998/1999 season the North-West team participated in the Bowl competition of the United Cricket Board of South Africa. The competition consisted of three-day matches. The team also competed in the Standard Bank limited over competition, which consisted of ten matches. A total of 25 days of cricket was played in the 1998/1999 season. The North-West cricket team then started to participate in the Super Sport four-day competition of the United Cricket Board of South Africa in the 1999/2000 season. The competition consisted of four-day matches. The team also competed in the Standard Bank limited over competition, which consisted of ten matches. The days of play increased by thirteen days of play from the 1998/1999 season (25 days) to the 2003/2004 season (38 days). The players were exposed to more playing time, increasing the possibility (risk) of injury. The 2002/2003 season was a shorter season as a result of the Cricket World Cup that was staged in South Africa. The playing time was much less as only four four-day matches and five limited-over matches were played (21 days of play). Thus the exposure time to injury was much less. The 2003/2004 season was played in the normal format, thus more

games and more playing time that could potentially lead to more injuries (38 days of play).

Diagram 4.5.1. Days of cricket played

Season	Official days of cricket played		Total of official days of cricket played per season
	More-day cricket	One-day cricket	
1998/1999	15 (3-day cricket)	10	25
1999/2000	24 (4-day cricket)	10	34
2000/2001	36 (4-day cricket)	10	46
2001/2002	36 (4-day cricket)	12	48
2002/2003	16 (4-day cricket)	5	21
2003/2004	28 (4-day cricket)	10	38
Total	**155**	**57**	**212**

A total of 212 days of cricket were played over the six-season period from the 1998/1999 season to the 2003/2004 season. More-day cricket was played on 155 days, and 57 days of one-day cricket were played. A total of eighty more days of cricket were played and 27 one-day cricket days were played over the last three seasons (2001/2002- 2003/2004), giving a total of 107 days of cricket played in the last three seasons (2001/2002 -2003/2004).

Injury suffered per season and the anatomical site of injury will be discussed in the next section of chapter 4. See p. 119, chapter 4 for the total number of persons evaluated per season.

4.5.3 Injury suffered per season and anatomical site of injury suffered over the six-season period (1998/1999–2003/2004)

Table 4.5.1a Injury suffered per season and anatomical site of injury suffered over the six-season period (1998/1999–2003/2004)												
	1998/1999		1999/2000		2000/2001		2001/2002		2002/2003		2003/2004	
	Number of injuries suffered	% of total injuries suffered	Number of injuries suffered	% of total injuries suffered	Number of injuries suffered	% of total injuries suffered	Number of injuries suffered	% of total injuries suffered	Number of injuries suffered	% of total injuries suffered	Number of injuries suffered	% of total injuries suffered
Injury suffered per season	6		12		12		15		9		20	
Anatomical site of injury												
Head, cervical spine and face	0	0,00%	0	0,00%	0	0,00%	0	0,00%	1	11,11	1	5,0%
Upper limb	3	50,00%	1	8,33%	2	16,67%	4	26,67%	4	44,44%	8	40,00%
Thoracic spine, lumbar spine and trunk	0	0,00%	5	41,67%	4	33,33%	6	40,00%	4	44,44%	4	20,00%
Lower limb	3	50,00%	6	50,00%	6	50,00%	5	33,33%	0	0,00%	7	35,00%

Injury suffered per season

Table 4.5.1a describes the injury suffered per season by the cricketers, as well as the anatomical site of injury suffered over the six-season period (1998/1999–2003/2004). In the 1998/1999 season there was a total of six injuries suffered throughout the season. In both the 1999/2000 and the 2000/2001 season a total of 12 injuries each were suffered. In the 2001/2002 season a total of 15 injuries (an increase in the total injuries) were suffered by the cricketers. The 2002/2003 season saw nine injurues (a decrease in the number of injuries suffered). In the 2003/2004 season a total of 20 injuries were suffered, an increase in the number of injuries. A total of 74 injuries were suffered during the six-season period (1998/1999–2003/2004).

In Table 4.5.1a the anatomical site of injury is described for the six-season period (1998/1999–2003/2004) and the last three seasons (2001/2002–2003/ 2004). In the 1998/1999 to the 2001/2002 season no injuries were suffered by the cricketers in the head, cervical spine and face region. One injury was recorded in the 2002/2003 and 2003/2004 seasons respectively for the head, cervical spine and face region.

A total of two (2,70% of the total injuries suffered over the six seasons) head, cervical spine and face injuries were suffered for the six-season period (1998/1999–2003/2004), no injuries during the first three seasons (1998/1999–2000/2001) and two injuries (4,5% of the total injuries suffered over the last three seasons) in the last three seasons (2001/2002–2003/2004).

Injuries to the upper limb increased from the 1998/1999 season (three injuries) to the 2003/2004 season (eight injuries). There were three upper limb injuries in the 1998/1999 season (50% of injuries suffered in the 1998/1999 season), one injury in the upper limb region was recorded in the 1999/2000 season (8,33% of the total injuries suffered in the 1999/2000 season) and two upper limb injuries in the

2000/2001 season (16,67% of the total injuries suffered in the 2000/2001 season). The upper limb injuries in all three seasons (1998/1999, 1999/2000 and 2000/2001) were injuries to the shoulder region. The upper limb region had four injuries in the 2001/2002 (26,67% of the total injuries suffered in the 2001/2002 season) and 2002/2003 (44,44 % of the total injuries suffered in the 2002/2003 season) seasons respectively. In the 2001/2002 season one injury (25%) was to the fingers, one injury (25%) was a fracture and two injuries (50%) were injuries to the shoulder region. In the 2002/2003 season all four injuries (100%) were to the shoulder region. The number of upper limb region injuries increased to eight injuries in the 2003/2004 season (40% of the total injuries suffered in the 2003/2004 season). Two of the eight injuries (25%) were to the hands and fingers of the cricketers. The injuries occurred as a result of fielding activities where players dived to stop a ball and in the process injured their hands and fingers. One injury (12,5%) was a result of a player running into an advertisement board and fracturing his right wrist. Two injuries (25%) were to the pectoral area of the upper limb region. Three injuries (37,5%) were to the shoulder of the upper limb region.

Overall a total of 22 upper limb injuries (29,72% of the total injuries suffered over the six seasons) were suffered during the six-season period 1998/1999–2003/2004). A total of six upper limb injuries (20% of the total injuries suffered during the three-season period) were suffered during the first three seasons (1998/1999–2000/2001) and 16 upper limb injuries (36,36% of the total injuries suffered during the last three seasons) during the last three seasons (2001/2002–2003/2004).

The percentage of injuries suffered in Table 4.5.1a shows a decrease in the percentage of upper limb injuries suffered from the 1998/1999 season (50% of the total injuries suffered) to the 2003/2004 season (40% of the total injuries suffered in the 2003/2004 season), a positive result. Shoulder region injuries also decreased (positive result) from the 1998/1999 season (100%), 1999/2000

season (100%) and 2000/2001 season (100%) to the 2003/2004 season (37,5%).

No injuries were suffered to the thoracic spine, lumbar spine and trunk in the 1998/1999 season (Table 4.5.1a). The number of injuries to this region increased to five injuries (Table 4.5.1a) in the 1999/2000 season (41,67% of the total injuries suffered in the 1999/2000 season). The number further increased to six injuries (40% of the total injuries suffered in the 2001/2002 season) in the region in the 2001/2002 season. The number of injuries decreased to four injuries (20% of the total injuries suffered in the 2003/2004 season) in the 2003/2004 season. Injury to the facet joint had the highest occurrence during the six-season period in this study. There were two injuries to the facet joint in the 1999/2000 season, one injury in the 2000/2001 season, three injuries in the 2001/2002 season, two injuries in the 2002/2003 season and three injuries in the 2003/2004 season.

The injuries to the thoracic spine, lumbar spine and trunk suffered during the six-season period (1998/1999–2003/2004) totalled 23 injuries (31,08% of the total injuries suffered over the six seasons), nine injuries (30% of the total injuries suffered during the first three seasons) being suffered during the first three seasons (1998/1999–2000/2001) and 14 injuries (31,81% of the total injuries suffered during the last three seasons) in the last three seasons (2001/2002–2003/2004).

Injuries to the lower limb area were the most during the six-season period in this study. There were three injuries (50% of total injuries suffered in the season) to this area in the 1998/1999 season. The same number of injuries (six injuries) occurred in the lower limb area in the 1999/2000 and 2000/2001 seasons (50% of total injuries suffered in the 1999/2000 and 2000/2001 seasons). The number of injuries decreased in the 2001/2002 season to five injuries (33,33% of total injuries suffered in the 2001/2002 season) and to no injuries to the lower limb area in the 2002/2003 season. The number of injuries increased to seven (35%

of the total injuries suffered in the 2003/2004 season) in the 2003/2004 season. The lower limb injuries suffered in the 2003/2004 season consisted of three impact injuries while fielding (42,85%), one impact injury where a spike of a fast bowler's bowling boot had broken off on impact with the ground and had stuck in the bowler's foot (14,28%), one injury as a result of medial tibial stress syndrome (14,28%), one injury to the tibialis anterior muscle (14,28%) and one hamstring injury (14,28%).

A total of 27 lower limb injuries were suffered over the six-season period (36,49% of the total injuries suffered over the six seasons), with 15 injuries (50% of the total injuries suffered over the first three seasons) to the lower limb area in the first three seasons (1998/1999–2000/2001) and 12 injuries (27,27% of the total injuries suffered over the last three seasons) suffered during the last three seasons (2001/2002–2003/2004).

The next section will focus on the nature of injury suffered over the six-season period.

4.5.4 Nature of injury suffered over the six-season period (1998/1999–2003/2004)

Table 4.5.1b describes the nature of injuries suffered in the six-season period (1998/1999–2003/2004) and the last three seasons (2001/2002–2003/2004).

In the 1998/1999 season most injuries suffered were muscle injuries, amounting to three (50% of the total injuries suffered in the season). There were two tendon injuries (33,33% of total injuries suffered in the season) and one joint injury (16,67% of the injuries suffered in the season).

Table 4.5.1b Nature of injury suffered over the six-season period (1998/1999–2003/2004)												
	1998/1999		1999/2000		2000/2001		2001/2002		2002/2003		2003/2004	
	Number of injuries suffered	% of total injuries suffered	Number of injuries suffered	% of total injuries suffered	Number of injuries suffered	% of total injuries suffered	Number of injuries suffered	% of total injuries suffered	Number of injuries suffered	% of total injuries suffered	Number of injuries suffered	% of total injuries suffered
Injury suffered per season	6		12		12		15		9		20	
Nature of injury suffered												
Fracture	0	0%	0	0%	0	0%	1	6,67%	0	0%	1	5,00%
Stress fracture	0	0%	0	0%	0	0%	0	0%	2	22,22%	0	0%
Joint	1	16,67%	2	16,67%	3	25,00%	3	20,00%	2	22,22%	2	10,00%
Dislocation	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Muscle	3	50%	7	58,3%	7	58,3%	4	26,67%	1	11,11%	9	45,00%
Tendon	2	33,33%	1	8,33%	1	8,33%	5	33,33%	4	44,44%	6	30,00%
Ligament	0	0%	1	8,33%	1	8,33%	0	0%	0	0%	0	0%
Facia	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Cartilage	0	0%	1	8,33%	0	0%	1	6,67%	0	0%	0	0%
Nerve	0	0%	0	0%	0	0%	1	6,67%	0	0%	1	5,00%
Open wound	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Other	0	0%	0	0%	0	0%	0	0%	0	0%	1	5,00%

In the 1999/2000 season two joint injuries (16,67%) and one tendon (8,33%), one ligament (8,33%) and one cartilage (8,33%) injury occurred. The injury to the muscle complex was the highest, with seven injuries (58,3%).

In the 2000/2001 season there were three joint injuries (25%), one tendon (8,33%) and one ligament (8,33%) injury. The injury to the muscle complex was the highest, with seven injuries (58,3%).

In the 2001/2002 season one fracture (6,67% of total injuries suffered in the season) was suffered, three joint injuries (20%), five tendon injuries (33,33%), one cartilage injury (6,67%) and one nerve injury (6,67%). Muscle injuries suffered totalled four (26,67%).

In the 2002/2003 season, two stress fracture were suffered (22,22% of the total injuries suffered in the season). Both the injuries were to fast bowlers. Two joint injuries (22,22%) were suffered, and four tendon injuries (44,44%). Only one muscle injury was suffered (11,11%). The 2002/2003 season was a short season, hence the low number of injuries suffered as a result of less playing time.

In the 2003/2004 season one fracture was suffered (5% of the total injuries suffered in the season). Two joint injuries were suffered (10%), six tendon injuries (30%), one nerve injury (5%) and one other injury (5%). Muscle injuries were the most frequent, with nine (45%) injuries suffered.

The nature of injury for each of the twelve different areas over the six-season period (1998/1999–2003/2004) and the last three seasons (2001/2002–2003/2004) will be discussed next.

Table 4.5.1b shows an increase in the number of fractures suffered from the 1998/1999 season (no fractures) to the 2001/2002 season (one fracture, 6,67 %

of the total injuries suffered in the 2001/2002 season) and the 2003/2004 season (one fracture, 5% of the total injuries suffered in the 2003/2004 season).

Two fracture injuries were suffered over the six-season period, 1998/1999–2003/2004, (2,70% of the total injuries suffered for the six-season period) and two fractures (4,5% of the total injuries suffered for the last three seasons) were suffered during the last three seasons (2001/2002–2003/2004).

Table 4.5.1b indicates an increase in the number of stress fractures suffered from the 1998/1999 season (no injuries) to the 2002/2003 season (two injuries, 22,22% of the injuries suffered in the 2003/2004 season). The injuries were suffered by two fast bowlers who were identified with mixed bowling actions.

Two stress fracture injuries were suffered over the six-season period, 1998/1999–2003/2004 (2,70% of the total injuries suffered for the six-season period) and two stress fractures (4,5% of the total injuries suffered for the last three seasons) during the last three seasons (2001/2002–2003/2004).

A total of thirteen joint injuries (Table 4.5.1b) were suffered over the six-season period, 1998/1999–2003/2004 (17,56% of the total injuries suffered for the six-season period), and seven joint injuries (16,90% of the total injuries suffered for the last three seasons) during the last three seasons (2001/2002–2003/2004).

Table 4.5.1b indicates an increase (negative) in the number of muscle injuries suffered from the 1998/1999 season (three injuries suffered, 50% of the total injuries in the 1998/1999 season) to the 2003/2004 season (nine injuries, 45% of the total injuries suffered during the 2003/2004 season). The opportunity for injury to the muscle area was greater in the 2003/2004 season, as there were more days of cricket played in the 2003/2004 season (38 days of play, Diagram 4.5.1) than in the 1998/1999 season (25 days of play, Diagram 4.5.1). The risk of injury increased as a result of more exposure time.

A total of 31 muscle injuries were suffered over the six-season period 1998/1999–2003/2004 (41,89% of the total injuries suffered for the six-season period) and 14 muscle injuries (31,81% of the total injuries suffered for the last three seasons) during the last three seasons (2001/2002–2003/2004).

The results in Table 4.5.1b show a decrease in the percentage of tendon injuries suffered from the 1998/1999 season (33,33%, two tendon injuries suffered in the 1998/1999 season) to the 1999/2000 season (8,33%, one tendon injury suffered in the 1999/2000 season) and the 2000/2001 season (8,33%, one tendon injury suffered in the 2000/2001 season). It further shows an increase in the tendon injuries from the 1998/1999 season (33,33%) and the 2000/2001 season (8,33%) to the 2002/2003 season (44,44%, four tendon injuries in the 2002/2003 season). A decrease in the tendon injuries is seen from the 1998/1999 season (33,33%) to the 2003/2004 season (30,00%, six tendon injuries suffered in the 2003/2004 season).

A total of 19 tendon injuries were suffered over the six-season period of 1998/1999–2003/2004 (26,67% of the total injuries suffered for the six-season period), four tendon injuries (13% of the total injuries suffered during the first three seasons) during the first three seasons (1998/1999–2000/2001) and 15 tendon injuries (34,09% of the total injuries suffered during the last three seasons) during the last three seasons (2001/2002–2003/2004).

Table 4.5.1b shows one ligament injury suffered in the 1999/2000 season (8,33%) and one ligament injury suffered in the 2000/2001 season (8,33%). Both injuries sustained were ankle injuries, one a grade two ligament tear and the other a grade three ligament tear.

A total of two ligament injuries were suffered over the six-season period, 1998/1999–2003/2004 (2,70% of the total injuries suffered for the six-season

period), two ligament injuries (2,70% of the total injuries suffered for the first three seasons) during the first three seasons (1998/1999–2000/2001) and no ligament injuries during the last three seasons (2001/2002–2003/2004).

Two cartilage injuries were suffered over the six-season period (1998/1999–2003/2004). Table 4.5.1b indicates one cartilage injury was suffered in the 1999/2000 season (8,33%) and one cartilage injury in the 2001/2002 season (6,67%). Both injuries were sustained by medium-fast bowlers.

Two cartilage injuries were suffered over the six-season period, 1998/1999–2003/2004, (2,70% of the total injuries suffered for the six-season period), one cartilage injury (3,00% of the total injuries suffered for the first three seasons) during the first three seasons (1998/1999–2000/2001) and one cartilage injury (2,30% of the total injuries suffered for the last three seasons) during the last three seasons (2001/2002–2003/2004).

One nerve injury (Table 4.5.1b) was suffered in the 2001/2002 season (6,67% of the total injuries suffered in the 2001/2002 season) and one nerve injury in the 2003/2004 season (5,00% of the total injuries suffered in the 2003/2004 season). Both injuries were suffered by batsmen, both in the lower-back area.

Two nerve injuries were suffered over the six-season period, 1998/1999–2003/2004 (2,7% of the total injuries suffered for the six-season period), no nerve injuries during the first three seasons (1998/1999–2000/2001) and two nerve injuries (4,5% of the total injuries suffered for the last three seasons) during the last three seasons (2001/2002–2003/2004).

Table 4.5.1b indicates that one other injury was suffered in the 2003/2004 season (5%), when a spike of a bowler's boot broke off and stuck in his foot.

One other injury was suffered over the six-season period, 1998/1999–2003/2004, (1,3% of the total injuries suffered for the six-season period) and one other injury (2,3% of the total injuries suffered for the last three seasons) during the last three seasons (2001/2002–2003/2004).

4.5.5 Mechanism of injury suffered over the six-season period (1998/1999–2003/2004)

Table 4.5.1c describes the mechanism of injury over the six-seasons (1998/1999–2003/2004), the first three seasons (1998/1999–2003/2004) and the last three seasons (2001/2002–2003/ 2004). Structural vulnerability was responsible for four injuries (66,67%) in the 1998/1999 season. Overuse as a mechanism of injury was responsible for two injuries (33,33%) in the 1998/1999 season.

Contact or impact as a mechanism for injury was responsible for three injuries (25% of the total injuries suffered in the season) in the 1999/2000 season. Dynamic overload was responsible for two injuries (16,67%) and structural vulnerability was responsible for two injuries (16,67%). Overuse injuries accounted for five (41,67%) of the injuries suffered in the 1999/2000 season.

Contact or impact as a mechanism of injury was responsible for two injuries (16,67% of the total injuries suffered in the season) in the 2000/2001 season. Structural vulnerability was responsible for four of the injuries (33,33%) that occurred. Overuse injuries were responsible for six (50,00%) of injuries suffered.

Table 4.5.1c Mechanism of injury suffered over the six-season period (1998/1999–2003/2004)												
	1998/1999		1999/2000		2000/2001		2001/2002		2002/2003		2003/2004	
	Number of injuries suffered	% of total injuries suffered	Number of injuries suffered	% of total injuries suffered	Number of injuries suffered	% of total injuries suffered	Number of injuries suffered	% of total injuries suffered	Number of injuries suffered	% of total injuries suffered	Number of injuries suffered	% of total injuries suffered
Injury suffered per season	6		12		12		15		9		20	
Mechanism of injury												
Contact or impact	0	0,00%	3	25,00%	2	16,67%	5	33,33%	0	0%	8	40,00%
Dynamic overload	0	0,00%	2	16,67%	0	0%	0	0%	1	11,11%	2	10,00%
Overuse	2	33,33%	5	41,67%	6	50,00%	5	33,33%	5	55,56%	7	35,00%
Structural vulnerability	4	67,67%	2	16,67%	4	33,33%	5	33,33%	3	33,33%	2	10,00%
Inflexibility	0	0%	0	0%	0	0%	0	0%	0	0%	1	5,00%
Muscle imbalance	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Rapid growth	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%

In the 2001/2002 season contact or impact injuries as a mechanism of injury accounted for five injuries (33,33%). Structural vulnerability was responsible for five injuries (33,33%). Overuse injuries accounted for five injuries (33,33%) suffered by the cricketers in the 2001/2002 season.

The 2002/2003 season was a short season as a result of the World Cup cricket tournament. Although fewer matches were played, there were still injuries that occurred during the season. Dynamic overload as a mechanism of injury was responsible for one (11,11%) of the injuries suffered in the 2002/2003 season. Structural vulnerability was responsible for three injuries (33,33%). Overuse was responsible for five injuries (55,56%).

The 2003/2004 season was played over the normal period of time, with more matches played than in the previous season. In the 2003/2004 season contact or impact injuries as a mechanism was responsible for eight injuries (40%). Dynamic overload was responsible for two injuries (10%). Structural vulnerability was responsible for two injuries (10%) and one injury was the result of inflexibility (5%). Overuse as a mechanism of injury was responsible for seven injuries (35%).

To be discussed next is the mechanism of injury for the six-season period (1998/1999–2003/2004) and the last three seasons (2001/2002–2003/ 2004). For each one of the mechanisms (contact or impact, dynamic overload, overuse, structural vulnerability, inflexibility, muscle imbalance and rapid growth).

Table 4.5.1c shows an increase in the injuries suffered as a result of contact or impact from the 1998/1999 season (no injuries, 0%) to the 2003/2004 season (eight injuries, 40%). Eighteen injuries were suffered as a result of contact or impact over the six-season period and accounted for 24,32% of the injuries suffered over the six-season period (1998/1999–2003/2004).

A total of 18 contact or impact injuries (in terms of mechanism of injury) were suffered over the six-season period, 1998/1999–2003/2004, (24,32% of the total injuries suffered for the six-season period), five contact or impact injuries (16,67% of the total injuries suffered for the first three seasons) during the first three seasons (1998/1999–2000/2001) and 13 contact or impact injuries (29,54% of the total injuries suffered for the last three seasons) during the last three seasons (2001/2002–2003/2004).

Results in Table 4.5.1c show an increase in the percentage and number of dynamic overload as a mechanism of injury from the 1998/1999 season (no injuries as a result of dynamic overload as a mechanism of injury) to the 2003/2004 season (two injuries, 10% of the total injuries suffered in the 2003/2004 season as a result of dynamic overload as a mechanism of injury). Most injuries (percentage-wise) as a result of dynamic overload as a mechanism of injury occurred in the 1999/2000 season, namely 16,67%. Dynamic overload as a mechanism of injury was responsible for 6,75% of the total injuries suffered over the six-season period (1998/1999–2003/2004).

There were five dynamic overload injuries (in terms of mechanism of injury) over the six-season period 1998/1999–2003/2004 (6,75% of the total injuries suffered for the six-season period), two dynamic overload injuries (6,67% of the total injuries suffered for the first three seasons) during the first three seasons (1998/1999–2000/2001) and three dynamic overload injuries (6,81% of the total injuries suffered for the last three seasons) during the last three seasons (2001/2002–2003/2004).

The number of injuries as a result of overuse as a mechanism of injury was higher (35%), a negative result, in the 2003/2004 season than the number in the first season (33,33%) in 1998/1999. There were a total of 74 injuries over the six-seasons of the study. Overuse as a mechanism of injury was responsible for 30

injuries over the six seasons. Overuse as a mechanism of injury was responsible for 40,54% of the total injuries suffered over the six-season period (1998/1999–2003/2004).

Thirty overuse injuries (in terms of mechanism of injury) were suffered over the six-season period, 1998/1999–2003/2004 (40,54% of the total injuries suffered over the six-season period), 13 overuse injuries (43,33% of the total injuries suffered for the first three seasons) during the first three seasons (1998/1999–2000/2001) and 17 overuse injuries (38,63% of the total injuries suffered for the last three seasons) during the last three seasons (2001/2002–2003/2004).

Table 4.5.1c shows a decrease (positive result) in the percentage of structural vulnerability as a mechanism of injury from the 1998/1999 season (67,67%) to the 2003/2004 season (10%). A total of 74 injuries were suffered in the six-season period (1998/1999–2003/2004), and structural vulnerability accounted for 20 of the injuries suffered (27,02%) over the six-season period (1998/1999–2003/2004).

Structural vulnerability, as a mechanism of injury, was responsible for 20 injuries suffered over the six-season period, 1998/1999–2003/2004 (27,02% of the total injuries suffered for the six-season period), ten injuries (33,33% of the total injuries suffered for the first three seasons) as a result of structural vulnerability during the first three seasons (1998/1999–2000/2001) and ten injuries (22,72% of the total injuries suffered for the last three seasons) as a result of structural vulnerability during the last three seasons (2001/2002–2003/2004).

Inflexibility as a mechanism of injury was responsible for the one injury suffered in the 2003/2004 season (5%, Table 4.5.1c).

One injury as a result of inflexibility (in terms of mechanism of injury) was suffered over the six-season period, 1998/1999–2003/2004 (1,35% of the total

injuries suffered for the six-season period), no injury as a result of inflexibility during the first three seasons (1998/1999–2000/2001) and one injury as a result of inflexibility (2,27% of the total injuries suffered for the last three seasons) during the last three seasons (2001/2002–2003/2004).

The decrease in the number of injuries suffered as a result of structural vulnerability as a mechanism of injury is a positive result (67,67% in the 1998/1999 season compared to 10% in the 2003/2004 season). This supports the statement made that the cricketers had a better biomechanical profile in the 2003/2004 season than in the 1998/1999 and 2000/2001 seasons (when the new evaluations were introduced), and the programme was successful in helping the cricketers to achieve an improved biomechanical profile.

4.5.6 Severity of injury suffered over the six-season period (1998/1999–2003/2004)

Table 4.5.1d describes the severity of injury suffered by the cricketers over the six-season period. The severity of the injuries suffered was classified into the following: (1) minor injuries 1–7 days; (2) moderately serious injuries 8–21 days; and (3) serious injuries 21+ days.

In the 1998/1999 season there were four minor injuries (66,67% of the total injuries suffered in this period), one (16,66%) moderately serious injury and one serious injury (16,66%). In the 1999/2000 season there were ten minor injuries (83,33% of the total injuries suffered in the 1999/2000 season) and two (16,67%) moderately serious injuries. In the 2000/2001 season there were six minor injuries (50% of the total injuries suffered in the 2000/2001 season), five moderately serious injuries (41,67%) and one serious injury (8,33%). In the 2001/2002 season there were seven minor injuries (46,67% of the total injuries suffered in the 2001/2002 season), six moderately serious injuries (40,00%) and two serious injuries (13,33%). In the 2002/2003 season there were four minor

injuries (44,44% of the total injuries suffered in the 2002/2003 season), two moderately serious injuries (22,22%) and three serious injuries (33,33%). In the 2003/2004 season there were ten minor injuries (50% of the total injuries in the 2003/2004 season), seven moderately serious injuries (35%) and three serious injuries (15%).

Table 4.5.1d Severity of injury suffered over the six-season period (1998/1999–2003/2004)												
	1998/1999		1999/2000		2000/2001		2001/2002		2002/2003		2003/2004	
	Number of injuries suffered	% of total injuries suffered	Number of injuries suffered	% of total injuries suffered	Number of injuries suffered	% of total injuries suffered	Number of injuries suffered	% of total injuries suffered	Number of injuries suffered	% of total injuries suffered	Number of injuries suffered	% of total injuries suffered
Total number of injuries	6		12		12		15		9		20	
Minor injuries 1–7 days	4	66,67%	10	83,33%	6	50,00%	7	46,67%	4	44,44%	10	50,00%
Moderately serious injuries 8–21 days	1	16,66%	2	16,67%	5	41,67%	6	40,00%	2	22,22%	7	35,00%
Serious Injuries 21+ days	1	16,66%	0	0,00%	1	8,33%	2	13,33%	3	33,33%	3	15,00%

During the six-season period a total of 74 injuries were suffered. Of these 74 injuries, minor injuries accounted for 41 injuries (55,4% of the total injuries suffered), moderately serious injuries accounted for 23 injuries (31,08% of the total injuries suffered) and serious injuries accounted for ten injuries (13,51% of the total injuries suffered).

The severity of injury over the six-season period (1998/1999–2003/2004), the first three seasons (1998/1999–2000/2001) and the last three seasons (2001/2002–2003/2004) are discussed in the next section (minor injuries suffered, moderately serious injuries suffered and serious injuries suffered).

The minor injuries increased (Table 4.5.1d) from the 1998/1999 season (66,67%) to the 1999/2000 season (83,33% of the total injuries suffered in that season). Minor injuries decreased from the 1998/1999 season (66,67%) to the 2003/2004 season (50,00%).

A total of 41 minor injuries (55,40% of the total injuries suffered for the six-season period) occurred during the six-season period (1998/1999–2003/2004), 20 minor injuries (66,67% of the total injuries for the six-season period) during the first three seasons (1998/1999–2000/2001) and 21 minor injuries (47,72% of the total injuries for the last three seasons) during the last three seasons (2001/2002–2003/2004).

The most moderately serious injuries occurred in the 2000/2001 season (41,67%) and the 2001/2002 season (40%) (Table 4.5.1d). The moderately serious injuries increased from 16,67% in the 1998/1999 season to 35% in the 2003/2004 season.

A total of 23 moderately serious injuries (31,09% of the total injuries suffered for the six-season period) were suffered during the six-season period (1998/1999–2003/2004), eight moderately serious injuries (26,67% of the total injuries for the

six-season period) during the first three seasons (1998/1999–2000/2001) and 15 moderately serious injuries (34,10% of the total injuries for the last three seasons) during the last three seasons (2001/2002–2003/2004).

The serious injuries showed an increase from one injury (16,66%) in the 1998/1999 season to 33,33% (three injuries out of a total of nine injuries for the season) in the 2002/2003 season and down to 15% in the 2003/2004 season. Two injuries were suffered to the lower back as a result of a faulty bowling technique (mixed bowling action) in the 2003/2004 season.

A total of ten serious injuries (13,51% of the total injuries for the six-season period) were suffered during the six-season period (1998/1999–2003/2004), two serious injuries (6,67% of the total injuries for the six-season period) during the first three seasons (1998/1999–2000/2001) and eight serious injuries (18,18% of the total injuries for the last three seasons) during the last three seasons (2001/2002–2003/2004).

The next part of this chapter will discuss the injury incidence per 10 000 hours.

4.5.7 Injury incidence per 10 000 hours of play over the six-season period (1998/1999–2003/2004)

The injury incidence per 10 000 hours played will be discussed next. These results include some of the official more-day cricket and one-day cricket played over the six-season period (1998/1999–2003/2004). The formula used by De Loës *et al.* (2000) was used to calculate the injury incidence per 10 000 hours of play (described in chapter 3, p. 111).

A total of 75 days of more-day cricket and 30 days of one-day cricket were played in the first three seasons (1998/1999–2000/2001), totalling 105 days of cricket played, a total of 680 hours and 1 minute of cricket in the first three

seasons). Eighty days of more-day cricket and 27 days of one-day cricket were played during the last three seasons (2001/2002–2003/2004), totalling 107 days of cricket played (686,5 hours of cricket in the last three seasons). Overall, a total of 155 days of more-day cricket and 57 days of one-day cricket were played during the six-seasons (1998/1999–2003/2004), totalling 112 days of cricket played (1366,5 hours of cricket over the first six seasons).

Table 4.5.7a Hours of cricket played per season for the six-season period (1998/1999–2003/2004)

Season	Days played per season (more-day cricket)	Hours played per day	Total hours played per season	Days played per season (1 -day day cricket)	Hours played per day	Total hours played per season	Total hours played
1998/1999	15	7	105	10	6,167	61,67	166,67
1999/2000	24	6,5	156	10	6,167	61,67	217,67
2000/2001	36	6,5	234	10	6,167	61,67	295,67
2001/2002	36	6,5	234	12	6,167	74	308,00
2002/2003	16	6,5	104	5	6,167	30,83	134,83
2003/2004	28	6,5	182	10	6,167	61,67	243,67
Total	**155**	**39,5**	**1015**	**57**	**37,00**	**351,50**	**1366,50**

Table 4.5.7b Number of players per season and number of injuries per season for the six-season period (1998/1999–2003/2004)		
Season	**Number of players per season**	**Number of injuries per season**
1998/1999	9	6
1999/2000	11	12
2000/2001	18	12
2001/2002	23	15
2002/2003	16	9
2003/2004	16	20
Total	**93**	**74**

Table 4.5.7c Number of players per season and number of injuries per season for the six-season and three-season periods (1998/1999–2003/2004)		
Season	**Number of players per season**	**Number of injuries per season**
1998/1999–2003/2004	93	74
1998/1999–2000/2001	38	30
2001/2002–2003/2004	55	44

Table 4.5.7d Injury incidence per 10 000 hours of cricket played over the six-season period (1998/1999–2003/2004)	
Season	**Injury incidence per 10 000 hours cricket played**
1998/1999	40,000
1999/2000	50,118
2000/2001	22,548
2001/2002	21,174
2002/2003	41,718
2003/2004	51,300
1998/1999–2003/2004	5,823

Table 4.5.7e Injury incidence per 10 000 hours of cricket played	
Season	**Injury incidence per 10 000 hours cricket played**
1998/1999–2003/2004	5,823
1998/1999–2000/2001	11,610
2001/2002–2003/2004	11,653

Table 4.5.7d shows how the injury incidence per 10 000 hours of play increased (negative result) from the 1998/1999 season (40 injuries per 10 000 hours of play) to the 2003/2004 season (51,3 injuries per 10 000 hours of play). The best result was found in the 2002/2001 season (22,55 injuries per 10 000 hours of play) and in the 2001/2002 season (21,17 injuries per 10 000 hours of play). In these two seasons the most cricket was played (Diagram 4.5.1, 46 days of play in 2000/2001 and 48 days of play in the 2001/2002 season).

The 2003/2004 season (Table 4.5.7d) had the most injuries per 10 000 hours of play (51,3 injuries per 10 000 hours of play), a negative result.

Table 4.5.7e shows the overall injury incidence for the six-season period (1998/1999–2003/2004) to be 5,823 injuries suffered per 10 000 hours of play, 11,61 injuries suffered for the first three seasons (1998/1999–2000/2001) per 10 000 hours of play and 11,65 injuries suffered for the last three seasons (2001/2002–2003/2004) per 10 000 hours of play.

Conclusion

The total number of injuries increased from six injuries in the 1998/1999 season to 20 injuries in the 2003/2004 season, which could be attributed to the increased hours of play during the 2003/2004 season compared to the 1998/1999 season. The anatomical site of injury had lower limb injuries decreasing from 50% in the 1998/1999 season to 35% in the 2003/2004 season and the upper limb injuries decreasing from 50% of injuries in the 1998/1999 season to 40% of injuries in the 2003/2004 season.

As for the nature of injuries, the percentage of muscle injuries decreased from the 1998/1999 season to the 2003/2004 season (see p. 257, chapter 4). As regards the mechanism of injury, contact or impact injuries increased by 40% from the 1998/1999 season to the 2003/2004 season. Indicating contact or impact injuries were responsible for the most injuries suffered in the 2003/2004 season (10,81% for contact or impact injuries in the 2003/2004 season). Overuse injuries increased by 2% from the 1998/1999 season to the 2003/2004 season. Injuries as a result of structural vulnerability decreased from 67,67% (being responsible for injuries suffered during that season) in the 1998/1999 season to 10% (being responsible for injuries suffered during the season) in the 2003/2004 season. A total of twenty injuries (27,02% of total injuries suffered, 20 out of 74 injuries) suffered over the six-season period as a result of structural vulnerability. It was responsible for 5,40% of the total injuries suffered in the 1998/1999

season. This number decreased to 2,70% of the total injuries suffered in the 2003/2004 season. Minor injuries as a subdivision of severity of injury decreased from 66,67% of the total injuries suffered in the 1998/1999 season to 50% of the total injuries suffered in the 2003/2004 season.

The injury incidence per 10 000 hours of play, over the six-season period (1998/1999–2003/2004), indicates a low injury incidence of 5,82 injuries per 10 000 hours of play, which is a positive result.

Chapter 5. Summary, conclusions and recommendations

Chapter 5 will be a summary of the literature study done, conclusions on the results of the injury prevention evaluations (biomechanical, physical and motor and anthropometric variables) for the six off-season periods 1998/1999–2003/2004 and the injury epidemiology for the six-season period 1998/1999–2003/2004. Lastly, specific recommendations concerning the shortcomings of this research study as well as recommendations for further study will be highlighted.

5.1. Summary

The primary aim of this study was to evaluate the effectiveness of an injury prevention and training programme for elite cricketers in terms of biomechanical, physical and motor and anthropometric variables. This was done over a period of six cricket seasons (1998/1999–2003/2004) for the off-season. A secondary aim was to report the injury epidemiology for the six-season period (1998/1999–2003/2004).

The purpose of a biomechanical evaluation is to assess an athlete's susceptibility to injury, and the biomechanical evaluation could potentially be used to decrease the incidence of injury (Mullin & Skolfield, 2001; Stone, 1996). One of the aims of a biomechanical evaluation is to assess the presence of any predisposing factors to musculoskeletal injury, such as lack of flexibility, muscle weakness, muscle imbalances, impaired proprioception and abnormal biomechanics. And as biomechanical abnormalities are one of the major causes of injuries, it is important to include biomechanical evaluations in the assessment of injuries (Brukner & Khan, 2001; Wilder *et al.*, 2001) The information gathered by the

biomechanical evaluation could be used to develop a sport-specific profile of possible problem areas which may lead to injury for the cricketer. This profile can then be used to develop the necessary training and prevention programmes to improve the performance of cricketers as well as to reduce the number of injuries they suffer.

The physical and motor evaluation gives an indication of the cricketer's physical (fitness) condition, indicating if the cricketer is conditioned for the rigours of the game, and also plays an important role in the prevention of injuries (Headley, 2003). A cricketer's physical condition is a primary factor in determining his or her chances of suffering from an injury (Whiting & Zernicke, 1998). Poor physical preparation can be a cause of injury (Jamison, 1994; Foster & John, 1989). The better conditioned the cricketer is, the less likely it is that he will be injured, and if an injury occurs the better-conditioned cricketer will generally have a less severe injury and recovery time might be less (Whiting & Zernicke, 1998).

The anthropometric evaluation has shown through research that certain sports codes tend to develop their own morphological identities and that these identities need to be present to be successful in the particular sports code (Bloomfield *et al.*, 1994; Houtkooper & Going, 1994). The anthropometric information can be helpful to evaluate if a player possesses the anthropometric-morphological (anthropometric) build that is needed to participate in a particular sport. If the desired morphological (anthropometric) build is present, it could help prevent injuries from occurring as the player concerned possesses the right build for a particular sport or discipline in a sports code (Bloomfield *et al.*, 1994). The assessment of a cricketer's body composition is an important component in his physiological preparation and injury prevention (Woolford *et al.*, 1993).

Several epidemiology studies from different cricket-playing countries were described in Chapter 2. These include the studies of Leary and White (2000) of England, Stretch (2003) and Stretch (2001a) of South Africa and Ocrhard *et al.* (2002) of Australia, and although their methods differ, similar results for injury

incidence, body area and site of injury have been found by the authors of the different studies. The one major body area of injury identified by all the different epidemiology studies was the lower limb area (Stretch, 2003a; Orchard *et al.*, 2002; Stretch, 2001a; Leary & White, 2000). This suggests that even if the game of cricket is played in a different country the injuries that occur are specific to the game of cricket. By using the epidemiology of cricket injuries, a pattern of potential injury risks has been and can be identified.

It is clear from the epidemiology studies done that cricketers suffer from a wide variety of injuries and that these injuries may occur at any time while cricketers participate in the game or even prepare to participate in the game of cricket.

In this study a total of 93 cricket players, who were part of the North-West professional cricket squad, were evaluated at the end of each of the off-seasons (middle September) over the six-season period from 1998/1999 to 2003/2004. The players were all evaluated at the end of the off-season (middle September) of the commencing season. All the evaluations (biomechanical, physical and motor and anthropometric) were done in middle September (end of the off-season), as the playing season started in October. The biomechanical evaluations were done by the physiotherapists and fitness trainer of the North-West Cricket Union. The physical and motor and anthropometric evaluations were done by the fitness trainer of the North-West Cricket Union and a qualified sports scientist. The injury lists were compiled throughout the playing season by the physiotherapists and the fitness trainer of the North-West Cricket Union. These injury reports were then sent to the medical research committee of the United Cricket Board of South Africa and formed part of their investigation into injury epidemiology in South African cricket. This included all players who needed medical attention due to injury sustained while representing the North-West province in a cricket match

5.2. Conclusion

5.2.1 Aim one

The first aim of this study was to investigate the effectiveness of an injury prevention and training programme on biomechanical, physical and motor and anthropometrical variables of elite cricket players over a six-season period (1998/1999 – 2003/2004).

To achieve this aim, three different protocols have been implemented and investigated (see p.73). The purpose of the three protocols was to investigate different variables and methods that can play a role in the effectiveness of the injury prevention and training programme during the off-season. According to the results of these three protocols (chapter 4) it was clear that regardless of whether the evaluation was done annually on the total number of players, or whether it was the first, second, third, fourth of fifth evaluation (protocol 1), of whether the players where divided into exposure times (protocol 2), or whether the same group of elite players were evaluated over a period time (protocol 3), the injury prevention and training programme showed more or less the same effect on all the result of the biomechanical evaluation, physical and motor evaluation and anthropometric evaluation for the three protocols.

The conclusion can therefore be drawn that the injury prevention and training programme brought about an effective improvement in the majority of biomechanical, physical and motor and anthropometric results of elite cricket players during the off-season evaluations during the six year period (1998/1999–2003/2004). The adaptations made on an annual basis, due to the different test results, also certainly played a role in improving the results.

As described at the end of Chapter 4, the discussion of the conclusions below will only focus on the results found in protocol 1 for the evaluations done over the six off-season periods (1998/1999 – 2003/2004). The reason for this are the similarities that were found with the other two protocols. Protocol 1 was also

suggested by the senior statistician of the North-West University as the research method to be used in this study.

5.2.1.1 Biomechanical evaluation

The biomechanical evaluations (76 evaluations) done for the six off-season periods (1998/1999–2003/2004) indicate an improvement (decrease in the mean value, positive result) in 52 (68,42%) of the evaluations done, with 19 (25%) of evaluations done showing an increase (negative result) in the mean value, and five evaluations (6,58%) staying consistent for the six off-seasons. Nine (47,3%) of the 19 decreases in the mean value for the biomechanical evaluations were in regard to the feet. Nine (90%) of the ten other that showed no improvements had a low practical significance and only one (10%) had a practical significance of medium value. The evaluations where the mean value stayed consistent are seen as a positive result as the mean values for these evaluations stayed consistent or did not deviate from the ideal mean value identified for the particular evaluation. Overall in 57 (75%) of the 76 biomechanical evaluations of the musculoskeletal system an improvement (positive) in the mean value is indicated by the results, although not all the improvements were of high practical significance (d-value ≥ 0,80), indicating an improvement in the biomechanical profile of the elite cricketer, which means that the risk of injury as a result of faulty biomechanics has potentially been decreased over the six off-season periods (1998/1999–2003/2004). The results therefore indicate that the injury prevention and training programme contributed more positively to the improvement of the overall biomechanical profile of the cricketers in the 2003/2004 off-season than in the 1998/1999 off-season and in the 2000/2001 off-season (when new tests were introduced to evaluate the players).

A comparison of the biomechanical evaluations used in this study to other research studies was difficult as little information of such studies on biomechanical evaluations of the musculoskeletal system done on elite cricketers

was available. This study is the first of its kind to use these specific biomechanical evaluations on elite cricketers.

Next follows a discussion of the most important results found in this study for biomechanical evaluations done, and of how the results compare with current literature.

Ankle dorsiflexion improved consistently over the six off-season evaluations for the six-season period 1998/1999–2003/2004 season (of high practical significance) (see Table 4.2.1a (p. 121) and Table 4.2.1b, p. 122).

Tightness (an increase) in ankle dorsiflexion could lead to an increase in ankle pronation (Levin *et al.*, 2003; Davis & Prentice, 1994; McPoil & Brocato, 1990). An increase in ankle pronation could then further lead to a host of possible lower leg injuries along the kinetic chain (Brukner & Khan, 2001). Beck (1998) points out the importance of attaining good flexibility in ankle dorsiflexion prior to weight-bearing exercise or participating in a competitive sport, and also states that it is seen as an essential strategy in the prevention of lower leg injuries.

The pelvic girdle region (leg-length discrepancy, anterior superior iliac spine, posterior superior iliac spine, pubic tubercle height, sacroiliac crest) improved consistently over the six off-season evaluation times for the six-season period 1998/1999–2003/2004 (a high practical significance) (see Table 4.2.1i, p. 139) and Table 4.2.1j, p. 140). Arnheim and Prentice (1993a) state that the pelvic girdle region is the foundation for the spine (core), and when the hip girdle is not level the spine and the upper body must compensate in an attempt to keep the body alignment balanced.

Leg-length differences, as part of the pelvic girdle region, may be structural or functional. Structural differences occur when different length osseous structures are present. Functional differences occur with asymmetry of the pelvic girdle

alignment (anterior superior iliac spine, posterior superior iliac spine, pubic tubercle height and sacroiliac crest) (Agosta, 2001; Arnheim & Prentice, 1993a).

MaCaw (1992) stated that joint congruency is affected by a skeletal imbalance (functional difference), such as leg-length discrepancy, and this in turn alters the pattern of the mechanical stress within the joint. This structural imbalance can also affect the muscle tension patterns around the joint, increasing the compressive stress within the joint and the tensile stress imposed at the sites of muscle insertion (Saudek, 1990; Neumann, 1989). Increasing the load or decreasing the area of load distribution increases the predisposition to the development of stress-related injuries, making leg-length discrepancy then a plausible factor in overuse injuries (MaCaw, 1992).

In running, a certain amount of pelvic movement is required (rotation, anterior-posterior and lateral tilt). If the stabilizing muscles are not conditioned enough and therefore has poor muscular control, excessive movement may be present in any of the three planes (sagittal, frontal and transverse). Less effective transmission of forces through the pelvis, as a result of this poor control by the stabilizing muscles, leads to less efficient movement. Frequently this abnormality is present in more than one plane and the lack of stability in one plane may lead to the development of injury or problems in another plane (Brukner & Khan, 2001; Hruska, 1998). Derman (2001a) states that the leg-length discrepancy evaluation is an important evaluation as it may be a subtle predisposing factor of chronic groin pain. The results found in this study (see p. 152, the pelvic girdle region in chapter 4) for the pelvic girdle region show the injury prevention and training programme contributed in strengthening the core stability of the cricketer and that the possibility of injury to this area has been decreased. The results found in this study are in accordance with what was found in the literature regarding the pelvic girdle region.

The upper limb region also improved consistently over the six off-season evaluations for the 1998/1999–2003/2004 seasons (the shoulder positional test being of high practical significance), with the hand behind back ROM being of high practical significance for the left anatomical side and of small practical significance for the right anatomical side; the hand behind neck ROM being of medium practical significance for the left anatomical side and of small practical significance for the right anatomical side; and with the shoulder positional testing being of medium practical significance) (see Table 4.2.1o, p. 148 and Table 4.2.1p, p. 149).

It is reported that shoulder position depends on the position of the scapulae (Kendall *et al.*, 1993) and that the movement of the scapulae also plays an important role (scapulohumeral rhythm) (Kibler. 2001). Kendall *et al.* (1993) state that faulty positions of the scapulae could adversely affect the position of the shoulder joint and that misalignment of the shoulder joint can predispose an athlete to injury and chronic pain. Arnheim and Prentice (1993d) report that protracted or forward rotated shoulders are usually associated with muscular tightness in the chest area and weakened muscles of the upper back region (scapula stabilisers). The results found for this area (the upper limb region) in the study therefore indicate that the injury prevention and training programme contributed successfully to developing a good shoulder position and shoulder flexibility through the development of the scapula stabilisers.

The straight-leg raise: left and right anatomical sides as part of the neurodynamics evaluation also improved over the six off-season evaluations for the six-season period 1998/1999–2003/2004 season (being of high practical significance) (see Table 4.2.1q, p. 151 and Table 4.2.1r, p. 152). The straight-leg raise test is used to reproduce back and leg pain to determine its cause (Brukner & Khan, 2001, Arnheim & Prentice, 1993c). Arnheim and Prentice (1993c) report that straight-leg raising might be limited and painful as a result of tight hamstrings, lumbosacral or sacroiliac joint injury or a problem with the sciatic

nerve. Elliott *et al.* (1992) reported that bowlers with poor hamstring flexibility displayed an inter-vertebral disc abnormality. Moreland (1994) found that with a clinical presentation of spondylolysis or spondylolisthesis in young bowlers, in addition to pain, there was evidence of hamstring tightness. The injury prevention and training programme played a positive role in improvement in this area for the cricketers.

The foot evaluation (forefoot position standing, rear foot position standing, rear foot position lying, transverse arch area comparison and foot mobility) was an area where a weakening in the biomechanical profile was present over all the evaluation times (see p. 135, Table 4.2.1g and p. 136, Table 4.2.1h in chapter 4). Exercises for this area have been incorporated into the adapted training and prevention programme in an effort to improve the biomechanical profile of the foot (see p.390 and 391, annexure 3.5)

The gluteus maximus mobility showed a decrease in the mean value over the six season period (1998/1999–2003/2004, a medium practical significance for the left anatomical side and a small practical significance for the right anatomical side) (see p. 122, Table 4.2b, chapter 4). The gluteus medius and gluteus minimus muscles are the stabilizing muscle in the hip girdle (Shier *et al.*, 1999) and the gluteus maximus is a prime mover of the hip, providing extension of the hip (Saudek, 1990). Tight muscles may lead to a joint's assuming an asymmetrical position. It is therefore important to stretch the shortened muscle in order to restore the balance of muscle length, leading to a more normal reaction to resistance, and to restore the tension around the specific joint (Norris, 1995). Therefore more gluteal flexibility exercises should be introduced into the injury prevention and training programme (see annexure 3.5, p. 336).

Functional flexion mobility, rotational mobility and side flexion mobility also showed a decrease in the mean value, although the decrease was of small

practical significance (see p. 142, Table 4.2.1k and Table 4.2.1l (p. 143) in chapter 4).

Finally as regards the biomechanical evaluations over the six off-season periods, the conclusion can be drawn that there was a definite improvement for the cricketers in their biomechanical profile. This is also confirmed by similar research results.

5.2.1.2. Physical and motor evaluation

Results for the physical and motor evaluations indicate the mean values for most of the evaluations (6 of the 9, i.e. 66,67%) increased over the six off-season periods (1998/1999-2003/2004).

A high practical significance (d-value = 0,90, year 1 to year 6) in the aerobic fitness (multistage fitness test: shuttle run test) was found from the 1998/1999 off-season (84,4 shuttles, level 10,04) to the 2003/2004 off-season (103,88 shuttles, level 11,11), indicating the players were aerobically more prepared in the sixth off-season (2003/2004) than in the first off-season (1998/1999). A high practical significance (d-value = 0,98, year 3 to year 6) in the anaerobic fitness (5-metre multiple shuttle test) was found from the 2000/2001 off-season (702,22 m) to the 2003/2004 off-season (736,56 m). The results for the 5-metre multiple shuttle test indicate that the players were better prepared anaerobically for the game of cricket in the sixth off-season (2003/2004) than at the end of the first off-season when the test was introduced (2000/2001).

Increased aerobic fitness will raise the anaerobic threshold. This will enable the athlete to sustain a higher intensity of activity before the onset of fatigue (Bentley, 1996). A lack of physical fitness can be a risk factor for musculoskeletal injury during physical activity (Neely, 1998). The result of 103,88 shuttles (level 11,11) on the multistage fitness test rates as good on the classification of Jamison

(1994) for cricket players. Similar to the minimum requirements set for the West Indies cricket team (Headley, 2003). The increase in the minimum shuttles required from the 1998/1999 off-season to the 2003/2004 off-season is in line with the comments made by Headley (2003), Jamison (1994) and Bull *et al.* (1992) that the modern cricketer needs to be physically fitter to cope with all the training and with playing more matches. This has also been illustrated by Noakes and Durandt (2000) in chapter 2. The results for the aerobic and anaerobic test in this study indicate that the injury prevention and training programme had contributed to the improvement in the aerobic and anaerobic capacity of the cricketers.

The increase (a small practical significance) in the abdominal strength (4,125 in the 2002/2003 off-season to 4,44 in the 2003/2004 off-season), the increase (small practical significance left and right anatomical side) in the oblique sit-up: left and right (63,63 for the left anatomical side in the 2002/2003 off-season to 66,19 for the left anatomical side in the 2003/2004 off-season, and 60,00 for the right anatomical side in the 2002/2003 off-season to 64,56 for the right anatomical side in the 2003/2004 off-season) as well as the increase in the push-ups (41,69 in the 2002/2003 off-season to 43,63 in the 2003/2004 off-season) also indicates that the players were physically better prepared in the 2003/2004 season.

The abdominal obliques have a stabilizing role in controlling rotational pelvic motion (Hemmingway *et al.*, 2003). Norris (1993) reported that the oblique abdominals work harder in twisting actions. The external oblique works when rotating the trunk to the opposite side and the internal oblique when rotating the trunk to the same side. If the trunk rotates to the right the internal right oblique and external left oblique are active. The oblique abdominals are therefore considered to be important trunk stabilizers (Snijders *et al.*, 1995; Lee, 1994). In analysing their pitching data Watkins *et al.* (1989) found the same patterns of muscle activity, and therefore power, exhibited as seen in simple postural loading

activities. Therefore they concluded that they should be able to apply the concept of trunk strengthening for improved function and decreased injury. Important aspects such as twisting of the body plays a role in almost all aspects in the game of cricket, such as batting, bowling and throwing.

Parnianpour *et al.* (1988) documented the role of fatigue in both motion output and patterns of trunk movements, showing that fatigued muscles are slower and subsequently take longer to respond to change in workloads. This demonstrated the phenomenon of compensation (kinetic chain) of secondary muscle groups, causing loading in some injury-prone athletes.

It is important for an athlete to have maximal strength to maintain level of performance and avoid injury. Maintaining a strong trunk helps avoid other injuries as well, for example a shoulder injury that occurs where there are poor trunk mechanics (Watkins *et al.*, 1989). The results for the abdominal strength and oblique sit-up evaluations show an increase, although of small practical significance, in the mean value for the tests (see p 159, chapter 4), indicating that the injury prevention and training programme contributed to the improvement in this area.

The mean value of 10,38 seconds for the run a three test in the 2003/2004 off-season rates as fair on the classification scale of Jamison (1994) for cricketers (p 108, chapter 3). The mean value for the 505 agility test in the 2003/2004 off-season of 2,35 seconds is rated as good on the classification scale of Jamison (1994) for cricketers (p 100 chapter 3).

Overall the cricketer's physical fitness profile was better at the end of the 2003/2004 off-season than was experienced at the end of the 1998/1999 off-season and in the 2002/2003 season (when the new evaluations were introduced). The results indicate the injury prevention and training programme contributed to improving the physical and motor variables of the cricketers.

5.2.1.3. Anthropometric evaluation

The results show the cricketers to have a better anthropometric profile in the 2003/2004 off-season compared to the 1998/1999 off-season. The results show a decrease (low practical significance) in the mean body mass from the 1998/1999 off-season (84,48 kg) to the 2003/2004 off-season (82,98 kg), a decrease (small practical significance) in the fat percentage from 16,30% in the 1998/1999 off-season to 13,51% in the 2003/2004 off-season, a decrease (small practical significance) in the fat mass from 14,52 kg in the 1998/1999 off-season to 11.54 kg in the 2003/2004 off-season and an increase (low practical significance) in the lean body mass from 69,95 kilogram in the 1998/1999 off-season to 71,53 kilogram in the 2003/2004 off-season.

The study by Moss *et al.* (1992) found that an increase in body weight can be used as a predictor of pattelofemoral stress syndrome in a group of high-school athletes, indicating an association between body weight and the risk of injury. Jones *et al.* (1994) found that the risk of injury was greater in men with a higher body fat percentage. According to Neely (1998), several studies did not find a relationship between the percentage of body fat and the risk of injury (Harwood *et al.*, 1989; Cowan *et al.*, 1988; Jones *et al.*, 1988) but an equal number of studies have reported a relationship between body fat percentage and the risk of injury (Rayson *et al.*, 1996; Jones *et al.*, 1994; Jones *et al.*, 1993). The mean values found in this study, at the end of the sixth off-season, for body fat percentage (see p 164, Table 4.2.3a in chapter 4) are in line with the values reported in the literature, which indicates that body fat percentage should be between 10 and 15% for a cricketer (Headley, 2003; Noakes & Durandt, 2000; Woolford *et al.*, 1993; Bull *et al.,* 1992; Stretch, 1991; Stretch, 1987). These results indicate that the injury prevention and training programme contributed to the improvement and maintenance of the fat percentages of the cricketers in line with what the literature suggests it should be.

The improvement (small practical significance) of the endomorphic component from 3,62 in the 1998/1999 off-season to 3,25 in the 2003/2004 off-season also indicates a better morphological profile for the cricketers. The improvement (a medium practical significance) of the ectomorphy component from 1,89 in the 1998/1999 off-season to 2,61 in the 2003/2004 off-season also indicates a better morphological profile for the cricketers. The decrease (small practical significance) of the mesomorphic component from 4,88 in the 1998/1999 off-season to 4,43 in the 2003/2004 off-season impacts negatively on the improvement of the anthropometric profile of the cricketers.

Overall the somatotype score of 3,25 – 4,43 – 2,61 is a better score in the 2003/2004 off-season than the somatotype score of 3,62 – 4,88 – 1,89 in the 1998/1999 off-season and compares well to the results found in the literature as regards somatotype (Stretch, 1991; Stretch, 1987; Jones *et al.*, 1965).

In conclusion, the results found in this study for the anthropometric evaluations correlates with the results found in the literature. Thus the results indicate the injury prevention and training programme contributed to the maintenance and/or improvement of the anthropometric profile of the cricketers.

5.2.2 Aim two

The second aim of this study was to investigate the injury epidemiology of elite cricket players over a six-season period (1998/1999–2003/2004). This was done as a follow-up to the injury prevention and training programme that was followed during the six off-season periods of 1998/1999–2003/2004. Firstly, it aimed to investigate the injury incidence but secondly, to investigate if the injury prevention and training programme followed during the six off-season periods (1998/1999–2003/2004) had any influence on the injury epidemiology over this six-season period.

According to the results found in regard to the injury incidence it can be concluded that the reduction in the percentage of injuries suffered in certain areas per season can be attributed to the injury prevention and training programme, the adjustments made annually and the maintenance programme followed during the cricket season. To support this conclusion drawn for research aim two, the same conclusions will be cited, as well as the most important result, in regard to protocol 1, as argued earlier.

A total of 74 injuries were suffered during the six-season period (1998/1999–2003/2004), with 30 injuries suffered during the first three seasons (1998/1999–2003/2004) and 44 injuries during the last three seasons (2001/2002–2003/2004). A total of 38 players were evaluated during the first three seasons and a total of 55 players during the last three seasons, giving a total of 93 players evaluated over the six season period. The total number of players evaluated was more in the last three seasons, therefore the possibility of injury increased as a result of the increase in the number of players over the last three seasons.

Conclusions for the injury incidence will be discussed in the order used in chapter 4 (anatomical site of injury, nature of injury suffered, mechanism of injury, severity of injury and injury incidence per 10 000 hours of play).

Regarding the anatomical site of injury, the lower limb suffered most injuries during the six-season (1998/1999–2003/2004) period, with 27 injuries (36,49% of the total injuries suffered during the six-season period). The results of the studies of Leary and White (2000) of England, Stretch (2003a) and Stretch (2001a) of South Africa and Orchard *et al.* (2002) of Australia also found the lower limb area to be the most injured anatomical site. Lower-limb injuries decreased from the first three seasons (1998/1999–2000/2001) from 50% of the total injuries suffered during this period to 27,27% of the total injuries suffered during the last three seasons (2001/2002–2003/2004).

The thoracic spine, lumbar spine and trunk were the second most injured anatomical site over the six-season period (1998/1999–2003/2004) with 31,08%, the upper limb the third most injured anatomical site (29,73%) and the head, cervical spine and face the least injured site with 2,7%. The upper limb was found to be the second most injured anatomical site by Stretch (2003a), Orchard *et al.* (2002) and Leary and White (2000), and the thoracic spine, lumbar spine and trunk the third most injured anatomical site by Stretch (2003a) and Orchard *et al.* (2002).

As for the nature of injury suffered, muscle injuries were the most frequent, with 31 injuries (41,89% of the total injuries suffered during the six-season period 1998/1999–2003/2004). This is similar to the results found by the studies of Stretch (2003a), Stretch (2001a) and Leary and White (2000). Muscle injuries made up 57% of the total injuries suffered during the first three seasons (1998/1999–2000/2001) and 31,81% of the total injuries suffered during the last three seasons (2001/2002–2003/2004). The results indicate that the injury prevention and training programme assisted in the decrease of muscle injuries suffered during the last three seasons (2001/2002-2003/2004).

Overuse as a mechanism of injury led to the most injuries for the six-season period (1998/1999–2003/2004) with 30 injuries (40,54% of the total injuries suffered during this period). Results are consistent with the findings of the studies of Stretch (2003a), Orchard *et al.* (2002) and Stretch (2001b), where overuse as a mechanism of injury was the main cause of injury. Overuse injuries made up 43,33% of the total injuries suffered during the first three seasons (1998/1999–2000/2001) and 38,63% of the total injuries suffered during the last three seasons (2001/2002–2003/2004).

As a mechanism of injury, structural vulnerability was second, with 20 injuries for the six season period of 1998/1999–2003/2004 (27,02% of the total injuries suffered during this period). Structural vulnerability was responsible for 33,33% of

the total injuries suffered in the first three seasons (1998/1999–2000/2001) and for 22,72% of the total injuries for the last three seasons (2001/2002–2003/2004). Also, structural vulnerability was responsible for 67,67% of the injuries in the first season (1998/1999) and for 10% of the injuries in the last season (2003/2004). It was responsible for 5,40% of the total injuries suffered in the 1998/1999 season. This number decreased to 2,70% of the total injuries suffered in the 2003/2004 season. The results indicate the injury prevention and training programme contributed in improving the biomechanical profile of the cricketers, thereby reducing the possibility of injury as a result of structural vulnerability.

Contact or impact as a mechanism of injury increasingly played a role in the occurrence of injury towards the sixth-season with eight injuries (10,81% of the total injuries suffered over the six-season period in the 2003/2004 season, eight out of seventy-four injuries suffered over the six-seasons). Contact or impact also played a role in muscle injuries suffered, increasing the number of muscle injuries suffered. An area where the injury prevention and training programme could not play a prevention role. For example if a player gets hit by a cricket ball on the leg whilst bowling or fielding.

Minor injuries suffered had the highest occurrence rate, with 55,40% of the total injuries suffered during the six-season period (1998/1999–2003/2004), 66,67% of the total injuries suffered for the first three seasons (1998/1999–2000/2001) and 47,72% for the last three seasons (2001/2002–2003/2004). These findings are similar to the results of Stretch (2001c) for minor injuries suffered (ranging between 47,3 and 69%).

Moderately serious injuries made up 31,09% of the total injuries suffered during the six-season period (1998/1999–2003/2004), 26,67% of the total injuries suffered for the first three seasons (1998/1999–2000/2001) and 34,10% for the last three seasons (2001/2002–2003/2004). Results found for moderately serious

injuries by Stretch (2001c) ranged between 19,6 and 29,1%. The results found for this study are a little higher than the results of Stretch (2001c).

Serious injuries made up 13,51% of the total injuries suffered during the six season period (1998/1999–2003/2004), 6,67% of the total injuries suffered for the first three seasons (1998/1999–2000/2001) and 18,18% of the total injuries suffered during the last three seasons (2001/2002–2003/2004). These findings are similar to the results found by Stretch (2001c) for serious injuries (ranging between 5,0 and 23,6%).

Most injuries per season per 10 000 playing hours in this study were suffered in the 2003/2004 season, with 51,30 injuries suffered per 10 000 playing hours. Overall the injuries suffered per 10 000 hours in this study were 5,82 injures for the six season period 1998/1999–2003/2004. Leary and White (2000) found 2,6 injuries per 10 000 hours of cricket played in their study and Orchard *et al.* (2002) found 18,4 injuries per 10 000 hours of cricket played in their domestic cricket league. The results for injuries per 10 000 hours of cricket play found in this study compare favourable with the results found in the literature.

Injuries suffered per 10 000 playing hours for the first three seasons (1998/1999–2000/2001) were 11,61 injuries per 10 000 playing hours and 11,65 injuries per 10 000 playing hours for the last three seasons (2001/2002–2003/2004). Orchard *et al.* (2003) found 21,0 injuries per 10 000 hours for the last three seasons of their study of cricket played for their domestic cricket league.

The results of this study indicate that the prevention and training programme contributed successfully to the improvement as well as maintenance of the biomechanical, physical and motor and anthropometric profile of the elite cricketer. The prevention strategies (biomechanical, physical and motor and anthropometric evaluations) helped in the prevention of certain injuries, for example shoulder injuries, hamstring injuries, groin injuries and medial tibial

stress syndrome of the lower leg. The prevention programme could not prevent injuries as a result of impact or contact, or other injuries like being spiked by contact with cricket shoes.

5.3. Recommendations

Due to the conclusions made in this study according to the aims and results of the other studies, the following conclusions can be drawn:

1. The injury prevention and training programme that was developed during the six-season period can be used with great effectiveness by coaches of elite school boy, senior and national cricket players during the off-season to prepare themselves physically for the game of cricket and to prevent possible injury during the playing season. Shortcomings that were identified during the last evaluation (2003/2004 off-season) were addressed and added to the programme (see annexure 3.5 p. 390 for the feet exercises and p. 336 for the gluteal stretches for the new specific exercises that were incorporated into the adapted injury prevention and training programme).

2. The battery of tests (the biomechanical, physical and motor and anthropometric evaluations) used in this study can be used by persons who have been trained as medical personnel, sports scientists and biokineticists and coaches to evaluate elite cricketers. These trained personnel could also implement the injury prevention and training programme with the necessary adjustment made for certain age and gender groups. The shoulder exercises for example can be done with tubular bands, and the leg exercises with lighter weights.

3. The huge amount of research data that was collected in this study on the biomechanical, physical and motor and anthropometric measurements can be used with great effect by other researchers. For future research to evaluate the

effectiveness of injury prevention strategies the 4-step method promoted by van Mechelen *et al.* (1992) can be used and implemented for further study by other researchers. The steps are as follows: (1) identify the extent of the sports injury problem (describing the distributions of the incidence and severity of injuries); (2) establish the aetiology and mechanism of injuries (identifying injury causes and potential risk factors); (3) introduce preventative measures designed to address these risk factors; and (4) assess the effectiveness of these preventative measures by repeating step 1.

5.3.1. Shortcomings of this study

Little information was available on the use of this specific biomechanical evaluation in cricket, although a thorough biomechanical evaluation was recommended by different authors (Bell-Jenje, 2003; Stretch, 2003; 2001a; Finch *et al.*, 1999). More research on this topic is needed before reliable conclusions can be drawn.

The continuous movement of elite cricketers from season to season among different provinces or their retiring from the game of cricket made it difficult to evaluate all the players throughout a six-season period (1998/1999–2003/2004). The ideal was to evaluate a specific group in a longitudinal study. However, the evaluation of a specific group of elite cricket players over a three off-season period did provide useful information.

5.3.2. Recommendations for further study

The injury prevention strategies used in this study could be used to streamline the biomechanical, physical and motor and anthropometric evaluation according to the different disciplines in cricket (batters, bowlers, all-rounders (players that bat and bowl in a team) and the wicket-keepers). The results found from such studies, on the different disciplines in the game of cricket, will help in the

compilation of specific injury prevention and training programmes for each of the different disciplines.

The strength aspect in cricket needs to be researched further, especially upper-body and lower-body strength. Upper-body and lower-body strength evaluations were done in the 2002/2003 season. The inclined leg press was used to determine one-repetition leg strength and the one-repetition bench press to determine upper body strength. Results indicated the body weight to one repetition inclined leg press ratio to be an average of three times body weight and the one-repetition bench press to be at an average of 85% of body weight. It is also suggested that the abdominal strength evaluation used (Kendal *et al.*, 1993) should be replaced with the seven-stage abdominal strength test (Ellis *et al.*, 2000).

Find and implement a way to determine if the injury prevention and training programme can prevent injuries from occurring, reducing the possibility of injury or the severity of the injuries.

Lastly, it is recommended that the methodology of this study can be used for further evaluation of the effectiveness of an injury prevention and training programme on the improvement of the biomechanical, physical and motor and anthropometric profiles of elite cricketers of other provinces.

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ANNEXURE 3.3.1

Biomechanical evaluation form

Players information							
Name						**Age**	
Dominant hand		Left	Right	**Dominant foot**		Left	Right
Medical history							
Present				**Past**			
Biomechanical evaluations							
	Grade						
Area	Left	Right	Left	Right	Left	Right	**Grade detail**
Lower limb region							
Ankle dorsiflexion	1	1	2	2	3	3	**1:** 30°+ **2:** 20° **3:** < 20°
Thomas test							
Iliotibial band mobility	1	1	2	2	3	3	**1:** 12H00 **2:** 11H55 or 12H05 **3:** 11H50 or 12H10
Quads mobility	1	1	2	2	3	3	**1:** 50°+ **2:** 30°- 50° **3:** < 30°
Iliopsoas mobility	1	1	2	2	3	3	**1:** 30°+ **2:** 15 - 30° **3:** < 15°
Gluteus maximus mobility	1	1	2	2	3	3	**1:** 90°+ **2:** 60°- 90° **3:** < 60°

Area	Grade						Grade detail
	Left	Right	Left	Right	Left	Right	
Hip joint							
Adductor mobility	1		2		3		**1:** 120°+ **2:** 100° - 120° **3:** < 100°
Hip internal mobility	1	1	2	2	3	3	**1:** 30°+ **2:** 15° - 30° **3:** < 15°
Hip external mobility	1	1	2	2	3	3	**1:** 30°+ **2:** 15° - 30° **3:** < 15°
The knee region							
Q-angle	1	1	2	2			**1:** 9°< **2:** 9°>
Patella squint	1	1	2	2			**1:** 9°< **2:** 9°>
Patella tilt	1	1	2	2			**1:** 0°< **2:** 0°>
Vastus medialis – lateralis comparison	1	1	2	2			**1:** Normal **2:** Anomalies
The foot							
Longitudinal arch status	1	1	2	2	3	3	**1:** Flat **2:** Normal **3:** High
Forefoot positional	1	1	2	2			**1:** Normal **2:** Anomalies
Rear foot standing	1	1	2	2	3	3	**1:** 0° - 9° **2:** 0° **3:** 9°+
Rear foot lying	1	1	2	2	3	3	**1:** 0° - 9° **2:** 0° **3:** 9°+
Transverse arch area comparison	1	1	2	2			**1:** Normal **2:** Flat
Foot mobility	1	1	2	2	3	3	**1:** Hyper **2:** Normal **3:** Ridged
Toes positional	1	1	2	2			**1:** Normal **2:** Anomalies
Detail anomalies	Forefoot positional				Toes positional		

Area	Grade						Grade detail
	Left	Right	Left	Right	Left	Right	
Pelvic girdle region							
Leg length discrepancy	1	1	2	2	3	3	**1:** Left = Right **2:** 1 cm discrepancy **3:** 1 cm + discrepancy
ASIS	1		2				**1:** Left = Right **2:** Discrepancy
PSIS	1		2				**1:** Left = Right **2:** Discrepancy
Pelvic tubercle height	1		2				**1:** Left = Right **2:** Discrepancy
Sacroiliac cleft	1		2				**1:** Left = Right **2:** Discrepancy
Bilateral pelvic position	1		2		3		**1:** 2 -3 cm **2:** 3 -5 cm **3:** 5cm +
Spinal region: **Spinal dynamic mobility**							
TLF mobility	1	1	2	2	3	3	**1:** 2 -3 cm **2:** 3 -5 cm **3:** 5cm +
Sacral rhythm	1	1	2	2			**1:** Left = Right **2:** Anomalies
Functional extension mobility	1		2		3		**1:** Easy ROM **2:** Limited ROM **3:** Hyper
Functional flexion mobility	1		2		3		**1:** Easy ROM **2:** Limited ROM **3:** Hyper
Rotational mobility	1		2		3		**1:** Easy ROM **2:** Limited ROM **3:** Hyper
Side flexion mobility	1		2		3		**1:** Easy ROM **2:** Limited ROM **3:** Hyper

Area	Grade						Grade detail
	Left	Right	Left	Right	Left	Right	
Spinal positional alignment: Coronal axis							
Head position	1		2				**1:** Normal **2:** Anomalies
Cervical	1		2				**1:** Normal **2:** Anomalies
Thoracic	1		2				**1:** Normal **2:** Anomalies
Lumbar	1		2				**1:** Normal **2:** Anomalies
Detail anomalies							
Spinal positional alignment: Sagital axis							
Head position	1		2				**1:** Normal **2:** Anomalies
Cervical	1		2				**1:** Normal **2:** Anomalies
Thoracic	1		2				**1:** Normal **2:** Anomalies
Lumbar	1		2				**1:** Normal **2:** Anomalies
Detail anomalies							
Upper limb region							
Hand behind back ROM	1	1	2	2	3	3	**1:** Left = Right or less 1cm **2:** 1 – 3 cm **3:** 3 cm +
Hand behind neck ROM	1	1	2	2	3	3	**1:** Left = Right or less 1cm **2:** 1 – 3 cm **3:** 3 cm +
Shoulder position	1	1	2	2			**1:** Neutral or two thirds + **2:** Two thirds +
Wining position	1	1	2	2			**1:** None **2:** Winging
Shoulder outline composition	1	1	2	2			**1:** Muscular **2:** Bony
Throwing position (ROM)	1	1	2	2			**1:**Coronal mid + **2:**Coronal mid -

Area	Grade						Grade detail
	Left	Right	Left	Right	Left	Right	
Neurodynamics							
Straight leg raise	1	1	2	2	3	3	**1:** 90° + **2:** 70° - 90° **3:** < 70°
Upper limb tesnsion test	1	1	2	2	3	3	**1:** 180° - 0° no tension **2:** 180° - 0° with tension **3:** 180° - 0° +
L3,4 prone knee bend	1	1	2	2	3	3	**1:** Full ROM no tension **2:** Full ROM with tension **3:** not touching
Slump test	1	1	2	2	3	3	**1:** Full ROM with dorsiflexion; no tension. **2:** Full ROM with dorsiflexion; with tension. **3:** Limited ROM with tension
Comments							

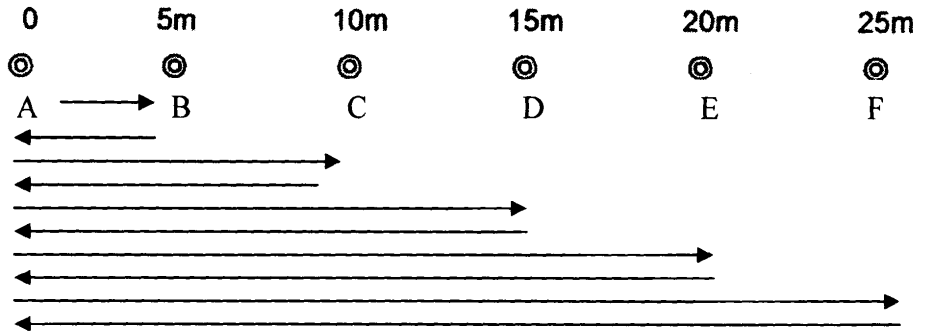
Annexure 3.3.2 Schematics of physical fitness and motor evaluation form

Name:						
Tests						
Multi stage fitness test: bleep test	Shuttles					
Sit and reach test			1.	2.	3.	
Abdominal strength test						
One minute oblique sit up test	Left side					
	Right side					
One minute push up test						
Run a three test			1.	2.		
505 agility test			1.	2.		
5-metre shuttle run test	**Distance**					
	1.	2.	3.	4.	5.	6.	Total m

Annexure 3.3.3 Schematic of the result form for the anthropometrical evaluation

Name			
Age			
Left or right dominant			
Body Stature		cm	
Body weight		kg	
	Measurements		
Skin folds	**1.**	**2.**	**3.**
Triceps			
Biceps			
Sub scapular			
Supra spinal			
Abdominal			
Thigh			
Calf			
Breadth Measurements			
Humeral			
Femoral			
Girth Measurements			
Flexed arm (bicep)			
Calf			
Mid thigh			

Annexure 3.3.2.7 Schematics and score sheet for the 5-meter multiple shuttle test



Distance (meter)	Reference
5	1 (A to B)
10	1B1 (B to A)
15	1F1 (A past B to C)
20	2 (A to C)
25	2B1(C past B to A)
30	2B2 (C to A)
35	2F1 (A past B to D)
40	2F2 (A past C to D)
45	3 (A to D)
50	3B1 (D past C to A)
55	3B2 (D past B to A)
60	3B3 (D to A)
65	3F1 (A past B to E)
70	3F2 (A past C to E)
75	3F3 (A past D to E)
80	4 (A to E)
85	4B1 (E past D to A)
90	4B2 (E past C to A)
95	4B3 (E past B to A)
100	4B4 (E to A)
105	4F1 (A past B to F)
110	4F2 (A past C to F)
115	4F3 (A past D to F)
120	4F4 (A past E to F)
125	5 (A to F)
130	5B1 (F past E to A)
135	5B2 (F past D to A)
140	5B3 (F past C to A)
145	5B4 (F past B to A)
150	5B5 (F to A)

ANNEXURE 3.4

Injury report form

Date:	Name:	
Age:		
Anatomical site of injury		
1. Head, cervical spine and face		
Head	Cervical spine	Face
2. Upper limb		
3. Thoracic spine, lumbar spine and trunk		
Thoracic spine	Lumbar spine	Trunk
4.Lower limb		

Severity of injury		
Type	**Days of play / practice**	
Minor	1 – 7 days	
Moderately serious	8 – 21 days	
Serious	21+ days	

Nature of injury suffered	
Fracture	
Stress fracture	
Joint	
Dislocation	
Muscle	
Tendon	
Ligament	
Fascia	
Cartilage	
Nerve	
Open wound	
Other	

Mechanism of injury	
Contact / impact	
Dynamic overload	
Overuse	
Structural vulnerability	
Inflexibility	
Muscle imbalance	
Rapid growth	

Annexure 3.5

Injury prevention and training programme

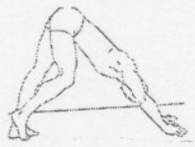
First in the annexure are the flexibility programme and the extra stretches for the gluteal muscle area. Following the flexibility programme is the first six week programme, second six week programme and the third six weeks programme. The maintenance programme will follow the third six week programme and lastly the feet exercises.

The first six week programme consist of leg exercises, shoulder exercises, lower back and stomach exercises, upper back exercises and the fitness programme. The second six week programme consist of leg exercises, shoulder exercises, lower back and stomach exercises, chest and back exercises and the fitness programme. The third six week programme consist of leg exercises, chest, back and shoulder exercises, lower back and stomach exercises and the fitness programme. The maintenance programme is a combination of all the above exercises in the three six week programmes. The feet exercise must be done once a week in conjunction with the leg programme. Feet exercise a to be done for the first six weeks and feet exercises b with the next six week programme.

Kilogramme (weight) to be used per exercise is not included, as the kilogramme per person might differ according to the strength and ability of the cricketer. The weight for the exercises should therefore be adjusted according to the specific requirements of the individual cricketer.

Flexibility programme

Calf stretch



- from a push-up position, move the hands closer to the feet to raise the hips
- slowly press the one heel into the floor and flex the other knee
- touch the floor with the heel, hold the stretch for 2 x 30 seconds for the left and right anatomical side

Achilles tendon stretch (TA)



- bend the back leg at the knee, toes pointing forward,
- keep the back heel on the floor, press down on the floor with body weight
- bend both knees a little and sink the hips down
- hold the stretch for 2 x 30 seconds for each anatomical sides

Hamstrings stretch



- sit on the floor with one leg straight and the other bent at the knee
- bent knee's heel touches inside of thigh of straight leg
- keep the back straight and lower the upper torso to the knee
- hold the stretch for 2 x 30 sec. for the left and right anatomical sides

or



- lie on back, one leg on the floor, the other in the air with a towel around the foot
- keep the knee straight and pull the foot towards you by pulling the towel with your hands
- keep the other leg on the floor, do not lift it from the floor, hold the stretch for 2 x 30 seconds for each anatomical side

Quadriceps stretch



- stand up straight, bend one knee and take the bent knee around the ankle
- pull the bent knee to the buttocks without arching the back
- hold the stretch for 2 x 30 seconds for the left and right anatomical side

or



- lie on one side, flex the knee, grab the ankle of the bent knee
- pull the heel towards the buttocks with without over-compressing the knee
- do not arch the lower back , hold the stretch for 2 x 30 seconds for the left and right anatomical sides

Adductor stretch



- sit up straight, legs flexed and spread with the heels of the feet touching each other
- take the ankles and pull them as close as possible to the groin
- place the elbows on the knees and push the knees to the floor
- hold the stretch for 2 x 30 seconds for each anatomical side

or



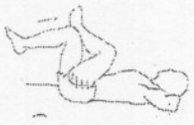
- sit on the floor with the feet/legs spread out as far as possible
- pull toes towards the nose, keep the back straight & head up
- bend towards the floor till stretching is felt, without forcing the stretch
- hold the stretch for 2 x 30 seconds for the anatomical sides

Iliotibial band stretch



- sit up straight, cross left foot over the right leg, slide the heel towards the buttocks, place the right elbow on outside of left knee
- look over left shoulder while turning the trunk
- gently push on the knee with the right elbow, hold the stretch for 2 x 30 seconds for the left and right anatomical side

Gluteal stretches



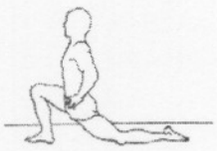
- lie on the back with one leg crossed over one knee
- lift the one leg from the floor and let it gently push the bent knee to the nose with the supporting leg
- keep the back, shoulders & neck on the floor, hold the stretch for 2 x 30 seconds for each anatomical side

or



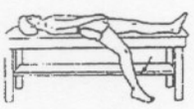
- lie on the floor with one leg flexed, grasp the knee with the hand on the same side
- grip the ankle with the opposite hand, pull the knee to the shoulder
- pull the ankle to the other shoulder, keep the back & shoulder on the floor, hold the stretch for 2 x 30 seconds for the left and right anatomical side

Iliopsoas stretch



- hands on the knees, one leg bent at the knee and the other leg straight
- keep the front leg bent at 90°, back straight
- press the straight leg to the floor
- hold the stretch for 2 x 30 seconds for the left and right anatomical sides

or



- lie on the side of a bench or a table, keep the one leg on the bench while the other hangs down the side of the table
- let the leg hang down till a stretch is felt
- hold the stretch for 2 x 30 seconds for the left and right anatomical side

Lower back stretches



- lie flat on the back, flex the knees to the knees
- grasp the thighs to prevent hyperextension of the knees
- pull the knees to the chest and shoulders
- hold the stretch for 2 x 30 seconds for the left and right anatomical sides

or



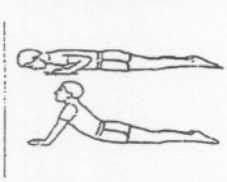
- pull one leg over the other leg, keep the knee straight.
- keep the shoulders on the floor
- hold the head in the other direction, try to keep the hips still
- feel stretch in lower back, hold the stretch for 2 x 30 seconds for the left and right anatomical sides

Side stretch (thoraco-lumbar stretch)



- lie on your side with your ankle, knees, hips, shoulders and head in a straight line
- place one of your hands on the floor under your shoulder
- push the trunk up until you feel your side stretching
- hold the stretch for 2 x 30 seconds for the left and right anatomical sides

Abdominal stretch



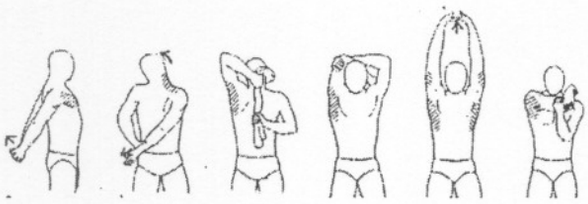
- lie face down on the floor with your body extended
- place your palms of your hands under your shoulders,
- fingers facing forward, press down on the floor, raise your head and trunk
- push the trunk up as far as possible, keeping your hips on the floor
- hold the stretch for 2 x 30 seconds for the anatomical sides

Neck stretch



- stand upright, back straight and hands on top of the head
- while keeping the back straight, pull the chin to the chest
- hold the stretch for 2 x 30 seconds

Shoulder stretches



- with all the shoulder stretches maintain a good body posture throughout
- keep the back straight throughout for all the stretches
- hold the stretch for 2 x 30 sec. for the left and right anatomical sides

Upper back stretches



- sit on all fours, push buttocks back onto heels, keep one arm straight in front
- other arm bent to let the forehead rest on
- hold the stretch for 2 x 30 seconds for the left and right anatomical sides

Wrist stretches

Flexion



- hold arm straight in front of shoulder, then with the other hand pull the palm of the hand towards the body
- hold the stretch for 2 x 30 seconds for the left and right anatomical sides

Extension



- hold arm straight in front of shoulder, then with the other hand pull the fingers of the hand towards the body
- hold the stretch for 2 x 30 seconds for the left and right anatomical sides

Gluteal stretches

Stretch 1



- lie on the back with one leg crossed over one knee
- lift the one leg from the floor and let it gently push the bent knee to the nose
- keep the back, shoulders and neck on the floor
- hold the stretch for 2 x 30 seconds per anatomical side

Stretch 2



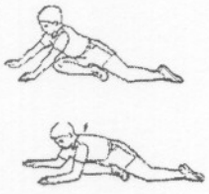
- lie on the floor with one leg flexed, grasp the knee with the same side hand
- the ankle with the opposite hand, pull the knee to the shoulder
- pull the ankle to the other shoulder, keep the back & shoulder on the floor
- hold the stretch for 2 x 30 seconds per anatomical side

Stretch 3



- stand in front of a table, hip height
- place one bent leg on the table and ankle flat on the table, keeping the back leg straight
- lean forward until a stretch is felt in the buttocks
- hold the stretch for 2 x 30 seconds per anatomical side

Stretch 4



- sit on one buttock, knee bent at 90° with the foot of the bent leg on the thigh on back leg
- hands in front of shoulders, keep the body square
- lean forward by bending the elbows, keeping the back straight, lean forward until a stretch is felt in the buttocks
- hold the stretch for 2 x 30 seconds per anatomical side

Stretch 5

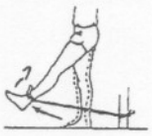


- sit up straight, place the one leg over the other
- pull the bent knee up and across towards the opposite shoulder
- the stretch should be felt on the outside of the hip
- hold the stretch for 2 x 30 seconds per anatomical side

First six weeks programme

Legs

1. Straight leg raise: pulley



- place the band of the pulley in line with the ankle, face away from the pulley
- bend the supporting leg a little bit, pull the toes up towards the nose
- with a straight knee pull the leg forward, approx. 45-60°
- do not lean backwards during the exercise and keep the stomach tight

2. Hip extension: pulley



- place the band around the ankle and face towards the pulley
- bend the supporting leg a little and tighten the stomach
- pull the leg back in a straight line without arching the back or turning the hips around
- stay square with the hips, do not bend forwards during the exercise

3. Leg adduction: pulley



- stand sideways to the machine, place the band around the inside ankle
- bend the supporting leg a little and keep the stomach tight at all times
- keep the leg straight and pull it towards the supporting leg without passing the midline
- do not hold onto the railing, stay upright (square) with the body

4. Leg abduction: pulley



- stand sideways to the machine, place the band on the outside leg
- bend the supporting leg a little and tighten the stomach, pull towards the outside (45-60°) with a straight leg.
- do not hold onto the railing and keep the body in an upright (square) position

5. Hip flexion: pulley



- stand with the machine at your back, place the band around one ankle
- bend the supporting leg a little and tighten the stomach
- keep the body in a straight position and pull the leg up with a bent knee
- let the leg extend fully after each repetition, thus let the heel touch the floor
- do not hold onto the railing and do not arch your back when doing the exercise

6. Seated calf raise



- place the feet on the angled foot raises
- make sure that the balls of the feet are in full contact with the platform, while heels must be free to move
- grasp the handles and pull the bar over the thighs, raise the heels as far up as possible
- balls of the feet must stay in contact with the platform

7. Single leg squat



- stand with feet shoulder-width apart, bend the one leg at the knee 90°, and press against the wall with the bent leg
- tighten the stomach and do a single leg squat keeping the pressure on the wall with the bent leg
- do not let the knee pass the toes when going down, and keep the body upright throughout

8. Lunges: (one leg at a time)

Forward



Sideways



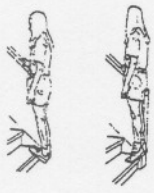
- **Forward:** keep the dumbbells in both hands, take a larger than normal step forward, keep the body upright and the stomach tight and bend the back leg a little.
- do not let the knee pass the toes when coming up
- **Sideways:** stand with feet a little wider than shoulder width apart, using dumbbells in the hands
- tighten the stomach and keep the back straight, step to the one side of the body,
- turn the toes a little to the outside (45-50°) so that when landing the leg is turned outward
- land on the ball of foot, then do a squat movement with lunging leg, keeping the stomach tight and the back straight, go down until the thigh is parallel with the ground, with the knee bent 90°
- knee not going past the toes, keep the push-off leg straight at the knee
- push back to starting position, with an upward and sideward movement, at moderate speed.

Backward



- **Backward:** keep the dumbbells in both hands, take a larger than normal step backward,
- keep the body upright and the stomach tight and bend the back leg a little
- do not let the knee pass the toes when coming up

9. Standing calf raises: step (single leg)



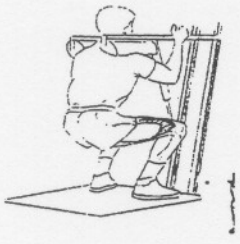
- stand on a step with the balls of the feet at the end of the step
- slowly go down as far as possible with the heels, supporting yourself
- push up as far as possible after reaching the lowest point
- upward movement must be faster than downward movement

10. Standing leg curl



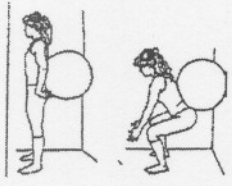
- stand upright with the bar just above the ankle
- tighten the buttocks, then the hamstring and lastly the back before lifting the weights
- do not lean forward when performing the exercise, 2 seconds up and 4 seconds down

11. Standing squats: calf-lift machine



- do the squats on the calf-lift machine or do the back squat
- keep the back straight throughout the exercise
- knee must never pass the toes when going down
- keep the stomach tight throughout
- going down, push the buttocks back, whilst keeping the back straight, weight goes onto the heels
- never go past 90° with the knees when going down
- push up with an explosive movement

12. Swiss ball wall glide: two legs (hold)



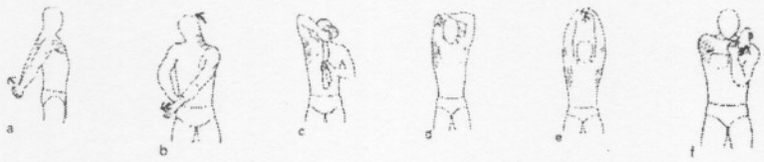
- lean against the wall with the back against the ball and ball against the wall
- push feet 30-40 cm from the wall
- slide down until the quads make a 90° angle with the feet
- keep the position for the duration of the exercise

Leg exercises										
Name	Date		Date		Date		Date			
	Week	1 & 2	Week	3 & 4	Week	5	Week	6	**Fitness**	
Exercises	Rep.	Weight	Rep.	Weight	Rep.	Weight	Rep.	Weight		
1. Straight leg raise: pulley	3x20	pl.	3x20	pl.	3x15	pl.	3x20	pl.	**Week1 & 2**	Rowing
2. Hip extension: pulley	3x20	pl.	3x20	pl.	3x15	pl.	3x20	pl.	2x2000m	t =
3. Leg adduction: pulley	3x20	pl.	3x20	pl.	3x15	pl.	3x20	pl.	**Week 3 & 4**	Rowing
4. Leg abduction: pulley	3x20	pl.	3x20	pl.	3x15	pl.	3x20	pl.	level 6	
5. Hip Flexion: pulley	3x20	pl.	3x20	pl.	3x15	pl.	3x20	pl.	2x2000m	t =
6. Seated calf raise	3x20	kg	3x20	kg	3x15	kg	3x20	kg	**Week 5**	Rowing
7. Single leg squat	3x10	kg	3x12	kg	3x15	kg	3x15	kg	level 6	
8. Lunges: (one at a time)	3x10	kg	3x10	kg	3x10	kg	3x10	kg	2x2000m	t =
9. Standing calf raises: step (single leg)	3x20	kg	3x20	kg	3x15	kg	3x20	kg	**Week 6**	Rowing
10. Standing leg curl	3x20	pl	3x20	pl	3x15	pl	3x20	pl	level 6	
11. Standing squats: calf-lift machine	3x20	kg	3x20	kg	3x15	kg	3x20	kg	2x2000m	t =
12. Swiss ball wall glide: two legs (hold)	2x	60 sec	3x	60 sec	3x	60 sec	4x	60 sec		

pl = plates; kg = kilogramme; L = level; treadmill on 13 = speed of treadmill is on 13 km/h.

Shoulders

1. Stretches: 2 x 30 sec per stretch



2. Empty the can





- start with the dumbbells in both arms next to the side of the body
- lift the arms to shoulder height with the thumbs facing downward
- now while keeping the dumbbells shoulder height, turn the thumbs upward and back so the palm of the hand is facing upward (towards the ceiling)
- immediately turn the thumbs back so that the palm is facing down towards the floor
- hands must remain at shoulder height at all times

3. Side way bend



- stand upright with the dumbbell in one hand next to the side of the body
- slowly bend to the other side as far as possible in a straight line, come up slowly and repeat

4. Wagon wheel



- keep the dumbbells at your hips with the palms facing forward
- keep the stomach tight, pull the dumbbells up in a straight line past the ears until the hands touch above the head
- do not arch the back; fast up and slow down

5. Lateral T to external T



- elbow bent at 90° with the hands in front of the elbows and the elbows in line with the shoulders, always keep the elbows at shoulder level
- pull the hands up, keeping the position of the elbow, until the palm of the hand faces forward and is in line with the elbow
- keep the stomach tight throughout the exercise

6. Triceps push-out



- stand upright with the arm in front of the shoulder and elbow bent at 90°
- the other arm must support under the bent elbow
- extend the bent arm forward, keeping the elbow straight and not lowering the arm lower than shoulder level, keep the stomach tight, do not arch the back

7. Bend over flies





- bend over, bend the knees and keep the back straight during the exercise (do not arch the back), and also keep the elbows straight during the exercise
- keep the head up by looking up and forward, then only lift the dumbbells to shoulder height/ level when pulling up (do not use back when executing)
- keep the stomach tight and let the dumbbells down in a controlled fashion

8. Seated biceps curl



- sit on an incline bench with the seat at 45°, pull the arm up towards the shoulder
- do not arch the back when pulling up, keep the back against the seat the whole time
- extend the arm fully when going down,
- keep the line between the shoulder, the elbow and the arm

9. Pec dec and military press: exercises combined into one







- take the dumbbells in both hands and assume the position for the pec dec
- elbows in line with the shoulders and the hands above the bent elbow
- keeping the stomach tight, pull the elbows towards each other, elbows still in line with shoulders
- when the shoulders touch return to starting position
- now extend the arms upward in line with the ears, keep the stomach tight and do not arch the back
- return to starting position; this is one rep.

10. Appeal



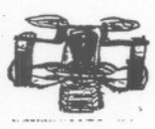
- hold the dumbbell with both hands in front of body
- tighten the stomach and lift the arms while keeping them straight at the elbows
- lift up next to the ears, pull up in 2 seconds and down in 4 seconds
- **do not arch your back and keep the body straight**

11. Push up: staggered



- place one hand on the bench and the other hand on the floor
- go down and do a push up with one hand on the floor and the other on the bench
- keep the stomach tight and the body straight throughout the exercise

12. Reverse pec dec



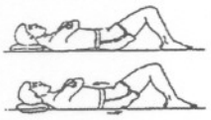
- same execution as the normal pec dec, only here you sit with your head to the machine
- keep the stomach tight during the exercise
- elbows in line with the shoulders, pull the shoulders back
- controlled back to the front

Shoulders

Name	Date		Date		Date		Date		Fitness
	Week	1 & 2	Week	3 & 4	Week	5	Week	6	
Exercises	Rep.	Weight	Rep.	Weight	Rep.	Weight	Rep.	Weight	
1. Stretches:	3 x	20 sec	3 x	20 sec	3 x	20 sec	3 x	20 sec	**Week 1 & 2** 15 min
2. Empty the can	3x15	kg	3x20	kg	3x25	kg	3x20	kg	treadmill on 13
3. Side way bend	3x15	kg	3x20	kg	3x15	kg	3x20	kg	**Week 3 & 4** 12 min
4. Wagon wheel	3x15	kg	3x20	kg	3x25	kg	3x20	kg	treadmill. 1 min on 11,
5. Lateral T to external T	3x15	pl	3x20	pl	3x25	pl	3x20	pl	12, 13, 14, 8 min 13
6. Triceps push-out	3x15	kg	3x20	kg	3x25	kg	3x20	kg	**Week 5** 12 min x2
7. Bend over flies	3x15	kg	3x20	kg	3x15	kg	3x20	kg	treadmill. 1 min on 11,
8. Seated biceps curl	3x15	kg	3x20	kg	3x25	kg	3x20	kg	12, 13, 14, 8 min 13
9. Pec dec and military press	3x15	kg	3x20	kg	3x15	kg	3x20	kg	**Week 6** 2 x 12 min
10. Appeal	3x10	kg	3x20	kg	3x25	kg	3x20	kg	treadmill. 1 min on 11,
11. Push up:staggered	2x10	each side	2x10	each side	2x10	each side	2x10	each side	12, 13, 14, 8 min 13
12. Reverse pec. Dec	3x15	kg	3x15	kg	3x15	kg	3x15	kg	

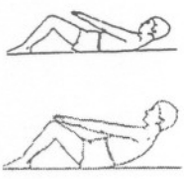
Lower back and stomach

1. Pelvic tilt: press ball



- lie on the back, with the knees bent, hands on the thighs or on the chest and the chin on the chest
- place a lightweight ball between the knees and press slightly, tighten stomach, push the back into the floor
- tighten the buttocks, lifting 1-3 cm off the floor, hold for 5 seconds

2. Crunches



- lie on your back with the knees bent and hands on your thighs
- slowly move the hands up until the palms of the hands reach your knees,
- keep the head and the shoulders in a straight line
- slowly return to starting position

3. Static stomach exercise



- lie on the back with the knees bent, push with the hands on the thighs
- push the back into the floor by tightening the stomach muscles
- place the chin on the chest, hold for 5 seconds

4. Side to side roll



- lie on your back and grab the rail with both hands, bend the knees at 90° and at the hips at 90°
- keep the legs from the ground, tighten the stomach and roll side to side
- maintain a good posture during the exercise

5. Lower trunk lift: pull knees to chest



- lie flat on the back with the legs straight out & the hands next to the body
- tighten the stomach and keep the back in contact with the floor at all times
- lift both legs from the floor slowly, then lift until the knees form a 90° angle with the hips
- NB!! back must stay flat and in contact with the floor at all

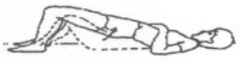
6. Stomach exercise: reach the roof





- lie on your back with the hands together in front of the chest
- keep the feet on the floor and reach for the roof with both hands
- keep the head and shoulders in a straight line

7. Pelvic lift: press ball



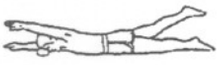
- lie on the floor on your the back, hands next to the side of the body or on the chest
- tighten the gluteus muscles and stomach and lift the buttocks off the floor (15–30 cm)
- place a light ball between the legs and slightly press against the ball with the legs
- knees, stomach and shoulders in line and keep the head on the floor, hold the position for duration

8. Heel touches



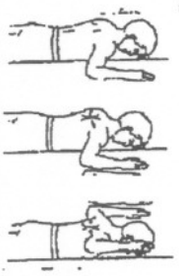
- lie on your back with the knees bent, cup your hands
- tighten your stomach and lift your body and move to one side, touching the heel with a cupped hand

9. Lie on stomach: lift opposite arm and leg



- lie on stomach with arms and legs straight, lift the opposite hand and leg from the floor
- forehead and hips must stay on the floor, tighten the gluteal muscles first, hamstring next and the back last to lift

10. Upper trunk extension



- lie flat on the ground with the forehead on the ground, elbows bent at 90° in line with the shoulders
- pull the scapulas together, & lift arms & elbows from the ground
- keep the forehead on the ground the whole time during the exercise

11. Leg thrusts



- lie on your back and grab the rail with both hands, bend the hips at 90°, keep the knees locked during the exercise
- lift the buttocks from the floor (10-15 cm) towards the roof in a straight line, controlled up and down

12. All fours: lift bend leg (sideways)



- stand on all fours, hands under the shoulders, knees under the hips
- press down on the floor with hands and knees, tighten the stomach and keep the back straight
- tighten buttock muscles, come onto one knee & lift other knee
- stop when knee is in line with the hips, stay square at all times and keep balancing on the knee

13. Lie elbows and toes



- lie on the floor with the elbows under the shoulders, tighten the buttocks and the stomach,
- come onto the toes, lifting the body from the floor and keeping the neck in a straight line with the shoulders
- keep the shoulders, back, hips, knees and heels in a straight line

14. All fours: lift opposite arm and leg



- stand on all fours, hands under the shoulders & knees under the hips
- press down on the floor with hands & knees
- tighten the stomach, lift an arm and a leg opposite to each other .
- arm straight and in line with ears, leg straight and in line with hips, keep the balance and the back straight
- tighten the gluteal muscles before lifting the leg

15. Side up





- lie on your side, elbow bent under the body in line with the shoulder
- the ankles, hips, shoulders and head must be in a straight line
- tighten your stomach and lift your body from the floor in a straight line, up and down

16. Bridging: hold



- lie on your back, hands on your stomach or next to your body
- lift one leg so that it is in line with the bent knee and pull the toes to the nose
- tighten stomach and buttocks, then lift buttocks off the floor
- knees, hips and stomach in a straight line head and neck on the floor, and hold 8 sec

Lower back and stomach

Name	Date		Date		Date		Date		
	Week	1 & 2	Week	3 & 4	Week	5	Week	6	**FITNESS**
Exercises	Rep.	Hold	Rep.	Hold	Rep.	Hold	Rep.	Hold	
1. Pelvic tilt: press ball	2x10	5 sec	2x12	5 sec	3x10	5 sec	3x10	5 sec	**Week 1 & 2** 20 min
2. Crunches	2x15		2x20		3x12		3x15		treadmill on 11
3. Static stomach exercise	2x10	5 sec	2x12	5 sec	2x12	5 sec	2x12	5 sec	**Week 3 & 4**
4. Side to side roll	2x10		2x15						20 min treadmill
5. Lower trunk lift: knees to chest	2x10		2x15		3x10		3x12		on 11
6. Stomach exercise: reach the roof	2x12		2x20		3x12		3x15		**Week 5**
7. Pelvic lift: press ball	2x10	8 sec	2x12	8 sec	3 x10	8 sec	3x12	8 sec	25 min treadmill
8. Heel touches	2x10		2x12		3x10		3x12		on 11
9. Lie on stomach: lift opposite arm & leg	3x10		3x12		3x15		3x20		
10. Upper trunk extension	2x12		2x15		3x10	3 kg	3x12	3 kg	
11. Leg thrusts	2x12		2x15		3x12		3x15		
12. All fours: Lift bend leg (sideways)	2x10		2x12		2x15		2x15		**Week 6**
13. Lie elbows and toes	2 x	45 sec	2 x	50 sec	2 x	55 sec	2 x	60 sec	30 min treadmill
14. All fours: opposite arm and leg	10 x	8 sec	10 x	8 sec	10 x	8 sec	10 x	8 sec	on 11
15. Side up	10 x		12 x		2x10		2x12		
16. Bridging: hold	10 x	8 sec	12 x	8 sec	2x10	8 sec	2x12	8 sec	

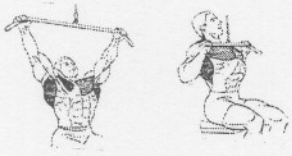
Upper back

1. Sideways bend



- stand upright with the dumbbell in one hand next to the side of the body
- slowly bend to the other side as far as possible, in a straight line
- come up slowly and repeat

2. Lateral pull down to chest



- take the bar just wider than shoulder width
- keep the back straight and the stomach tight
- pull down towards the chest
- return to the starting position in 4 sec

3. Pulley: standing biceps curl



- stand up straight, stomach tight, elbows at shoulder level, hands 15-20 cm above the elbows
- grab the handles with the palms facing upward, stand in the middle of the cables
- pull the hands towards the ears, keeping the body tight and still, elbows staying at shoulder level
- hold for 2 seconds and slowly return to the starting position in 4 sec.
- whole body must be stabilized during the exercise to ensure that only the biceps are working

4. Pulley: triceps push down



- stand in front of the cable machine, feet shoulder width, elbows next to body,
- start with hands next to shoulders and push down till elbows are extended, fast down and slow up,
- keep the stomach tight and back straight, only use the triceps to execute the exercise

5. Dumbbell external rotation



- hold the hands in front of the body in line with the shoulders and tighten the stomach
- rotate the arms externally to the side of the body (as far as possible), pinch the scapulas together
- keep the elbows in contact with the body at all times
- slowly return to the starting position

6. Dumbbell: bend-over flies





- bend the knees and keep the back straight during the exercise (do not arch the back)
- keep the elbows straight during the exercise, keep the head up by looking up and forward
- lift the dumbbells to shoulder level when pulling up (do not use the back when executing the exercise)
- keep the stomach tight and let the dumbbells down in a controlled fashion

7. Reverse pec dec



- the same execution as the normal pec dec. only here sit with the head facing the machine
- keep the stomach tight during the exercise, elbows in line with the shoulders, pull the shoulders back.
- controlled movement back to starting position

Upper back

Name	Date		Date		Date		Date		FITNESS
	Week	1 & 2	Week	3 & 4	Week	5	Week	6	
Exercises	Rep.	Weight	Rep.	Weight	Rep.	Weight	Rep.	Weight	
1. Sideways bend	3x15	kg	3x20	kg	3x15	kg	3x20	kg	**WEEK 1 & 2** 20 min
2. Lateral pull down to chest	3x15	kg	3x20	kg	3x25	kg	3x15	kg	stepper: manual L 10
3. Pulley: standing biceps curl	3x15	pl	3x20	pl	3x15	pl	3x20	pl	**Week 3 & 4** 20 min
4. Pulley: triceps push down	3x10	kg	3x12	kg	3x10	kg	3x12	kg	stepper: manual L 11
5. Dumbbell external rotation	3x15	kg	3x20	kg	3x15	kg	3x20	kg	
6. Dumbbell: bend over flies	2x10	pl	2x12	pl	3x10	pl	3x12	pl	**Week 5** 25 min
7. Reverse pec dec	3x15	kg	3x20	kg	3x25	kg	3x15	kg	stepper: manual L 11
									Week 6 30 min stepper: manual L 11

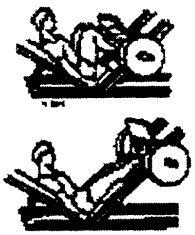
Fitness program: first six weeks

Name:			
Date: **Week 1 & 2**	**Date:** **Week 3 & 4**	**Date:** **Week: 5**	**Date:** **Week: 6**
1. 5 min. Cycle warm up & stretches	**1. 5 min. Cycle warm up** & stretches	**1. 5 min. Cycle warm up** & stretches	**1. 5 min. Cycle warm up** & stretches
2. 20 min Treadmill speed 12 Distance _____	**2. 25 min Treadmill speed 12** Distance _____	**2. 30 min Treadmill speed 12** Distance _____	**2. 35 min Treadmill speed 12** Distance _____
3. 20 min Cycle choose constant rpm put the rpm on 90 put the speed on distance & try to reach 8 miles thus going as fast as possible distance _____	**3. 20 min Cycle** choose constant rpm put the rpm on 85 put the speed on distance & try to reach 8 miles thus going as fast as possible distance _____	**3. 20 min Cycle** choose constant rpm put the rpm on 80 put the speed on distance & try to reach 8 miles thus going as fast as possible distance _____	**3. 25 min Cycle** choose constant rpm put the rpm on 80 put the speed on distance & try to reach 8 miles thus going as fast as possible distance _____
4. 4000 m Rowing **Level 6** time _____	**4. 4000 m Rowing** **Level 6** time _____	**4. 4500 m Rowing** **Level 6** time _____	**4. 4500 m Rowing** **Level 6** time _____

Second six week programme

LEGS

1. Incline leg press



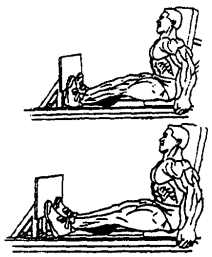
- sit in the incline leg press machine, feet shoulder width apart
- balls of the feet and heels in touch with the plate,
- let the plate come down until knees form 90° angle with hips
- from this 90° position, push the plate up to starting position
- hands hold on to the side of the machine and the back straight against the back plate

2. Standing leg curl



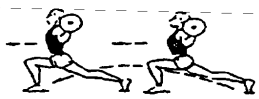
- stand upright with the bar just above the ankle, 2 seconds up and 4 seconds down
- tighten the buttocks, then the hamstring and lastly the back before lifting the weights
- lean a little bit forward when performing the exercise

3. Seated squat machine: seated calf raises



- sit on the seated squat machine, feet shoulder width apart, balls of the feet in touch with the plate, heels in the air
- keeping the knees straight and push forward with the toes as far forward as possible
- return to the starting position in a controlled fashion
- keep the back straight in the chair

4. Lunges walking with dumbbells



- the exercise is done with dumbbells, not with a barbell, keep the stomach tight and back straight
- knees never pass toes, front leg put down in a running action
- only go down to 90° with front leg, bend back leg a little

5. Standing calf raise: single leg



- stand on a step with the balls of the feet at the end of the step, lift one foot and place it behind the other
- slowly go down as far as possible with the heel, supporting yourself
- push up as far as possible after reaching the lowest point
- upward movement must be faster than downward movement

6. Side lunge



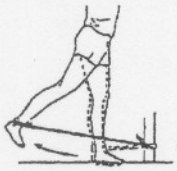
- stand with feet a little wider than shoulder width apart
- dumbbells in the hands, tighten the stomach and keep the back straight
- step to the one side of the body, turn the toes a little to the outside (45-50°) so that when landing the leg is turned outward
- land on the ball of the foot, then do a squat movement with lunging leg
- go down until the thigh is parallel with the ground, 90° with knee, knee not to go past the line upward from the toes
- keep the push-off leg straight at the knee, push back to starting position, with an upward and sideward movement at moderate speed

7. Hip flexion: onto step with high knee drive



- stand in front of a bench (30–50 cm), feet shoulder width apart
- hold dumbbells in the hands, one leg at a time
- tighten the stomach and hold the back straight while stepping onto the bench
- on top of the bench do a hip drive with the leg coming up from the ground (keeping the balance)
- place the leg back next to the other foot and climb down the bench in a controlled fashion

8. Hip extension: pulley



- place the band around the ankle and face towards from the pulley
- bend the supporting leg a little and tighten the stomach
- pull the leg back in a straight line without arching the back or turning the hips a round
- stay square with the hips
- do not bend forward during the exercise

9. Single leg squat



- stand with feet shoulder width apart, bend the one leg at the knee 90°
- place the bent leg on a bench at knee height
- tighten the stomach and do a single leg squat keeping the pressure on the bench with the bent leg
- do not let the knee pass the toes when going down, keep the body upright throughout and hold the dumbbells in the hands

10. Swiss ball: wall glide



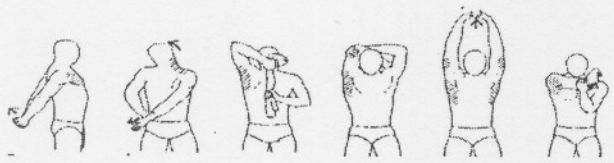
- lean against the wall, with the back against the ball and ball against the wall
- place a light-weight ball between the knees and push the feet 30–40 cm from the wall
- slide down until the quads form a 90° angle with the feet, press slightly against the light-weight ball
- keep the position for the duration of the exercise

Leg exercises

Name	Date		Date		Date		Date		Fitness
	Week	1 & 2	Week	3 & 4	Week	5	Week	6	
Exercises	Rep.	Weight	Rep.	Weight	Rep.	Weight	Rep.	Weight	
1. Incline leg press	4x15	kg	4x12	kg	4x10	kg	4x8	kg	**Week 1 & 2** Rowing
2. Standing leg curl	3x15	pl	3x12	pl	3x10	pl	3x8	pl	3 x 1000m level 6 rest = 120 sec
3. Seated squat machine: seated calf raises	3x15	kg	3x12	kg	3x10	kg	3x8	kg	**Week 3 & 4** Rowing
4. Lunges walking with dumbbells	4x8	kg	4x8	kg	4x8	kg	4x8	kg	3 x 1000m
5. Standing calf raise: single leg	3x15	kg	3x12	kg	3x10	kg	3x10	kg	level 6 rest = 120 sec
6. Side lunge	3x10	kg	3x10	kg	3x10	kg	3x10	kg	**Week 5** Rowing
7. Hip flexion: onto step with high knee drive	3x15	kg	3x12	kg	3x10	kg	3x8	kg	5 x 800m
8. Hip extension: pulley	3 x 12	pl	3x12	pl	3x10	pl	3x10	pl	level 6 rest = 120 sec
9. Single leg squat	3x10	kg	3x10	kg	3x10	kg	3x10	kg	**Week 6** Rowing
10. Swiss ball: wall glide	3x	60 sec	3x	60 sec	4x	60 sec	4x	60 sec	5 x 800m
									level 6 rest = 120 sec

Shoulders

10 min cycle warm-up and stretches: hold each stretch 2 x 30 sec.



1. Sideways bend



- stand upright with the dumbbell in one hand next to the side of the body
- slowly bend to the other side as far as possible in a straight line, come up slowly and repeat, fast down and 3 seconds up

2. Empty the can





- start with the dumbbells in both hands next to the side of the body
- lift the arms to shoulder height with the thumbs facing downward
- while keeping the dumbbells at shoulder height turn the thumbs upward so the palm of the hand is facing upward (towards the ceiling)
- immediately turn the thumbs back so that the palm is facing

3. Lateral dumbbell lift



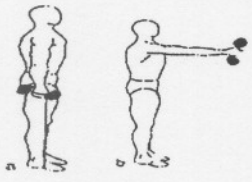
- hold the dumbbells in both hands next to the side of the body
- keep the stomach tight and lift the arms up laterally 30° to the front of the shoulders
- do not lift higher than shoulder level

4. Upright rowing



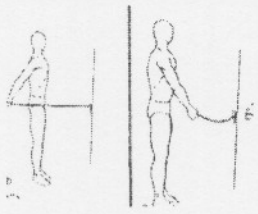
- stand with the feet shoulder width apart
- with dumbbells in hands, palms facing towards the body, tighten the stomach and lift the dumbbells to the chin with elbows bend
- do not arch the back when lifting the dumbbells, keep the body square at all times

5. Frontal dumbbell lift



- hold the dumbbells in both hands next to the side of the body
- keep the stomach tight and lift the arms directly out in front of the body, keeping the elbows straight, never higher than shoulder height
- return slowly to the start, keeping the stomach tight at all times

6. Arm extension: pulley



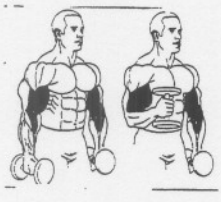
- start the exercise with the arm 45° in front of body
- grasp the pulley and pull the straight arm directly backwards
- do not bend forward when pulling back and hold the stomach tight
- fast backwards and 4 seconds to return to starting position

7. 1 arm lateral T to external T: pulley



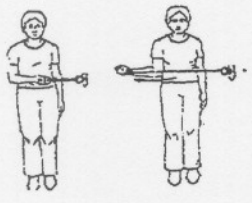
- stand in front of pulley machine, grab the bar with in one hand and the elbow bent at 90°
- hold the hand in front of the elbow and the elbow in line with the shoulder, stomach tight
- always keep the elbow at shoulder level
- pull the hand up whilst keeping the position of the elbow, until the palm of the hand faces forward and is in line with the elbow

8. Hammer curls



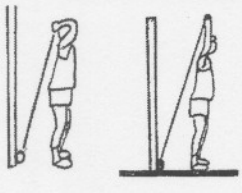
- stand upright, holding a dumbbell in each hand at the sides of the body
- grip with the thumb around the bar and the palm facing the body
- keep the elbows still next to your body during the entire curling action
- keep the stomach tight during the exercise and do not arch the back when pulling up the dumbbell
- slow and controlled down (4 seconds)

9. External rotation: pulley



- stand sideways to the machine, bend the elbow at 90°, place the elbow at the side of the stomach
- rotate the shoulder to the outside as far as possible
- keep the elbow at the side
- keep the body straight during the exercise and keep the elbow still at the side

10. Triceps extension: pulley



- stand with back to the pulley machine, take the bar with both hands at the back of the neck
- bend elbows at 90° next to the head
- stomach tight and back straight, knees bent a little
- extend the forearms, keeping the elbows still next to the head

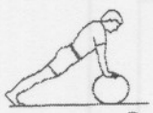
11. Push-up: balance board (hold)



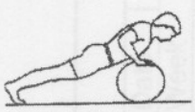
- place the hands just wider than shoulder width on the balance ball
- stomach tight and back straight
- do a push up and hold the push-up position for the duration

or

Swiss ball push-up



- place hands on ball just wider than shoulder width
- stomach tight and back straight
- do required amount of push-ups



Shoulders

Name	Date		Date		Date		Date		Fitness
	Week	1 & 2	Week	3 & 4	Week	5	Week	6	
Exercises	Rep.	Weight	Rep.	Weight	Rep.	Weight	Rep.	Weight	
Stretches	3 x	20 sec.	3 x	20 sec.	3 x	20 sec.	3 x	20 sec.	
1. Sideways bend	3x15	kg	3x20	kg	3x15	kg	3x20	kg	**Week 1 & 2** 20 min
2. Empty the can	3x15	kg	3x20	kg	3x25	kg	3x20	kg	treadmill 1 min on 9,
3. Lateral dumbbell lift	3x15	kg	3x20	kg	3x25	kg	3x20	kg	4 min on 13
4. Upright rowing	3x15	kg	3x20	kg	3x25	kg	3x20	kg	repeat for 20 min
5. Frontal dumbbell lift	3x15	kg	3x20	kg	3x25	kg	3x20	kg	**Week 3 & 4** 25 min
6. Arm extension: pulley	3x15	pl	3x20	pl	3x15	pl	3x20	pl	treadmill 1 min on 9,
7. One arm lateral T to external T: pulley	3x15	pl	3x20	pl	3x25	pl	3x20	pl	4 min on 13
8. Hammer curls	3x15	kg	3x20	kg	3x15	kg	3x20	kg	repeat for 25 min
9. External rotation: pulley	3x15	pl	3x20	pl	3x25	pl	3x20	pl	**Week 5** 25 min
10.Triceps extension: pulley	3x15	pl	3x20	pl	3x15	pl	3x20	pl	treadmill 1 min on 9,
11.Push-up: balance board (hold)	5x	30 sec	5x	35 sec	5x	40 sec	5x	45 sec	4 min on 14
									repeat for 25 min
									Week 6 30 min
									treadmill 1 min on 9,
									4 min on 14
									repeat for 30 min

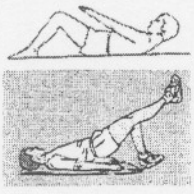
Lower back and stomach exercises

1. Bridging: hold (press ball between knees)



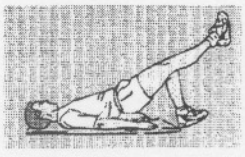
- lie on floor, knees bent and hands on chest
- place a light-weight ball between the knees and press slightly with knees against the ball
- lift one leg to the line of other knee and pull toes toward the nose
- tighten the stomach and tighten the buttocks then lift body from the floor in a straight line
- knees, hips and stomach in a straight line, neck on the floor

2. Crunches: hold for duration



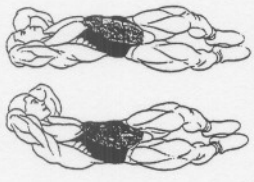
- lie on the floor, knees bent at 45°, feet flat and arms straight and pointing to the knees
- tighten the stomach and lift the upper body until the palms of the hands are touching the knees
- keep the back straight and the ears in line with the shoulders. hold for duration

3. Bridging: lift body up and down



- lie on floor, knees bend hands next to body
- lift one leg to the line of other knee
- pull toes towards the nose, tighten the stomach and tighten the buttocks, and lift the body from the floor
- knees, hips and stomach in a straight line, neck on the floor
- continue lifting the body up and down, maintaining tightness in the gluteus muscles and stomach

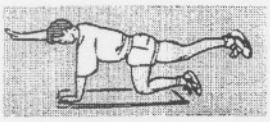
4. Oblique sit up



- lie on the back with the shoulders flat on the floor, the hips rotated at 90° on the one side
- hips almost perpendicular to the shoulders, bend the knees and hands behind the neck
- lift the head and shoulders from the floor until they are 20° from the floor
- head and shoulders in a straight line

5. All fours: lift opposite arm and leg (fast up and down)





- stand on all fours, hands under the shoulders and knees under the hips
- press down on the floor with hands and knees, tighten the stomach
- tighten the gluteus muscles before lifting the leg
- then lift an arm and a leg opposite to each other up and down fast
- arm straight and in line with ears, leg straight and in line with hips, keep the balance and keep the back straight

6. Bridging: straight leg up and down







- lie on the floor, knees bent and the hands on chest, lift one leg to the line of the other knee, pull toes towards nose.
- tighten the stomach, tighten the gluteus muscles and lift the body from the floor
- knees, hips and stomach in a straight line, neck on the floor
- maintain tightness in the gluteus muscles and stomach muscles
- lift the straight leg until it is in line with the knee providing the stability
- at the top move the straight leg down till the heel touches the floor, while keeping the body in the air
- only movement with the straight leg, up and down

7. Lie on stomach: lift opposite arm and leg



- lie on the stomach with arms and legs straight
- lift the opposite hand and leg from the floor
- forehead and hips must stay on the floor
- tighten the gluteal muscles first, hamstring second and the back last before lifting the leg and the arm from the floor

8. One-leg jack-knife





- lie on the back, bend one leg and the other leg in line with the bent knee
- hands are in front of the chest
- keep the back straight and touch the toes with the hands
- go down all the way before lifting again

9. Lie elbows toes



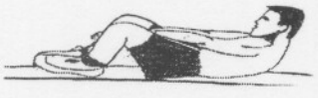
- place the bent elbows under the shoulders, tighten the stomach and back
- lift the body from the floor and come on to the toes
- keep the back and stomach tight for the duration of the exercise

10. Floor back extensions



- lie on your stomach on the floor, hands behind the neck,
- partner sits on lower legs with the hands on the hamstrings
- keep the hips on the floor and lift the upper body from the floor
- lift up as far as possible without lifting the hips from the floor
- stop exercise when any discomfort is experienced

11. Stomach exercise: butterfly



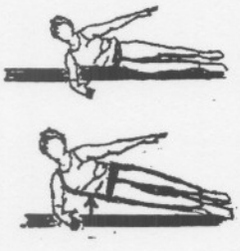
- lie on the back, place the soles of the feet together, feet 15 cm from the gluteus muscles
- drop the knees to the sides into the butterfly position
- hands are in front of the body between the knees
- tighten the stomach muscles
- lift the shoulder blades from the ground and touch the ankles with both hands

12. All fours: lift the bent leg laterally



- stand on all fours, hands under the shoulders, knees under the hips
- press down on the floor with hands and knees
- tighten the stomach muscles and keep the back straight
- tighten the gluteus muscles, come onto one knee and lift the other knee
- stop when knee is in line with hips, stay square at all times

13. Side up



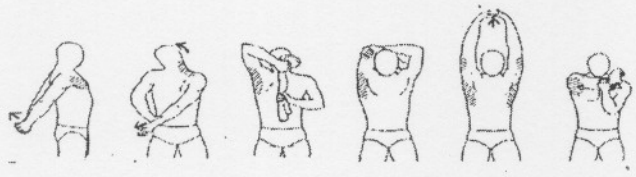
- lie on the side with the elbow bent under the body in line with the shoulder
- the ankles, hips, shoulders and head must be in a straight line
- tighten the stomach muscles
- lift the body up and down from the floor in a straight line,

Lower back and stomach

Name	Date		Date		Date		Date		Fitness
	Week	1 & 2	Week	3 & 4	Week	5	Week	6	
Exercises	Rep.	Hold	Rep.	Hold	Rep.	Hold	Rep.	Hold	
1. Bridging: hold (press ball between knees)	2x10	8 sec	2x12	8 sec	3x10	8 sec	3x10	8 sec	**Week 1 & 2** 20 min
2. Crunches: hold	2x10	15 sec	2x8	20 sec	2x6	25 sec	2x4	30 sec	treadmill on 12
3. Bridging: lift body up and down	2x10		2x12		3x10		3x12		**Week 3 & 4**
4. Oblique sit up	2x12		2x15		3x12		3x15		20 min treadmill
5. All fours: lift opposite arm & leg	2x10		2x12		2x15		3x10		on 12
6. Bridging: straight leg up and down	2x10		2x10		2x12		2x12		**Week 5**
7. Lie on stomach: lift opposite arm and leg	2x10		2x12		3 x10		3x12		25 min treadmill
8. One-leg jack- knife	2x10		2x12		3x10		3x12		on 12
9. Lie elbows toes	2 x	60 sec	3 x	45 sec	3 x	50 sec	3 x	55 sec	**Week 6**
10.Floor back extensions.	2x12		2x15		3x12		3x15		30 min treadmill
11.Stomach exercise: butterfly	2x10		2x12		3x10		3x12		on 12
13.Side up	2x12		2x15		2x20		3x12		

Chest and back exercises

1. 10 min cycle warm-up and stretches (hold 2 x 30 sec)



2. Dumbbell bench press



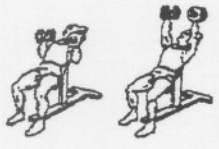
- lie on your back with the dumbbells in the hands
- keep the back flat on the bench and keep it from arching during the exercise
- keep the elbows in line with the shoulders
- do not go to far down past the line of your shoulders

3. Seated cable row



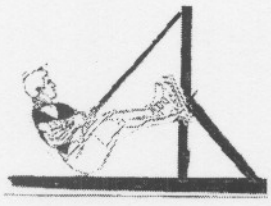
- sit with the knees bent a little, keep the back straight and stomach tight
- pull only with the arms to the chest, keeping the back straight at all times
- do not lean back with the back to pull the weight, and go fast back and slowly forward
- shoulder blade to touch when pulling back

4. Incline dumbbell press



- lie on a bench at a 45° angle
- keep the head on the bench, push upward in line with the shoulders
- shoulders down at 60° of the shoulder plane, don't let hands go lower than shoulder level

5. Incline cable row



- sit with the feet at an incline and the knees bend a little, keep the back straight and stomach tight
- pull only with the arms to the chest, keep the back straight at all times, elbows close to the body, shoulder blades to pinch when pulled back
- do not use the back to pull the weight, fast back and slowly forward

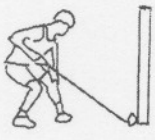
6. Seated military press



- sit in a chair that supports the back, keep the stomach tight during the exercise,
- press up in front of the ears,
- do not press behind the ears and do not arch your back

7. One-arm cable row





- stand with one foot in front of the other, knees a little bent, in front of the pulley machine
- keep the back straight and the stomach tight, the other hand resting on the front knee for support
- the arm is at a 45° holding the bar of the pulley
- pull the arm up until the hand is in line with the shoulder, keeping the body square at all times
- hold for 2 seconds, back in 4 seconds

8. Seated biceps curl



- sit on an incline bench with the seat at 45°, and pull the arm up towards the shoulder
- do not arch the back when pulling up, keep the back against the seat the whole time
- extend the arm fully when going down, keep the line between the shoulder, the elbow and the arm

9. Triceps extension



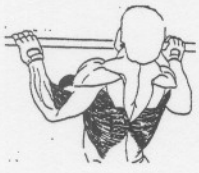
- keep the back straight, place the hand nearest to the bench on the bench
- keep the elbow still while extending the lower part of the arm
- stop when hand is in line with the elbow

10. One-arm cable abduction



- grab the handle with the palm facing inward, palm on the opposite thigh
- pull the hand up so that the palm is facing forward and is in line with the shoulder (level with shoulder); do not arch the back when pulling up
- keep the stomach tight, pull up fast, and slowly down (4 sec.)

11. Pull up: palm out



- grasp the bar with the hands just wider than shoulder width
- keep the elbows bent a little, thus not fully extending the arms
- keep the stomach tight and do not swing around

Chest and back									
Name	Date		Date		Date		Date		
	Week	1 & 2	Week	3 & 4	Week	5	Week	6	**FITNESS**
Exercises	Rep.	Weight	Rep.	Weight	Rep.	Weight	Rep.	Weight	**constant rpm**
1. 10 min cycle warm- up and stretches	3 x	20 sec	3 x	20 sec	3 x	20 sec	3x	20 sec	**Week 1 & 2** 15 min
2. Dumbbell bench press	4x10	kg	4x10	kg	4x8	kg	4x6	kg	cycle. Rpm = 90 D=
3. Seated cable row	3x15	kg	3x15	kg	3x12	kg	3x12	kg	**Week 3 & 4** 20 min
4. Incline dumbbell press	3x10	kg	3x10	kg	3x8	kg	3x6	kg	cycle. Rpm = 90 D=
5. Incline cable row	3x15	kg	3x15	kg	3x12	kg	3x12	kg	
6. Seated millitary press	3x10	kg	3x10	kg	3x8	kg	3x6	kg	**Week 5** 20 min
7. One- arm cable row	3x15	pl	3x15	pl	3x12	pl	3x10	pl	cycle. Rpm = 85 D=
8. Seated biceps curl	3x15	kg	3x15	kg	3x12	kg	3x10	kg	
9. Triceps extension	3x15	kg	3x15	kg	3x12	kg	3x10	kg	**Week 6** 20 min
10.One-arm cable abduction	3x10	pl	3x10	pl	3x10	pl	3x10	pl	cycle. Rpm= 80 D=
11.Pull up: palm out	7x		7x		7x		7x		

Fitness program: second six weeks

NAME:			
Date: **Week 1 & 2**	**Date:** **Week 3 & 4**	**Date:** **Week 5**	**Date:** **Week 6**
1. 2 laps around field & Stretch **2. 4 x 400 m** time = 70 -80 sec rest = 5 min in between **3. 30 shuttles over 20 meters** repeat 3 x rest between sets = 90 sec	1. 2 laps around field & stretch **2. 5 x 400 m** time = 70 -80 sec rest = 5 min in between **3. 30 shuttles over 20 meters** repeat 3 x rest between sets = 90 sec **4. 10 x 15 m sprints** sprint 15 m walk back, turn & sprint	1. 2 laps around field & stretch **2. 6 x 400 m** time = 70 -80 sec rest = 5 min in between **3. 35 shuttles over 20 meters** repeat 2x rest between sets = 90 sec **4. 10 x 20 m** **sprints** sprint 20 m walk back, turn & sprint	1. 2 laps around field & Stretch **2. 6 x 400 m** time = 60 -70 sec rest = 5 min in between **3. 35 shuttles over 20 meters** repeat 2 x rest between sets = 90 sec **4. 10 x 25 m sprints** sprint 25 m walk back, turn & Sprint

Third six week programme

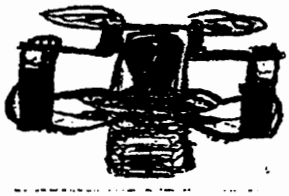
CHEST & BACK AND SHOULDERS

1. Barbell bench press



- hands just wider than shoulder width
- elbows go down to 30° of the shoulder plane, elbows not too far down past the shoulders and keep the back from arching
- do a warm up set with the weight as prescribed
- do a set with one weight, decrease the weight and do another set
- immediately decrease the weight again and repeat the last set, no rest between sets

2. Reverse pec dec



- Sit with the face to the machine, keep the stomach tight during the exercise
- elbows in line with the shoulders, pull the shoulders back, controlled back to the front and do a warm-up set
- do a set with one weight, decrease the weight and do an other set immediately, decrease the weight again and repeat the last set, no rest between sets

3. Pec dec



- sit on the pec dec machine with the back against the seat and the head against the machine
- adjust the seat so that the elbows are in line with the shoulders
- keep the stomach tight and pull the elbows to each other,
- keep the back and head against the machine,
- do a set with one weight, decrease the weight and do another set immediately, decrease the weight again and repeat the last set, no rest between sets

4. Seated cable row



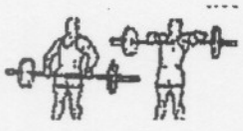
- sit with the knees bent a little, keep the back straight and stomach tight
- pull only with the arms to the chest, keep the back straight at all times and pinch the scapulas together at the back
- do not use the back to pull weights; fast back and slowly forward
- do a warm-up set
- do a set with one weight, decrease the weight and do another set immediately, decrease the weight again and repeat the last set, no rest between sets

5. Shoulder press: in front



- sit on the machine with the handles in front, not behind, like in the picture
- keep the back straight and stomach tight, hands just wider than shoulder width and press up and forward
- do a warm-up set
- do a set with one weight, decrease the weight and do another set immediately, decrease the weight again and repeat the last set, no rest between sets

6. Upright rowing: barbell



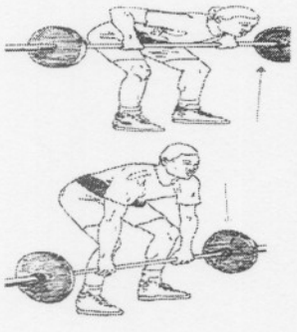
- stand with the feet shoulder width apart
- take the barbell in both hands just wider than shoulder width
- let the barbell hang in front of the thighs, palms facing towards the body
- pull elbows up to your ears, keep stomach tight and back straight, fast up and slowly down
- do a warm-up
- do a set with one weight, decrease the weight and do another set immediately, decrease the weight again and repeat the last set. no rest between sets

7. Shoulder press: behind



- keep the back straight and stomach tight, hands just wider than shoulder width
- press up in a straight line, yet with hands never behind the ears when the weight is being pressed upward
- do a warm-up set with the weight as prescribed
- do a set with one weight, decrease the weight and do another set immediately, decrease the weight again and repeat the last set, no rest between sets

8. Bend over row



- stand with feet shoulder width apart, grasp the barbell just wider than shoulder width
- bend the knees, bend the back at the hips, keep the back straight and the head up
- pull the barbell up towards the chest, keeping the back straight
- do a warm-up set
- do a set with one weight, decrease the weight and do another set immediately, decrease the weight again and repeat the last set, no rest between sets

9. Standing biceps curl





- stand with one foot behind the other for a stable base
- stand upright and keep the stomach tight
- grip the barbell just wider than shoulder width and let the barbell hang down in front of the thighs
- do not arch the back during the exercise; the moment arching of the back starts, stop with the exercise
- pull the hands up to the shoulders, controlled down
- do a warm-up set
- do a set with one weight, decrease the weight and do another set immediately, decrease the weight again and repeat the last set, no rest between sets

10. Triceps push out: dumbbell



- sit in a upright chair that supports the back
- grip the dumbbell, with the palms facing upward and hands under the weight
- bend the elbows to lower the dumbbell behind the neck, keeping the elbows pointed upward
- with stomach tight and back straight, lower the dumbbell until the triceps start stretching
- after feeling the stretch, push the dumbbell upward and straighten the elbows, keeping the elbows in one place, lower the weight to he starting position and keep looking forward
- do a warm up set with the weight as prescribed ,do a set with one weight, decrease the weight and do another set immediately, decrease the weight again and repeat the last set, no rest between sets

EXERCISE : Chest, back & shoulders						
Name		Date			Date	
		Week			Week	
		Reps	Weight		Reps	Weight
1. Barbell bench press	**Warm up**	10		**Warm up**	10	
	Set 1	15		Set 1	15	
	Set 2	15		Set 2	15	
	Set 3	15		Set 3	15	
2. Reverse pec dec	**Warm up**	10		**Warm up**	10	
	Set 1	15		Set 1	15	
	Set 2	15		Set 2	15	
	Set 3	15		Set 3	15	
3. Pec dec	**Warm up**	10		**Warm up**	10	
	Set 1	15		Set 1	15	
	Set 2	15		Set 2	15	
	Set 3	15		Set 3	15	
4. Seated cable row	**Warm up**	10		**Warm up**	10	
	Set 1	15		Set 1	15	
	Set 2	15		Set 2	15	
	Set 3	15		Set 3	15	
5. Shoulder press: in front	**Warm up**	10		**Warm up**	10	
	Set 1	15		Set 1	15	
	Set 2	15		Set 2	15	
	Set 3	15		Set 3	15	
6. Upright rowing: barbell	**Warm up**	10		**Warm up**	10	
	Set 1	15		Set 1	15	
	Set 2	15		Set 2	15	
	Set 3	15		Set 3	15	
7. Shoulder press: behind	**Warm up**	10		**Warm up**	10	
	Set 1	15		Set 1	15	
	Set 2	15		Set 2	15	
	Set 3	15		Set 3	15	
8. Bend over row	**Warm up**	10		**Warm up**	10	
	Set 1	15		Set 1	15	
	Set 2	15		Set 2	15	
	Set 3	15		Set 3	15	
9. Standing biceps curl	**Warm up**	10		**Warm up**	10	
	Set 1	15		Set 1	15	
	Set 2	15		Set 2	15	
	Set 3	15		Set 3	15	
10. Triceps push out: Dumbbell	**Warm up**	10		**Warm up**	10	
	Set 1	15		Set 1	15	
	Set 2	15		Set 2	15	
	Set 3	15		Set 3	15	

Legs

1. Incline leg press & vertical jump





- feet shoulder width, head up and stomach tight
- push the weight through the heels, without the knees passing the line of the toes, slowly down & explosive up (fast)
- at the end of each set, do a set of vertical jumps
- jump as high as possible but land softly

2. Standing leg curl & tuck jump with heel kick





- stand upright with the bar just above the ankle
- tighten the buttocks, then the hamstring and lastly the back before lifting the weight
- 2 seconds up and 4 seconds down
- after the leg curl exercises do a tuck jump with heel kick
- feet shoulder width apart, body in a vertical position, arms to side, keeping the knees pointed down, still in line with the body
- jump up and kick the buttocks with the heels, repeat jump immediately upon a soft landing, swing arms up when jumping, with a quick stepping action of the knees and lower legs

3. Seated calf raises & jump for distance





- place the feet on the angled foot raises,; balls of feet must be in contact with platform
- heels must be free to move
- raise the heels up as high as possible
- let the heels go down as far as possible in a slow controlled manner
- balls of feet must stay in contact with the platform at all times
- after each set do jumps for distance

4. Lunges walking with dumbbells & split squat jumps

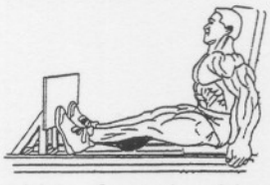




- exercise done with dumbbells, not with a barbell; keep the stomach tight and back straight
- knees must never pass the line of the toes
- put down the front leg in a running action, but only go down to 90° with front leg
- bend back leg a little
- after each set do split squat jumps
- stand in lunge position to jump
- land softly and on the balls of feet, stomach tight and back straight
- do jumps with both the left and the right anatomical side

5. Seated squat machine: calf raises & ankle hops







- sit on the seated squat machine, feet shoulder width apart, balls of the feet in touch with the plate,
- keep heels in the air and with the knees straight, push forward with the toes as far as possible
- back to starting position in a controlled fashion, back straight in the chair
- stand with feet shoulder width apart, body in a vertical position
- use only the ankles for momentum.
- hop continuously in one place, remember to land softly
- extend the ankles to their maximum range on each hop

6. One-leg hip drives onto bench & one-leg hip jumps





- stand in front of a bench (30-50 cm), feet shoulder width, hold dumbbells in the hands
- tighten the stomach and hold the back straight while stepping onto the bench
- on top of the bench do a hip drive with the leg coming up from the ground
- place the leg back next to the other foot and climb down the bench in a controlled fashion
- do one leg at a time.
- after each set, do one-leg drive jumps
- explosively up and land softly, with box or bench for jumps approx. 20 cm high

7. Side lunge & side to side jump





- stand with feet a little wider than shoulder width apart
- using dumbbells in the hands, tighten the stomach and keep the back straight
- step to the one side of the body, turn the toes a little to the outside (45-50°) so that when landing the leg is turned outward
- land on the ball of the foot, then do a squat movement with the lunging leg, keeping the stomach tight and back straight
- go down until the thigh is parallel with the ground, at 90° with knee,
- knee must not go past the line of the toes
- push-off leg straight at the knee.
- feet shoulder width apart, body in a vertical position.
- jump sideways to the left/right off the ground to land on the left/right foot
- upon landing, push off in the opposite direction, landing on the opposite foot
- repeat, with an explosive push-off and a soft controlled landing

8. Hip extension & single leg hop with heel touch





- place the band around the ankle and face the pulley
- bend the supporting leg a little and tighten the stomach
- pull the leg back in a straight line without arching the back or turning the hips
- stay square with the hips and do not bend forward during the exercise
- stand on one leg, jump into the air and touch the gluteal muscles with the heel of the foot and land on the other leg

Legs									
Name	Date		Date		Date		Date		Fitness
	Week	1 & 2	Week	3 & 4	Week	5	Week	6	
Exercises	Rep.	Weight	Rep.	Weight	Rep.	Weight	Rep.	Weight	
1. Incline leg press	3 x 10	kg	3 x 8	kg	3 x 8	kg	3 x10	kg	**Week 1 & 2**
Vertical jump	3 x 10		3 x 8		3 x 8		3 x10		4 x 500 m rowing
2. Standing leg curl	3 x 10	pl	3 x 8	pl	3 x 8	pl	3 x 10	pl	rest 60 sec
Tuck jump with heel kick	3 x 10		3 x 8		3 x 8		3 x 10		
3. Seated calf raises	3 x 10	kg	3 x 8	kg	3 x 8	kg	3 x 10	kg	**Week 3 & 4**
Jump for distance	3 x 10		3 x 8		3 x 8		3 x 10		4 X 500 m rowing
4. Lunges walking with dumbbells	4 x 6	kg	4 x 6	kg	4 x 6	kg	4 x 6	kg	rest 55 sec.
Split squat jumps	4 x 6		4 x 6		4 x 6		4 x 6		
5. Seated squat machine: calf raises	3 x 10	kg	3 x 8	kg	3 x 8	kg	3 x 10	kg	**Week 5**
Ankle hops	3 x 10		3 x 8		3 x 8		3 x 10		4 X 500 m rowing
6. One- leg hip drives onto bench	3 x 10	kg	3 x 8	kg	3 x 8	kg	3 x 10	kg	rest 50 sec.
One-leg hip jumps	3 x 10		3 x 8		3 x 8		3 x 10		**Week 6**
7. Side lunge	3 x 8	kg	3 x 8	kg	3 x 8	kg	3 x 8	kg	4 X 500 m rowing
Side to side jump	3 x 8		3 x 8		3 x 8		3 x 8		rest 50 sec.
8. Hip extension	3 x 10	pl	3 x 8	pl	3 x 8	pl	3 x 10	pl	
Single leg hop with heel touch	3 x 10		3 x 8		3 x 8		3 x 10		

Lower back and stomach

1. Pelvic lift: press ball



- lie on floor, knees bend, hands and arms next to the side of the body
- place light-weight ball between legs and press against ball slightly
- tighten the stomach and the gluteal muscles
- come up onto the heels and lift the pelvis from the floor (15-30 cm)
- knees and stomach in line, head on the floor

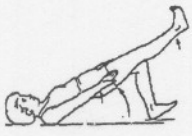
2. Crunches on Swiss ball





- lie on the ball with the lower back on the ball and the hands behind the neck
- tighten the stomach muscles, slowly come up with the head and do a crunch
- keep the balance on the ball and stay square on the ball
- press the feet into the floor, keeping the feet shoulder width apart

3. Bridging: lift body up and down (press ball)



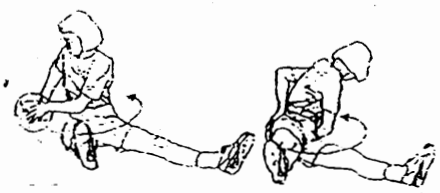
- lie on floor, knees bent, arms alongside the body
- place a light-weight ball between the knees and press slightly against the ball
- lift one leg to the line of other knee, pull toes towards the nose
- tighten the stomach and the gluteal muscles, come up onto the heel of the foot and lift from the floor
- knees, hips and stomach in a straight line, head on the floor.

4. Bench : knees to chest



- sit on the edge of a bench, lean a little bit back and use the arms for support
- keep legs straight, without the feet touching the floor
- keep the stomach tight and pull the knees to the chest, then lower the legs slowly to the starting position
- maintain a good posture during the exercise
- stop exercise when any pain is felt

5. Medicine ball: trunk rotation



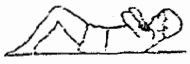
- sit on the floor with the legs spread and the ball behind the back, the stomach tight and the back straight
- rotate to the right, pick up the medicine ball and bring it around to left side
- the medicine ball makes a circle around the body
- do the exercise to the left and right anatomical sides

6. Lie stomach: lift opposite arm (arm bend at 90°)



- lie flat on the ground with the forehead on the ground, elbows bent at 90° in line with the shoulders
- pull the scapulas together, lift the arms and elbow from the ground and lift the opposite leg from the ground
- keep the leg straight at all times
- keep the forehead and hips on the ground during the exercise

7. Knees to elbows (ball between knees)





- lie on floor, knees bent at 45°, feet flat and a light-weight ball between the legs
- press slightly against the ball with the knees, hands crossed in front of body on the chest
- lift the head towards the ball, and also lift the knees towards the head
- these movements must happen simultaneously, thus rhythmically and in a co-ordinated fashion

8. Floor back extensions (hold weight in front of chest)





- lie on the stomach on the floor with the hands behind the neck,
- partner sits on lower legs with hands on the hamstrings
- hold a weight in front of the chest with both hands
- keep the hips on the floor and lift the upper body from the floor
- lift up as far as possible with out lifting the hips from the floor

9. Oblique sit-up



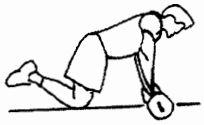
- lie on the ground and place one hand on the floor in line with the shoulder
- place the other hand on the ear and place one foot on the knee of the other leg, by crossing over the leg
- tighten the stomach and lift the elbow to the bent knee by rotating the trunk
- at all times keep the hips as well as the opposite shoulder in contact with the ground

10. Side up: lift top leg



- lie on one side, elbow under the shoulder, knee on the floor bent
- leg on the top is kept straight, with toes pulled toward the nose
- tighten the stomach and lift up the side from the floor, keeping the top leg in line with the top hip

11. All fours: roll forward





- stand on all fours with the hands under the shoulders and the knees under the hips
- take a barbell or roller in the hands
- tighten the stomach and roll forward, stop just before falling off balance
- keep this position for 2 seconds and roll back to the starting position

12. Good morning bend



- stand upright with the bar behind the neck
- tighten the stomach and bent forward to 90° with hips
- come up fast and controlled, bend the knees a little bit, **if pain occurs, do not do the exercise**

-

13. Hanging leg raises



- place the bent elbows in the belts and grip with the hands around the belts at the top
- hang with the body in a straight line and keep the body still (no swinging)
- pull the knees up until they form a 90° with the hips and keep the body in a straight line
- do not swing while doing the exercise and keep the back straight at all times

Lower back and stomach (stabilizers)									
	Date		Date		Date		Date		
	Week	1 & 2	Week	3 & 4	Week	5	Week	6	**Fitness**
Exercises	Rep.	Hold	Rep.	Hold	Rep.	Hold	Rep.	Hold	
1. Pelvic lift: press ball	2x10	8 sec	2x12	8 sec	3x10	8 sec	3x10	8 sec	**Week 1 & 2** 15 min
2. Crunches on Swiss ball	2x12		2x15		3x12		3x15	30 sec	Treadmill on 13
3. Bridging: lift body up and down (press ball)	2x10		2x12		3x10		3x12		**Week 3 & 4**
4. Bench: knees to chest	2x12		2x15		3x12		3x15		15 min treadmill
5. Medicine ball: trunk rotation	2x10	8 sec	2x12	8 sec	2x15	8 sec	3x10	8 sec	on 13
6. Lie stomach: lift opposite arm (arm bend at 90°)	2x10		2x12		3 x10		3x12		**Week 5**
7. Knees to elbows (ball between knees)	2x10		2x12		3x10		3x12		20 min treadmill
8. Floor back extensions (hold weight in front of chest)	3x10	kg	3x12	kg	3x15	kg	3x20	kg	on 13
9. Oblique sit- up	2x12		2x15		3x10		3x12		**Week 6**
10. Side up: lift top leg	2x8	10 sec	2x8	10 sec	2x5	12 sec	2x5	12 sec	20 min treadmill
11. All fours: roll forward	2x10		2x12		3 x 10		3 x 12		on 13
12. Good morning bend	2x12	kg	2x15	kg	2x20	kg	3 x12	kg	
13. Hanging leg raises	2x12		2x15		2x15		3 x10		

Fitness programme: third six week

NAME:			
DATE: **WEEK**	**DATE:** **WEEK** **WEEK**	**DATE:** **WEEK:**	**DATE:** **WEEK:**
1. 2 laps around field & Stretch **2. 4 x 400 m** time = 70 -75 sec rest = 5 min **3. 30 shuttles over 20 meters** repeat 3 **x** rest between sets = 90 sec	1. 2 laps around field & Stretch **2. 3 x 400 m** time = 65 -70 sec rest = 4 min **3. 10 x 60 m** 60 m has to be sprinted rest between 1 60 m = 25 sec **4. 2 x 1 min shuttle run 20 m** rest between run = 90 sec.	1. 2 laps around field & stretch **2. 2 x superior mum (300 m)** time = 60 -65 sec rest = 120 sec in between **3. 10 x 25 m** 25 m has to be sprinted rest between 1 25 m = 15 sec **4. 3 x 1 min shuttle run 20 m** rest between run = 90 sec.	1. 2 laps around field & stretch **2. 4 x 400 m** time = 65 -70 sec rest = 4 min **3. 10 x 60 m** 60 m has to be sprinted rest between 1 60 m = 25 sec **4. 4 x 1 min shuttle run 20 m** rest between run = 120 sec.

Maintenance programme

LEGS

1. Incline leg press





- sit with feet shoulder width apart
- balls of the feet and heels in touch with the plate
- let the plate come down until knees form a 90° angle with hips
- from this 90° position, push the plate up to the starting position
- keep the back straight against the back plate

Sets	repetitions	weight
3	15	kg

2. Standing leg curl

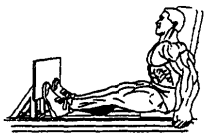


- stand upright with the bar just above the ankle
- tighten the gluteus muscles, then the hamstring and lastly the back before lifting the weights
- fast up and slowly down

Sets	repetitions	weight
3	15	pl

3. Seated squat machine: calf raises





- sit on the seated squat machine, feet shoulder width apart
- balls of the feet must touch the plate, heels in the air
- keeping the knees straight, push forward with the toes as far as possible
- back to starting position in a controlled fashion

Sets	repetitions	weight
3	15	kg

4. One-leg squat



- stand with feet shoulder width apart, bend the one leg 90° at the knee
- place the bent leg on a bench at knee height
- tighten the stomach and do a single leg squat keeping the pressure on the bench with the bent leg
- do not let the knee pass the line of the toes when going down, keep the body upright throughout and hold the dumbbells in the hands

Sets	repetitions	weight
3	15	kg

5. Side lunges



- step to the one side of the body, turn the toes a little to the outside (45-50°) so that when landing the leg is turned outward holding the dumbbells in both hands
- land on the ball of foot, then do a squat movement with lunging leg
- keep the body upright and the stomach tight and bend the back leg a little
- do not let the knee pass the line of the toes when coming up
- go down until the thigh is parallel with the ground, 90° with the knee
- knee should not go past the toes; keep the push-off leg straight at the knee
- push back to starting position, with an upward and sideward movement, at moderate speed

Sets	repetitions	weight
3	15	kg

6. Hip extension

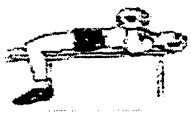


- place the band around the ankle and face towards the pulley
- bend the supporting leg a little and tighten the stomach
- pull the leg back in a straight line without arching the back or turning the hips around, keeping the hips square

Sets	repetitions	weight
3	15	kg

UPPER BODY

1. Dumbbell bench press



- lie on your back with the dumbbells
- keep from arching the back,
- keep the elbows in line with the shoulders

Sets	repetitions	weight
3	15	kg

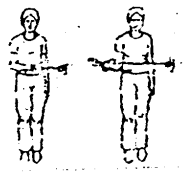
2. Reverse pec dec



- face the machine
- keep the stomach tight during the exercise
- keep the elbows in line with the shoulders, pull the shoulders back and keep the body still
- control the movement from the back to the front

Sets	repetitions	weight
3	15	kg

3. Pulley: external rotation



- stand sideways to the machine, bend the elbow at 90° and place the bent elbow on the side of the stomach
- rotate the shoulder to the outside as far as possible, keeping the elbow at the side of the stomach
- keep the body straight during the exercise

Sets	repetitions	weight
3	15	pl

4. Seated biceps curl



- sit on a incline bench with the seat at 45°
- pull the arm up towards the shoulder
- do not arch the back when pulling up,
- keep the back against the seat the whole time
- extend the arm fully when lowering
- keep the line of the shoulder and the elbow and the arm

Sets	repetitions	weight
3	15	kg

5. Triceps push-out



- stand upright with the arm in front of the shoulder and elbow bend at 90°
- with the other arm, support the bent elbow, extend the bent arm forward, keeping the elbow straight
- do not lower the arm below shoulder level, keep the stomach tight and do not arch the back

Sets	repetitions	weight
3	15	kg

6. One-arm cross abduction



- grip the handle with the palm facing inward,
- palm on the opposite thigh
- pull the hand up so that the palm is facing forward
- the hand is in line with the shoulder (level with the shoulder)
- do not arch the back when pulling up
- keep the stomach tight, pull up fast and lower down (4 seconds.)

Sets	repetitions	weight
3	15	pl

Lower back

1. Bridging: hold 10 x 8 sec



- lie on the back, hands on stomach or next to the body
- lift one leg so that it is in line with the bent knee
- tighten the stomach and the buttocks, then lift the buttocks from the floor
- knees, hips and stomach in a straight line head and neck on the floor; hold for 8 seconds

2. Lie stomach: lift arm and leg 20 x 3 sec hold



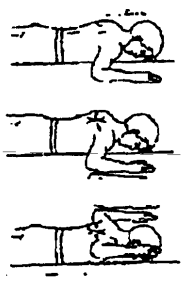
- lie on stomach with arms and legs straight
- lift the opposite hand and leg from the floor
- forehead and hips must stay on the floor.
- tighten the gluteal muscles first, hamstring second and the back last to lift

3. Bridging: up and down 10 x per leg



- lie on floor, knees bent and hands on chest
- lift one leg up to in line with the other knee, pull toes towards nose
- tighten the stomach and the buttocks, and lift the body from the floor
- knees, hips and stomach in a straight line, neck on the floor
- keep lifting the body up and down, maintaining tightness in the gluteus muscles and stomach

4. Lie on stomach: lift bent arms 20 x



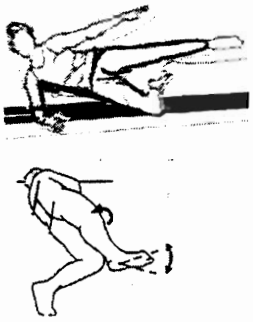
- lie flat on the ground with the forehead on the ground, elbows bent at 90° in line with the shoulders
- pinch the scapulas together
- lift arms and elbows from the ground
- keep the forehead on the ground the whole time during the exercise

5. Floor back extensions 2 x 20



- lie on your stomach on the floor and the hands behind the neck
- partner sits on lower legs with the hands on the hamstrings
- keep the hips on the floor and lift the upper body from the floor
- lift up as far as possible with out lifting the hips from the floor

6. Side up top foot in and out 3 x 10 left and right anatomical side



- lie on the one side, elbow under the shoulder, knee on the floor, bent
- leg on the top kept straight, toes pulled towards the nose
- tighten stomach and lift the body up from the floor
- keep the top leg in line with the top hip
- move foot up and down, from 11:50 to 12:10 on clock face

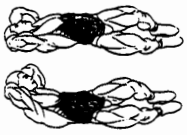
Stomach exercises

1. Leg thrusts 2 x 20



- lie on back and grab the rail with both hands
- bend the hips at 90° and keep knees straightened and locked during the exercise
- lift lower back from the floor (10-15 cm) by thrusting legs towards roof in a straight line, controlled up and down

2. Oblique sit-up 2 x 15 left and right anatomical side



- lie on the back with the shoulders flat on the floor, the hips rotated at 90° on the one side
- with the hips almost perpendicular to the shoulders, bend the knees, hands behind the neck
- contract the abdominal muscles and lift the head and shoulders from the floor until they are 20° from the floor
- keep the head and shoulders in a straight line

3. Hanging leg raises 2 x 15



- place the hands on the rests with the elbows bent at 90°
- let the feet hang down in a straight line, tighten the stomach
- lift until knees form 90° angle with hips, then lower the legs
- do not let the knees swing back at the bottom
- keep downward movement controlled and the stomach tight

4. Reach for roof 2 x 20



- lie on the back with the hands in front of the chest
- keep the feet on the floor and reach for the roof
- keep the head and shoulders in a straight line
- slow and controlled down to starting position

5. Side to side roll **2 x 10 left and right anatomical side**



- lie on the back and grab the rail with both hands
- bend the knees at 90° and the legs 90° at the hips
- keep the legs from the ground
- tighten the stomach and roll side to side
- maintain a good posture during the exercise
- stop exercise with any pain or discomfort

6. Heel touches **2 x 12 left and right anatomical side**



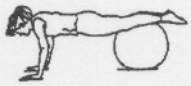
- lie on the back with the knees bent
- cup the hands
- tighten the stomach and lift one shoulder 5-10 cm off the ground
- move to the one side and touch the heel with a cupped hand

Maintenance fitness

Program 1

1. 5 min Cycle warm up & stretches
2. **10 min treadmill on 13**
3. Push up: staggered triceps push up push up: feet on swiss ball






3 x 8 reps 3 x 15 3 x 10

first do 1 set of staggered push up, then triceps push up's & last physio ball, rest 60 sec. between sets

4. **6 x 25 steps**. 25 steps in green light, rest red light.
5. 1 leg jack knives lie stomach: lift arms & legs jump onto bench: land soft





3 x 12 each side 3 x 12 each side (weight in hand, band around ankle)
3 x 12

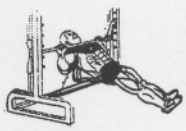
do one set of each, rest 60 sec. after 1 set of each are done

6. **15 min Treadmill on 13**
7. repeat 1 set of each of exercise 3
8. **7 x 25 steps**.
9. Repeat 1 set of each of exercise5
10. **Run a two, walk back to start. Repeat 15 x**

Program 2

1. **5 Min Cycle warm up.**
2. **30 min Stepper: 30 min on 12, last 10 min: 2 rows on 13, 1row on 9, 3 rows on 13, 1 row on 9, Start at 13 again, repeat till time is up.**
3. Pull up: palm out push up: staggered pull up: palm in triceps push up






3 x 15 reps. 3 x 8 3 x 15 3 x 15

Do pull up first, then push up, then pull up & last triceps

4. **7 x 25 super circuit steps**.
5. Oblique sit up floor back extensions knees to chest lie stomach: arms & legs






2 x 15 reps each side 2 x 20 2 x 20 (press ball between legs) 2 x15 each side

6. **7 x 300 m rowing sprints. Level 6, rest = 55 sec.**

Run a three: sprint 3, walk back turn & sprint , repeat 15 x

Feet exercises: A

1. Towel gather 3 x 1 minute per anatomical side



- sit with a towel in front of the toes, heel on the floor and the toes on the towel
- pull the towel towards the body by pulling it with the toes
- keep the heel pushed into the ground and push the toes into the ground when pulling
- continue until the whole towel is at the heel

2. Dorsiflexion of the foot 3 x 30 per anatomical side



- sit with the foot on the floor
- keep the heel on the ground and lift the toes up as high as possible towards the nose

3. Towel gather: inversion 3 x 1 minute per anatomical side



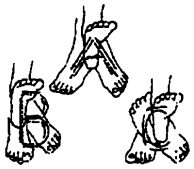
- sit with a towel to the outside of the toes, heel on the floor and the toes on the towel
- pull the towel to the inside with the toes
- keep the heel pushed into the ground and push the toes into the ground when pulling
- continue until the whole towel is at the big toe

4. Towel gather: eversion 3 x 1 minute per anatomical side



- sit with a towel to the inside of the toes,
- heel on the floor and the toes on the towel
- pull the towel to the outside with the toes
- keep the heel pushed in to the ground
- push the toes into the ground when pulling
- continue until the whole towel is at the big toe

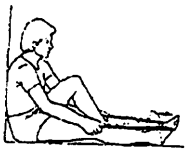
5. Write the alphabet with the foot 2 x per anatomical side



- keep the heel in one place while writing the alphabet with the toes in capital letters

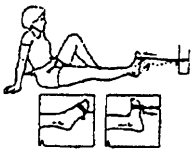
Feet exercises: B

1. Pulley: plantar flexion 2 plates 3 x 15 repetitions



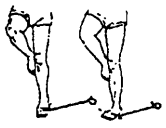
- sit with the back towards the pulley machine, place the band around the ball of the foot
- keep the foot still and the heel on the ground
- push the toes forward as far as possible, then bring the toes back to starting point in a controlled manner

2. Pulley: dorsiflexion 2 plates 2 x 15 repetitions



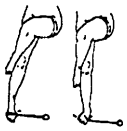
- sit in front of the machine, place the band around the toes
- keep the knee straight and the heel on the floor
- pull the toes towards the nose, slowly and controlled back to the starting position

3. Pulley: inversion 3 plates 3 x 15 repetitions



- sit sideways to the pulley machine, with the band around the foot nearest to the machine
- place the other foot next to the knee to keep it from moving
- pull the toes inwards without moving the knee to the inside
- work from a midline to the inside and back to the midline, keeping the heel on the ground

4. Pulley: eversion 2 plates 3 x 15 repetitions



- sit sideways to the pulley machine, place the band on the toes the furthest from the machine
- place the other foot on the outside of the knee to keep it from moving
- pull the toes to the outside, away from the midline without moving the knee to the outside
- keep heel flat on ground and work away from the midline, then back

5. Walk on heels and toes 2 x 1 min for each exercise



- walk on heels for duration of exercise
- pull the toes up towards the nose



- come onto the toes
- walk on toes for duration of exercise