THE INCIDENCE AND NATURE OF CRICKET INJURIES AMONGST SOUTH AFRICAN SCHOOLBOY CRICKETERS

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DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

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

ABSTRACT

INTRODUCTION: The primary aim of this study is to identify the prevalence and nature of injuries sustained by South African schoolboy cricketers. The results will then be used to set possible preventative measures in order to minimize the incidence of first-time and recurrent injuries.

METHODS: The population consisted of 196 cricketers representing all 16 provincial teams in the under 19 Coca-Cola Khaya Majola cricket week played in Pretoria from 16 - 20 December 2004. Data were collected retrospectively and the cricket players were asked to recall all injuries from June 2003 to May 2004. The researcher personally guided each cricketer through a questionnaire regarding training and injury. The questionnaire was designed to obtain the following information: i) anatomical site of injury, ii) month of injury, iii) diagnosis of injury, iv) cause of injury, v) whether it was a recurrence of a previous injury and vi) whether the injury recurred during the season. A questionnaire was handed to each of the coaches who then asked if they could complete the questionnaire in their own time. The questionnaire was designed to see the level of coaching qualifications achieved by them and their level of understanding of basic training principles.

RESULTS: The results showed that 67 injuries were sustained by 196 cricketers with a seasonal incidence of 34.2. Almost 72% of injuries occurred during matches, 14.9% occurred gradually due to the repetitive stresses sustained during matches and practices, 11.9% occurred during practice and 1.5% of the injuries occurred during other forms of training. Surprisingly, no injuries were sustained to the head, neck and face region while 34.3% were sustained to the upper limbs; 34.3% to the lower limbs and 31.3% to the back and trunk. Bowling accounted for 50.7% of the injuries, while fielding accounted for 32.8%, batting accounted for 14.9% and the remaining 1.5% occurred while warming-up or training. The primary mechanism of injury was the delivery and follow through of the fast bowler (34.3%), direct impact from the cricket ball when attempting to take a catch (10.4%), running after the ball

(6.0%), stopping the ball along the ground (6.0%) and landing incorrectly after diving for the ball (6.0%). Fifty eight of the injuries were reported as being first time injuries while only nine injuries were due to the recurrence of a previous injury. The majority of injuries (40.6%) reported were quite severe and took the cricketers more than 21 days to recover. Thirty six percent of injuries allowed the cricketers to return to play within seven days of acquiring the injury. Cricketers were found to be more prone to injury during December and January.

CONCLUSION: Potential risk factors for injury have been identified and it has been suggested that coaches and cricketers partake in continuous educational processes that focus on all the physical, training, mental and technical components necessary for success in cricket. Cricketers should undergo regular musculoskeletal evaluations and be given personalized training programs. It is essential that a National database for junior cricketers be implemented.

OPSOMMING

INLEIDING: Die primêre doel van hierdie studie is om die voorkoms en moontlike oorsake van krieketbeserings onder Suid Afrikaanse skoolseun te identifiseer. Die bevindinge sal gebruik word om voorkomende maatreëls daar te stel wat moontlik die voorkoms van eerste en herhaalde beserings sal minimaliseer.

METODE: Die steekproef het bestaan uit 196 krieketspelers wat verteenwoordigend is van al 16 provinsiale spanne wat aan die onder 19 Coca-Cola Khaya Majola krieket week in Pretoria vanaf 16 – 20 Desember 2004 deelgeneemgespeel het. Data is retrospektiewelik ingesamel. Krieketspelers is gevra om alle beserings vanaf Junie 2003 tot Mei 2004 op 'n vraelys te rapporteer. Die navorser het persoonlik elke krieketspeler deur die vraelys met betrekking tot oefeninge en beseringaspekte begelei. Die vraelys is ontwerp om die volgende inligting in te samel: i) anatomiese ligging van besering, ii) maand van besering, iii) diagnose van besering, iv) oorsaak van besering, v) of dit 'n herhaling van 'n vorige besering was, vi) of die besering gedurende die seisoen plaasgevind het. Elke afrigter het 'n verskillende vraelysl op hul eie tyd ingevul. Die vraelys is ontwerp om die vlak van die afrigter se afrigtingskwalifikasies te akkommodeer asook om sy begrip van basiese oefenbeginsels te bepaal.

RESULTATE: Die resultate het getoon dat 67 beserings opgedoen is deur 196 krieketspelers, met 'n seisoenale voorkoms van 34.2. Ongeveer 72% van die beserings het tydens wedstryde plaasgevind, 14.9% van beserings is a.g.v. herhaalde stres gedurende wedstryde en oefeningsessies opgedoen, 11.9% het gedurende oefening plaasgevind en 1.5% het plaasgevind gedurend ander vorme van oefening. Verrassend het geen beserings van die kop, nek en gesig areas plaasgevind nie, terwyl 34.3% aan die boonste ledemate, 34.3% aan die onderste ledemate en 31.1% aan die rug en romp. Boulwerk was verantwoordelik vir 50.7% van die beserings, veldwerk vir 32.8%, kolfwerk vir 14.9% en die oorblywende beserings het tydens opwarming en oefening plaasgevind. Die primêre

meganismes van besering was die aflewering en deurvolg van die snelbouler (34.3%), direkte impak van die krieketbal wanneer gepoog was om dit te vang (10.4%), hardloop vir die bal (6.0%), stop van die bal op die grond (6.0%) en foutiewe landing na ‘n duik vir die bal (6.0%). Agt en vyftig van die beserings is as eerste beserings aangemeld, terwyl slegs nege beserings as gevolg van die herhaling van vorige beserings was. Die meerderheid beserings (40.6%) wat gerapporteer is, was van ‘n redelike ernstige graad en het die krieketspelers meer as 21 dae geneem om te herstel. Ses en dertig persent (36%) van die beserings het die spelers toegelaat om binne sewe dae na dat die besering opgedoen is na die spel terug te keer. Krieketspelers is meer vatbaar vir beserings gedurende Desember en Januarie.

GEVOLGTREKKING EN AANBEVELING: Potensiële risikofaktore vir besering is geïdentifiseer. Daar word aanbeveel dat afrigters en krieketspelers deelneem aan ‘n deurlopende opvoedkundige-/opleidingsprogram wat fokus op al die fisieke, oefenkundige, sielkundige en tegniese komponente van krieket. Alle junior krieketspelers behoort gereelde muskuloskeletale evaluasies te ondergaan en behoort individuele oefenprogramme te ontvang. Die vestiging van ‘n Nasionale databank vir juniorkrieketspelers is ‘n noodsaaklikheid.

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ABBREVIATIONS

BFI	– back foot impact
CT	– computed tomography
EVA	– ethylene vinyl acetate
FFI	– front foot impact
GRF	– ground reaction forces
HAGL	– humeral avulsion of the gleno-humeral ligament
MRI	– magnetic resonance imaging
ODI	– one day international
P_AS_A	– pelvic-shoulder separation angle
rgCT	– reverse gantry computed tomography
SLAP	– superior labrum anterior to posterior
UCBSA	– United Cricket Board of South Africa

CHAPTER ONE
INTRODUCTION

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p.

1.1 INTRODUCTION

In 1300, during the time of Edward I, the word ‘creag’ is used which may refer to cricket (Tyler, 1975). According to Van der Merwe (2001) English variations of the word cricket include creckett (1509 – 1547), kreket (1622), cricketts (1629) and crekett (1677). The *Vlaamse Volkssport Centrale* suggests that the English word cricket was borrowed from the Flemish or Dutch word krik-ketsen (van der Merwe, 2001). The oldest reference to the modern English name dates back to the late 16th century where ‘crickett’ in some form was played at the Free School of Guildford (Tyler, 1975; van der Merwe, 2001).

Cricket officially arrived in South Africa along with the British forces in 1795. The first match was recorded on the 5th of January 1808 between the ‘Officers of the Artillery Mess’ and the ‘Officers of the Colony’ played at Green Point Common (Crowley, 1973). Clubs had been formed throughout the country by the middle of the 19th century with the first club, Port Elizabeth Cricket Club, being formed in 1843. The first touring team arrived on South African soil in 1888 - 1889 with the first test being played at St. George’s Park in Port Elizabeth in March 1889.

The game of cricket can be dangerous even though it is often still associated with the country club atmosphere (Temple, 1982). This can be illustrated by the untimely death of Frederick Louis, the Prince of Wales and farther of George III, in 1751 (Temple, 1982). He died several hours after being struck by a ball on the head. Today such injuries could lead to instantaneous fatalities if the correct protective gear is not worn, considering that the ball (156g) can travel up to 160 kilometres per hour (44.4 meters per second). Deaths resulting in being struck on the head by a cricket ball are not a daily occurrence but shows that the nature of the game is evolving: a game, traditionally associated with a low to moderate injury risk, is showing a dramatic increase in injury incidence (Stretch, 1995). Leary and White (2000) state that England has often had trouble fielding the strongest cricket team due to injury and suggest that it is not a recent phenomenon. In order to excel in the modern form of this game, cricketers need to train longer and harder than before and need to start training at an earlier age (Stretch, 2003a). They need to display a higher level of skill and fitness, making them susceptible to overuse injuries. Due to the dynamic and repetitive nature of the game, cricketers need to endure long periods out in the field which predisposes them to a wide range of injuries. Injuries can occur during any phase of the game – bowling, batting or fielding - and can involve any part of the body (McGrath and Finch, 1996).

Finch *et al.* (1999) noted two types of injuries: impact and overuse injury. Impact or collision injuries can occur in a number of ways on the cricket field. Batsmen and in-fielders are often exposed to balls of high speed and misjudgement of the ball or unanticipated bounce may lead to injury. In-fielders can also experience direct impact from the ball and out-fielders can run or slide into the boundary fence. Hours of repetitious practice can produce gradual deterioration in the functional capacity of the body. This deterioration is often matched by a form of overuse injury where repeated sub-threshold forces, each lower than the acute injury threshold for tissue, produces a combined fatigue effect in musculoskeletal tissue over a period of time. Overuse injuries occur with repetitive actions such as running, throwing and bowling.

Headley (2003) states that the volume of international cricket has grown rapidly over the past 20 years e.g. in 1980 the total number of games played (Tests and one day internationals (ODI)) was 92 while in 2002 the number of games played rose to 199. Although the annual number of tests played has remained relatively stable over this period, the increase in the total volume is a direct result of the increase in popularity of the ODI. In 1980, 42 ODIs were played while 145 ODIs were played in 2002. The expansion of the game to nations such as Bangladesh and Zimbabwe as well as the re-admission of South Africa into the international arena contributes to the increase in the number of matches played. Compared to 2002, it would appear as though the total number of matches (ODIs and Tests) played had decreased slightly to 161, with Test playing nations being involved in 112 ODIs and 49 Tests. These figures include three Afro-Asian ODIs, three ODIs in the International Cricket Council (ICC) Super Series where Australia took on a Rest of the World XI and a Tsunami Appeal ODI, as well as one Test in the ICC Super Series (Bal, 2006). Matches played by non-test playing teams were not taken into consideration and could be the cause of the decrease in the total number of international matches played.

Stretch (2001a) suggests that South African provincial and national cricketers are also being exposed to long and demanding seasons. According to Noakes and Durandt (2000), actual playing time increased by 280% in South Africa between 1970 and 1998. In 1970, international players were eligible to play four five-day matches, no ODI, four provincial three-day matches and three provincial one-day matches, giving a total of 35 days of cricket per year. In 1998, international players were eligible to play eight five-day matches, 17 ODIs, eight provincial four-day matches and 10 provincial one-day matches, giving a total of 99 days of cricket per year. These figures exclude all the time spent training, with the average provincial team training up to five days a week with at least two sessions per day depending on which phase of the season they are in.

It is vitally important for the modern day cricketer to be optimally fit in order to withstand the rigours of a packed schedule (Headley, 2003). Headley (2003) identifies the following factors affecting performance in cricket:

1. Skill – for an individual to succeed, they must have the technical skill to bat, bowl and field.
2. Tactics – both individual (how to approach a specific bowler etc.) and team (whether to bat or bowl first etc.).
3. Psychological factors – mental toughness, confidence, the ability to focus etc.
4. Environmental factors – pitch conditions, weather etc.
5. Nutrition – cricketers must be well nourished and hydrated in order to perform at an elite level.
6. Physical conditioning – gives the player the platform from which he can display his skill.

With an increase in playing and training time the game of cricket has had to become more professional. This can be seen by the increase in sponsorship as well as the restructuring of the contracting system by the United Cricket Board of South Africa (UCBSA) and various provincial teams. Players losing time due to injury could be affected by a decreased sponsorship and loss of their match fees, and possibly their positions, within the team. They could also be forced to sign a smaller contract. Temple (1982) suggests that the influx of money has been enough to over-ride sportsmanship and that the game itself now emphasizes aggressiveness rather than finesse.

With the expansion of the game, and an increase in the number of games being played, senior provincial and national fast bowlers have become more aware of their workloads. Coaches often call for the assistance of younger bowlers during net sessions in order to rest the senior bowlers. This leads to an increased susceptibility of younger bowlers to overuse injuries. Younger bowlers are more susceptible due to the fact that their growth cartilage may not be completely developed and that they may not yet have mastered the art of biomechanically efficient bowling (Finch and McGrath, 1996).

As cricket is a sport only played professionally in British Commonwealth nations, with the exception of Zimbabwe who was suspended from the Commonwealth in March 2002 (Katwala & Oliver, 2002), the amount of literature on the epidemiology, mechanisms and prevention of cricket injuries is limited, particularly at the non-elite levels of play (Finch *et al.*, 1999). Leary and White (2000) suggest that there is a need for a system of epidemiological data collection as well as the development of a national cricket injury data base to help predict, reduce and prevent injury at all levels. Stretch, together with the UCBSA, has set up a system of epidemiological data collection and has developed a national injury database. This was done in order to identify the incidence and mechanism of these injuries. With this information, they would be able to predict injuries and possibly reduce their prevalence at all levels of the game (Stretch, 2001b).

The only research found relating to the nature of injuries amongst schoolboy cricketers is a study carried out over 10 years ago by Stretch (1995) where it was reported that the seasonal incidence of injuries for schoolboy cricketers was 49%. Stretch (1995) found that the most common sites for injury were the back and trunk (33.5%), upper limbs (24.6%) and the lower limbs (22.8%). Bowlers (47.4%) were more prone to injury than batsmen (29.8%) and fielders (22.8%). A similar proportion of injuries occurred during matches (45.6%) and practises (47.4%) and was found to be more common at the start and towards the end of the season. Of the injuries reported, 29.8% of the injuries recurred from a previous season while 36.8% recurred again during the same season.

In a study conducted on senior provincial cricketers (Stretch, 2003b), it was found that 19 - 24 year old cricketers were more prone to injury than their older counterparts. Their injuries accounted for 46% of the total injuries reported in a four-season study of which 41% of the recurrent injuries were sustained by players younger than 24 years (Stretch, 2003b). It could be possible that these injuries had originated during their school days and that they had not been fully rehabilitated. If injuries are not fully rehabilitated, it predisposes cricketers to recurrent injuries.

The game of cricket has grown immensely since Stretch's data collection in the 1989/90 and 1990/91 seasons. Some of the major changes that have occurred include the reinstatement of the South African team into international cricket, the lengthening of the provincial three-day matches to four-day matches, the introduction of the Pro20 series, as well as that of the franchise set-up. Franchise teams were established in order to decrease the gap between the level of South African first class cricket and Test cricket, a change made to allow for strength versus strength competition. Top cricketers from the various provinces are selected for the six professional franchise teams while the remaining provincial cricketers are then contracted to the provincial amateur teams. A special effort has also been made to develop the game in the underprivileged communities as well as other rural areas. This can be seen by the inclusion of the Border Kei team in the 2004 Coca-Cola Khaya Majola Cricket Week. The Coca-Cola Khaya Majola Cricket Week is an interprovincial competition for elite under-19 schoolboy cricketers. At the end of the competition, selectors select the top players for the SA Schools or SA Colts team. These players could then be selected for the amateur senior provincial teams or moulded into senior provincial cricketers. It is at the Coca-Cola Khaya

Majola Cricket Week that future national players are identified. The UCBSA, in association with various sponsors, have played an integral part in the development of cricket amongst school children, particularly those from the disadvantaged communities. The changes to the game and the increased professionalism amongst senior provincial cricketers may have changed the nature of the game amongst schoolboy cricketers.

1.2 AIM OF THE STUDY

The primary aim of this study is to identify the prevalence and nature of injuries sustained by South African schoolboy cricketers. A comparison will be made between the current study and the study by Stretch (1995) as well as his most recent study on senior provincial South African cricketers. The results will then be used to draw possible preventative measures in order to minimize the incidence of first-time and recurrent injuries.

1.3 STRUCTURE OF THE THESIS

The introductory chapter (Chapter One) will be followed by a review of the literature (Chapter Two). Chapter Three includes a detailed description of the study design and methods used to obtain the data. Chapter Four will present the data and give a discussion of the results while Chapter Five concludes the thesis and sets certain recommendations.

CHAPTER TWO
LITERATURE REVIEW

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2.1 INTRODUCTION

Australia, England and South Africa rank among the top researching nations with regards to the epidemiology of cricket injuries at first class level (Orchard and James, 2004) with New Zealand and West Indies planning similar studies. Although it is a great step toward advancing science in cricket, researchers have not, until the article by Orchard *et al.* (2005) set a standard method for data collection and formulation. This has made adequate comparison between nations virtually impossible. Injury among cricketers, although not at pandemic levels, is of serious concern and the diverse nature of the game does not make matters any easier.

2.2 INJURY INCIDENCE AMONGST FIRST-CLASS MALE CRICKETERS

Temple (1982) was the first to report some of the results of a survey conducted by the British Sports Council. It was found that 213 teams in Northern England reported 251 injuries. The council estimated the risk of injury to cricket players at 2.6 per 10 000 man-hours played. These figures however exclude injuries thought to be trivial as well as many chronic overuse injuries (Stretch, 1989). The finger was found to be the most vulnerable with injuries including fractures, dislocations and contusions. The rate of injuries to first-class cricketers in Australia was found to be 333 per 10 000 man-hours played (Payne *et al*., 1987). The first comprehensive cricket injury study was conducted by Stretch (1989). Stretch (1989) recorded 193 injuries sustained by 92 South African first-class cricketers. These injuries were not restricted to the season in question but included all injuries received while playing club and provincial cricket. A seasonal incidence could not be reported.

2.2.1 Injury incidence amongst South African first-class cricketers

Stretch (1993a) conducted another study where 83 first-class cricketers in either the 1988/89 or 1989/90 seasons, reported a total of 88 injuries. An injury was defined as any physical damage that occurred during a match, practice or training session that prevented the player from completing that specific match, practice or training session. The seasonal incidence of cricket injuries in this group was 48.1% with the most common site of injury being the fingers (20.5%).

A six-season study, spanning from 1998 – 2004 was then undertaken by Stretch (2001a, 2001b, 2003a and 2003b) and Stretch and Venter (2005). During this six-season period, it was found that South African first-class cricketers are at risk of sustaining an average of 2.1 injuries per season. It is interesting to note however that the lowest injury risk of 1.6 injuries per player was achieved during the second season (1999/2000) while the sixth season (2003/04) showed the highest injury risk of 2.9 injuries per player. The high injury incidence in the 2003/4 season could be attributed to the inclusion of the Pro20 series which was the first series where the new franchise system was implemented. Throughout the season players could have been striving to attain contracts for the franchise teams thereby becoming more susceptible to injury.

Players aged 19 - 24 years were found to be more susceptible to injury than the other players. The highest incidence of injuries occurred during first-class matches, due to increased exposure. First-time injuries accounted for 65% of injuries, recurrent injuries from the previous season made up 22% of injuries, while recurrent injuries from the same season accounted for 12% of the total injuries.

Bowling accounted for the majority of injuries ranging from 33 - 42% while batting accounted for between 17 - 42%. Fielding injuries ranged from 17.1 - 33% of the total injuries. “Other” injuries were included and incorporated injuries acquired while doing fitness training, warming-up or cooling-down (Stretch 1989, 1993a and 2005). Stretch and Venter (2005) found the primary mechanism of injury to be the delivery and follow through of the fast bowler (25%).

Stretch (1989, 1993a and 2005) found that the lower limbs were most prone to injury and that the injury rate ranged from 30 - 49%. Injuries to the upper limbs ranged between 23 - 34.1%, while back and trunk injuries ranged from 19.3 -

23%. Head, neck and face injuries were found to be quite low. Although ranging between 5 - 18%, the risk of injury is generally less than 10%.

2.2.2 Injury incidence amongst Australian first-class cricketers

Orchard and James (2006) initially undertook a three-season (1995/96 - 1997/98) retrospective and seven-season (1998/99 - 2004/05) prospective study on the injury incidence of Australian first-class cricketers. A total of 886 injuries were reported according to the standard injury definition. The definition states that any ‘injury’ is any injury or other medical condition that either (1) prevents a player from being fully available for selection in a match or (2) during a major match causes a player to be unable to bat, bowl or keep wicket when required by either the rules or the team’s captain. Of the 886 injuries, 818 were reported as first-time injuries while 68 were recurrences. A total of 462 injuries occurred during major matches of which 209 were sustained while bowling, 96 while batting, 106 fielding, eight keeping wicket, with the remainder occurring gradually in an unknown activity.

It was found that the average injury match incidence, which considered only the number of injuries occurring during major matches using 12 players (per team) and length of match (in hours) in the denominator, varied from 31.4 per 10 000 man-hours in Test matches to 59.4 injuries per 10 000 man-hours in ODIs. The average seasonal incidence, which considered the number of defined injuries occurring per squad (25 players) per season (20 matches), was reported as 16.3 injuries. The average injury prevalence, considered the average number of squad members not available for selection through injury for each match divided by the total number of squad members, was found to be 8.2% for all the players, for the entire study. The injury prevalence was higher in pace bowlers (14.4%) than batsmen (4.2%), spin bowlers (3.7%) and wicket-keepers (2.0%) while no distinction was made for all-rounders. The average injury prevalence for the lower limbs is 4.1% while the back and trunk, upper limbs and head, neck and face comprise 2.4%, 1.7% and 0.1% respectively.

2.2.3 Injury incidence amongst professional English county cricketers

Leary and White (2000) conducted a study on 54 cricketers who played for the same county cricket club in any or all the seasons from 1985 – 1995. They reported that the injury incidence rate was 57.4 injuries per 1 000 days played. It was found that the highest number of injuries occurred during April (pre-season) when the least amount of cricket was played. The incidence of injury in all bowlers was greater than for any other player position followed by all-rounders, batsmen and wicket-keepers. No distinction was made between the phases of play in which the injuries were acquired e.g. batting, bowling and fielding; neither was there any mention made of the chronicity and recurrence of these injuries.

Newman (2003) compiled the most recent data on English first-class cricketers in a manner comparable to Orchard *et al.* (2002) and Orchard and James (2002 and 2004). An injury was defined as that which prevented a player from full participation in training or playing for more than one day even if there was no game or formal training planned for that day (Newman, 2003). Using the 2002 season, where all 18 first class counties were present, the seasonal incidence was reported as 10.8 per squad while the average match incidence was 15.3 per 10 000 man-hours played (22.6 ODI, 12.6 first class domestic). The seasonal injury incidence was described as the number of new injuries per squad per season based on the standardised squad of 25 players and a season of 25 matches (Newman, 2003). Newman (2003) defined match injury incidence as the number of injuries sustained per 10 000 man-hours calculated on the length of matches in hours multiplied by 12 players. The average injury prevalence was reported as 10.2%. Caution should be taken when analysing and comparing data as it is only a two-season study (Newman, 2003). Newman (2003) suggests that the lower seasonal and match injury incidence could be attributed to a slight difference in injury definition. Although the injury prevalence is slightly higher, perhaps depicting more long term injuries, it is important to note that the English county cricketers can play up to four matches a week where the Australian first-class cricketers will rarely play more than two.

Various factors can affect the data: sustaining an injury during a busy period of matches will have a greater affect on the injury prevalence than one acquired for the same length of time at a quieter time in the season. A long-term injury at the start of the season will affect injury prevalence more than one at the end of the season. Factors such as pitch conditions and climate could also impact the data.

Leary and White (2000) and Newman (2003) give the average injury risk to each anatomical region. The lower limbs (44.9 – 46%) are more prone to injury than any other anatomical region. This is followed by a similar risk of injury to the upper limbs (22.6 – 29.4%) and the back and trunk (20 – 24.3%). The head, neck and face (4.3 – 5.7%) are the least injured. Newman (2003) stated that the most likely activity to get injured in was bowling (5.6% prevalence), followed by batting (1.8% prevalence), fielding (2.1% prevalence) and wicket-keeping (0.1% prevalence).

2.2.4 Injury incidence amongst West Indian cricketers

The first cricket injury study in the West Indies, was conducted by Mansingh *et al*., (2006). Here the authors examined the injury incidence amongst 33 national players and 162 domestic cricketer players. A total of 79 injuries were reported, although only 50 injuries resulted in a match, or part thereof, being missed. There were 40 first-time injuries recorded while there were five recurrent injuries during the present season and five recurrent injuries from previous seasons. Thirty-eight acute injuries occurred while there were only eight acute-on-chronic and four chronic injuries. It was found that 50% of injuries sustained were by cricketers younger than 23 years of age.

It was shown that 40% of injuries occurred during the longer version of the game, first-class matches and test cricket. The remaining 60% of injuries were sustained during one-day matches (38%) and outside of matches (28%) including gradual onset, practise etc.

It must be noted that 22 of the injuries reported ensured that these players missed more than 21 days of play; 64% of these injuries were sustained while playing for the West Indies national team. Sixteen injuries affected the players' availability for up to three days.

It was reported that 26% of injuries were muscle strains, 12% ligament strains, 12% stress fractures and 10% other fractures. Two players were said to have been struck by lightning at the same time during a domestic one-day game. The match was immediately abandoned after the incident.

Fourteen injuries each were sustained while bowling and fielding while 10 injuries were sustained while batting. Most injuries were sustained by batsmen, to the phalanx or by fast bowlers to the lumbar spine. Of the 10 lumbar spine injuries, four were stress fractures (three bilateral), one sustained by a spin bowler, two symptomatic prolapsed intervertebral discs, two inflamed facet joints and two muscles strains, one sustained by a wicket-keeper.

The West Indian domestic season is different to domestic seasons in other countries. Their domestic season is spread over three months with each team playing seven four-day matches. The one-day competition is played six months later over a two to three week period.

The overall injury incidence among the Test team was 48.7 per 10 000 man-hours. The incidence in home series was 31.3 injuries per 10 000 man-hours, but 61.3 per 10 000 man-hours on overseas tours. A similar pattern was seen in ODIs, with, the injury incidence in overseas tours (50.2 per 10 000 man-hours) more than double that at home (23.1 injuries per 10 000 man-hours) giving an overall rate of 40.6 injuries per 10 000 man-hours. It was said that the accessibility of medical personnel during home series is easier than during away series, paying tribute to the lower injury rate during home series.

It was noted that very few West Indian players have adopted the sliding stop technique and have consequently reported none of the ankle or knee injuries caused by sliding.

2.3 INJURY INCIDENCE AMONGST SCHOOLBOY CRICKETERS

A significant increase in the occurrence of overuse injuries was found amongst young cricketers especially in the areas of stress fractures and growth cartilage injuries (Payne *et al*., 1987). However, the only study relating to the nature of injuries amongst schoolboy cricketers was conducted by Stretch (1995).

The seasonal incidence of injuries for schoolboy cricketers was 49% (Stretch, 1995). It was found that the most common site for injury was the back and trunk (33.5%). Upper limbs (24.6%), lower limbs (22.8%) and the head, neck and face (19.3%) were all injured to a lesser extent. Bowlers (47.4%) were more prone to injury than batsmen (29.8%) and fielders (22.8%). The primary areas of concern to the young fast bowler are damage to the growth cartilage of the knee, traction apophysis as well as compressive stress to the articular cartilage of the femur and talus and the femoral neck (Payne *et al*., 1987). Payne *et al.* (1987) states that spondylolysis of the lumbar vertebrae is often misdiagnosed amongst young cricketers.

A similar proportion of injuries were reported during matches (45.6%) and practices (47.4%) and injuries were found to be more common during the early and latter part of the season (Stretch, 1995). First time injuries accounted for 33.4% of the total injuries while 29.8% recurred from a previous season and 36.8% of the injuries recurred during the same season.

2.4 BOWLING

Bowling, in particular fast bowling, has been reported as the major cause of injury amongst cricketers of all ages (Foster *et al*., 1989; Stretch, 1993a; Bartlett *et al*., 1996; Elliott, 2000; Leary and White, 2000; Orchard *et al*., 2002; Newman; 2003). The prevalence of bowling injury is approximately 40% (Stretch, 2003a) amongst first-class cricketers and 47.4% amongst schoolboy cricketers (Stretch, 1995). Bowling injuries comprise between 22.2 – 23.9% of the injuries sustained by Australian first-class cricketers during major matches (Orchard *et al*., 2002; Orchard and James, 2002). Comparison with the above-mentioned studies would be inappropriate as Orchard *et al.* (2002) and Orchard and James (2002) restrict the definition of injury to that which affects the availability of the cricketer during major matches.

Bowling is a high impact, repetitive activity displaying a combination of hyperextension, lateral flexion and rotation of the trunk in an endeavour to position the body to achieve maximum delivery speed. These actions place the spine at an increased risk of injury (Stretch, 1989; Elliott 2000; Millson *et al.*, 2004; Ranawat and Heywood-Waddington, 2004).

Elliott (2000) reported that the fast bowler experiences his greatest impact with the pitch at front foot impact (FFI) of the delivery stride. Peak vertical forces of up to five times the cricketer's body weight and peak horizontal deceleration of twice the cricketer's body weight are generated, irrespective of the standard of the performance (Stretch, 1989; Elliott, 2000). These forces are transmitted through the kinetic chain (bone, cartilage, tendons and muscles via the foot, ankle, knee, hip and back joints) and can be modified by footwear and lower limb mechanics (Elliott, 2000).

2.4.1 Types of injuries found amongst bowlers

2.4.1.1 Lower limb injuries

Stretch (2001b) suggests that the lower limb is the anatomic region most frequently injured by fast bowlers (See Table 1). Lower limb injuries are generally associated with front foot strike in the delivery stride (Bartlett *et al.*, 1996).

Stretch and Venter (2005) states that acute soft tissue injuries to the lower limbs occur as a result of overuse. The most common overuse injuries are shin splints and bruised heels (Stretch, 1989; Bartlett *et al.*, 1996; Orchard and James, 2002). Overuse injuries occurring toward the end of the season include talotibial exostoses (Stretch, 1989) and patellar tendinitis (Stretch, 1989; Bartlett *et al.*, 1996). Stretch (1989), Bartlett *et al*. (1996) and Orchard and James (2002) report the frequent occurrence of stress fractures to the metatarsals, fibula and tibia. Bartlett *et al.* (1996) includes stress fractures of the calcaneus as well as

Table 1: The most common injuries seen amongst first-class cricketers [%, (n)]

	Orchard *et al.* (2002)	**Orchard & James (2004)**	**Leary & White (1999)**	**Newman (2003)**	**Stretch & Venter (2005)**	**Mansingh *et al.* (2006)**
Head, neck & face injuries	**3.4 (18)**	**4.2 (27)**	**5.7 (56)**	**4.3 (33)**	**5.5 (89)**	**12.0 (6)**
Cranium						8.0 (4)
Neck injuries	0.9 (5)				2.9 (47)	4.0 (2)
Concussion						
Lacerations	1.5 (8)					
Fractured facial bones	0.9 (5)					
Other head injuries						
Upper limb injuries	**19.7 (104)**	**20.6 (133)**	**29.4 (291)**	**22.6 (173)**	**22.7 (365)**	**28.0 (14)**
Shoulder tendon injuries	5.5 (29)		1.0 (10)			
Shoulder dislocations & sublaxations	0.8 (4)					
Other shoulder injuries						2.0 (1)
Arm lacerations & haematomas	0.8 (4)					
Elbow injuries	0.6 (3)				2.9 (47)	
Forearm fractures	0.9 (5)					2.0 (1)
Hand injuries	10.6 (56)		4.0 (40)	10.1 (77)	7.6 (122)	22.0 (11)
Wrist injuries						
Upper limb stress fractures	0.4 (2)					
Humerus						2.0 (1)
Gleno-humeral joint					5.0 (81)	
Other upper limb injuries	0.2 (1)					
Back and trunk injuries	**19.9 (103)**	**20.8 (134)**	**20.0 (198)**	**24.3 (186)**	**22.7 (364)**	**28.0 (14)**
Lumbar stress fractures	2.7 (14)		2.2 (22)	14.0 (107)		20.0 (10)
Lumbar injuries (other than stress fractures)	7.8 (41)			2.0 (15)	10.5 (169)	
Rib fractures	0.6 (3)				2.0 (32)	2.0 (1)
Side & abdominal strains	8.9 (45)				3.2 (52)	6.0 (3)
Thoracic spine					1.9 (31)	
Lower limb injuries	**49.1 (259)**	**47.8 (308)**	**44.9 (445)**	**46.1 (353)**	**49.1 (788)**	**28.0 (14)**
Groin injuries	7.2 (38)				3.5 (56)	6.0 (3)
Hamstring strains	10.6 (56)		8.0 (79)	6.0 (46)	8.8 (141)	8.0 (4)
Quadriceps strains	3.4 (18)				5.4 (86)	2.0 (1)
Calf muscle strains	2.7 (14)					
Knee ligament injuries	2.3 (12)		1.2 (12)			6.0 (3)
Knee cartilage injuries	5.9 (31)				6.3 (101)	
Knee tendon injuries	2.8 (15)		1.2 (12)			
Leg stress fractures	1.5 (8)					4.0 (2)
Lower limb fractures (not stress fractures	0.9 (5)					
Lower limb haematomas & lacerations	3.0 (16)		2.3 (23)			
Shin soft tissue overuse Injuries	0.2 (1)					
Ankle & foot sprains	4.2 (22)		1.1 (11)		5.8 (93)	2.0 (1)
Foot stress fractures	0.8 (4)					
Heel & achilles injuries	3.2 (17)					
Other lower limb injuries	0.4 (2)					
Other	**8.2 (43)**	**6.6 (43)**		**2.7 (21)**		**4.0 (2)**
Other soft tissue injury						4.0 (2)
Medical illness	8.2 (43)			2.7 (21)		
Total (N)	**527**	**645**	**990**	**766**	**1606**	**50**

intra-articular osteochandral stress fractures. Complete muscle tears of the hip flexors, adductor longus and rectus femoris are reported by Stretch (1989) while muscle strains to the hamstrings, quadriceps, gastrocnemius and groin are also quite common (Bartlett *et al*., 1996; Orchard *et al*., 2002; Orchard and James, 2002; Newman, 2003; Stretch and Venter, 2005).

Wear and tear of the articular cartilage on the anterior side of the knee is prevalent amongst straight leg bowlers (Bartlett *et al*., 1996; Orchard and James, 2002; Orchard *et al*., 2002). Stretch (1989) and Orchard and James (2002) have reported ligament and tendonous injuries to the knee. Patellar bursitis, compartment syndrome, achilles tendinitis and adjacent bursitis, periositis, ankle ligament sprains, plantar fasciitis, as well as chronic bruising of the big toe and the nail of the big toe have been reported (Bartlett *et al*., 1996; Orchard and James, 2002). Orchard and James (2002) also report lower leg haemotomas and lacerations.

2.4.1.2 Back and trunk injuries

McGrath and Finch (1996) state that the most severe overuse injury that can occur in bowlers, is the development of abnormal radiological features in the lumbar spine. Spondylolysis particularly of the third, fourth and fifth vertebrae, is very common amongst fast bowlers (Stretch, 1993a; Bartlett *et al*., 1996; Leary and White, 2000; Orchard *et al*., 2002; Orchard and James, 2002). Bartlett *et al*. (1996) identified spondylolisthesis, pedicle sclerosis, disc degeneration and bulging as being common injuries.

Stretch (1989), Orchard *et al*. (2002) and Orchard and James (2002) have reported various soft tissue injuries to the lumbar region while Bartlett *et al*. (1996) reports injuries to the facet joints of the lumbar vertebrae and their ligaments. Stretch (1989), Orchard *et al*. (2002), Orchard and James (2002) and Bartlett *et al*. (1996) have reported severe abdominal muscle tears. Bartlett *et al*. (1996) reported quadratus lumborum strains, while Orchard *et al.* (2002) and Stretch and Venter (2005) reported side strains. Bartlett *et al*. (1996) discovered the occurrence of rib-tip syndrome amongst bowlers to the tenth and eleventh rib, while Stretch (1989) reported the rare occurrence of acute pneumomediastinum and bilateral pneumothoraces.

2.4.1.3 Upper limb injuries

Shoulder tendon injuries are the most common upper limb injury amongst bowlers (Stretch, 1989; Orchard and James, 2002; Orchard *et al*., 2002). Orchard and James (2002) also make mention of wrist and hand injuries as well as various types of stress fractures to the upper limbs. Stretch (1989) reports of elbow strains as well as pinched nerves in the shoulder region. Rotator cuff sprains and impingement, olecranon bursitis and stress fractures as well as phalangeal stress fractures are also reported (Bartlett *et al*., 1996).

2.4.2 Risk factors associated with an increased injury incidence amongst bowlers

2.4.2.1 Age

Motley *et al*. (1998) suggests that a sudden growth spurt, as seen during adolescence, could lead to injury in that the surrounding musculature and ligaments are not strong enough to support the bony structure or are too strong for bony structures placing undue force on those immature structures. Young fast bowlers (under 24 years) were the most susceptible to traumatic or overuse injuries (Foster *et al.,* 1989; Burnett *et al.*, 1996; McGrath and Finch, 1996; Stretch, 2001b), perhaps due to the fact that their growth processes were not complete.

(a) Growth processes

The growth process of concern amongst cricket players is that of endochondral ossification which entails the ossification of cartilaginous structures (Watson and Lowrey, 1962). In young people, the diaphysis and epiphysis of a bone, are separated from one another by a cartilaginous structure, known as the epiphyseal plate. Continuous ossification of the epiphyseal plate leads to longitudinal growth. Between the 14^{th} and 25^{th} years of life, the various epiphyseal plates are known to completely ossify after which no more growth occurs. The average age of the closure of the various epiphyseal plates is given in Table 2.

Table 2: The average age (in months) of the closure of the epiphyseal plates.

	Males	**Females**
Shoulder		
Greater tuberosity of humerus	218	187
Head of humerus	66	49
Elbow		
Capitulum of humerus	182	149
Medial epicondyle of humerus	196	169
Trochlea of humerus	181	148
Lateral epicondyle of humerus	184	152
Proximal epiphysis of radius	194	162
Proximal epiphysis of ulna	185	152
Wrist		
Distal epiphysis of radius	216	191
Distal epiphysis of ulna	215	191
Hip		
Head of femur	195	170
Greater trochanter of femur	191	167
Knee		
Distal epiphysis of femur	199	177
Proximal epiphysis of tibia	203	178
Proximal epiphysis of fibula	206	182
Ankle		
Distal epiphysis of tibia	203	178
Distal epiphysis of fibula	203	179

*Adapted from Malina (2004).

Forriol and Shapiro (2005) state that the static loads exerted by the proximal growth plate of the tibia and the distal growth plate of the femur in adolescents is approximately 500N or between 5 - 25% of the individual's body weight. The stress exercised by each growth plate is around one mega-pascal. A pascal is defined as the pressure exerted by the force of one newton operating on an area of one square meter (Masterton and Hurley, 1997). A slight increase or decrease in the compressive forces on the growth plates seems to accelerate cartilaginous growth. The increase in growth is particularly true with intermittent dynamic loading. If the compressive forces are below physiological limits, growth can be reduced or halted whereas large increases in compressive forces can severely retard growth. It is said that the suppression of the longitudinal growth is proportional to the magnitude of the load (Farriol and Shapiro, 2005).

Dynamic loading is thought to increase osteogenesis (proliferation of osteocytes needed for bone growth) whereas static loading suppresses it.

Changes caused by growth and activity in childhood influences the process of skeletal development e.g. the development of the proximal femur reflects a change in the adaptation of the physeal and trabecular patterns to mechanical requirements (Farriol and Shapiro, 2005). In a game such as cricket, the cricketer is exposed to forces of between two to five times the individual's body weight while bowling (Stretch, 1989; Elliott, 2000). Farriol and Shapiro (2005) state that if these forces repeatedly act on the immature bone structure of adolescent cricketers, it can cause growth retardation. This is particularly true of the growth plate and traction apophysis in the knee of young bolwers (Payne *et al*., 1987) as well as that of the femur and talus.

Cricket has now become so competitive, offering greater career opportunities and financial rewards to those who reach the top that the younger players have to train harder than before in order to be selected for the team, to establish themselves within the team and to maintain their positions (Stretch, 2001c).

Orchard and James (2002) found no relationship between player age and injury risk amongst Australian first class cricketers. In a study on work load and injury incidence, Dennis *et al.* (2003) found no appreciable age difference between injured and uninjured players yet suggested that there was a slight increase in injury risk for 25 –29 year olds.

Bartlett *et al.* (1996) and Stretch (2001b) state that young fast bowlers are being forced to play more matches and to train longer and harder at an earlier age in order to excel. During the adolescent growth period, fast bowlers seen to be at an increased risk of developing lumbar spine pathology (Burnett *et al.,* 1996). The risk of injury is compounded if the bowler does not have a sound technique (Stretch, 2001b). A concern for McGrath and Finch (1996) is that young talented bowlers often suffer back injuries before they reach elite level. Young cricketers have elastic vertebral discs that transmit forces more readily to the facet joints placing undue stress on the pars interarticularis. Excessive bowling throughout the growth period when the spine is relatively immature will increase the cricketer's vulnerability to injury, as the forces associated with bowling are unable to be absorbed. These players will also be predisposed to bony abnormalities. McGrath and Finch (1996) and Stretch (2003b) state that young fast bowlers are more prone to stress fractures or disabling back injuries than their older counterparts.

Stretch (1991) suggests that young bowlers are also susceptible to damage of the growth cartilage of the knee and traction apophysis as well as compressive stress to the articular surface cartilage of the femur and talus. Young bowlers are said to be at a greater risk of sustaining acute injury to soft tissues of the lower limb during matches and practises in the early part of the season (Stretch, 2003a). It was found that young cricketers are susceptible to recurrent injuries; either during the same season or subsequent seasons, the primary cause being overuse and bowling (Stretch and Venter , 2005).

Stretch (2001c) stated that schoolboy cricketers have a lack of understanding of basic practice and training principles:

- Sudden increase in the length of bowling spells during matches and practices
- Attempts to bowl too quickly
- Captains and coaches over bowling a bowler who is performing well or bowling him unchanged
- Bowler returning for subsequent bowling spells often without adequate recovery or warm-up
- A sudden increase in the number of practices or matches played
- Inadequate warm-up
- Returning to match play too soon after injury

Young fast bowlers are often asked to bowl at provincial practices to allow batsmen extended batting practice while provincial bowlers are able to rest (Stretch, 2001b) further increasing the likelihood of overuse injuries.

2.4.2.2 Speed and Type of Bowling

Gregory *et al.* (2002) compared injuries of spin bowling (wrist and finger) with fast bowling in 112 young (average age of 14.9 years) cricketers. A total of 95 injuries were reported, 44 being attributed to bowling with only 29 impairing or preventing bowling. The most common sites of injury were the ankle, knee, shoulder and lower back. There was a statistically significant difference in injury between fast and spin bowlers at the ankle (8.6% vs. 0.0%), knee (11.4% vs. 0.0%) and shoulder (1.4% vs. 11.9%) but not the lower back (5.7% and 2.4%). Spin bowlers presented with more shoulder injuries while fast bowlers presented with more ankle and knee injuries. Wrist spinners were affected by the most severe shoulder injuries. Fast bowlers did not ascribe shoulder injuries to bowling. Although there was not a statistically significant difference in the number of lower back injuries, only fast bowlers were prevented from bowling due to lower back injuries. Gregory *et al.* (2002) found that 18% of bowling injuries were to the trunk while 61.5% were to the lower limb and suggested that age may be influential in the high numbers of lower limb injuries due to the skeletal immaturity of the cricketers. This is supported by the fact that two cases of Osgood-Schlatter disease were reported amongst these injuries.

Preventative measures for back injuries found in previous research conducted on fast bowlers could be responsible for a lower injury incidence in the above-mentioned group (Gregory *et al*., 2002). Wrist spinners could be more susceptible to injury due to the internal rotation of the bowling shoulder while the arm circumducts. Gregory *et al*. (2002) suggest that by eliminating certain confounding variables they would exaggerate the injury rate in fast bowlers. Injuries were self-reported and precise diagnosis was not given.

In studies by Orchard and James (2002 and 2004), it was found that pace bowlers (14.5 – 16%) have a higher injury prevalence than spin bowlers (3.7 – 4%). Newman (2003) reported that fast bowlers (18%) had a higher injury prevalence than fast-medium (15%) and slow (8.9%) bowlers.

2.4.2.3 Biomechanics of fast bowling

The biomechanics of fast bowling has been well documented due to the fact that it is one of the activities that results in the highest injury incidence amongst cricketers (Bartlett *et al*., 1996). Hurrian and Harmer (2003) filmed and analysed 60 junior (u/13 - u/19) fast-medium bowlers and identified seven faults that need to be eradicated to decrease the risk of injury.

(a) Approach Speed

The speed at which the bowler approaches the wicket, should be sufficient to produce as high a linear velocity of the body as possible for ball release (Bartlett *et al*., 1996; McGrath and Finch, 1996). The approach speed will determine the alignment of the hips and shoulders at back foot impact (BFI) (Bartlett *et al*., 1996; McGrath and Finch, 1996) which then relates to the type of bowling action adopted.

Bartlett *et al.* (1996) suggests a gradual build up of speed when adopting the front-on technique, with the maximum speed (between 3.9 - 5.5m.s^{-1}) reached three to four strides from the end. Hurrian and Harmer (2003) say that the quicker the bowler runs in, the greater the BFI and front foot impact (FFI). The bowler has a very short period in which to laterally flex, extend and rotate the spine further increasing the risk of injury (Bartlett *et al*., 1996). The cricketer will have to sustain a higher level of physical conditioning in order to withstand the increased ground reaction forces (GRF). Bartlett *et al.* (1996) and McGrath and Finch (1996) report that a slower run-up is required in order to comfortably convert to a side-on action.

(b) Long arms prior to delivery

Hurrian and Harmer (2003) suggested that the higher the bound in pre-delivery take off, the greater the force exerted on the body during landing. This can lead to several problems as well as a decrease in momentum for instance:

- Bowling hand and ball start in front of the body.
- Bowling arm begins to rise high above the bowler’s head.
- Ball and arm moving backwards while the body continues forward.

This results in the torso leaning too far backward and the bowling action becoming long and slow. At pre-delivery take-off, the ball is behind the bowler causing the momentum of the bowler to go upwards and not towards the wicket and target. This results in a loss of horizontal speed in the run-up. This fault is more commonly seen amongst side-on bowlers, as they need sufficient time during the pre-delivery stride to attain their side-on position. A ball release height of 114% or more of the bowler's standing height will predispose the bowler to abnormal radiological features (Bartlett *et al*., 1996).

(c) Back foot collapse

Ideally, with a side-on action, the back foot should land parallel to the popping crease with the bowler's body leaning away from the batsmen (Bartlett *et al.*, 1996). Two main reasons exist for a back foot collapse:

- The pre-delivery stride is said to be too long or too high. This will be inefficient, a waste of energy and heighten the risk of injury as the GRF at BFI and FFI impact will be increased.
- Angle of run up – several bowlers directed their momentum towards fine leg, which means that they had to redirect their momentum towards the target at the moment of BFI. The more time spent on the back foot, the more energy is expended and the more momentum is lost through the crease. It also creates unnecessary stress on the hip and knee joints of the back leg.

(d) Blocking and opening of the front foot

Bartlett *et al.* (1996) and McGrath and Finch (1996) suggested that the back foot, front foot and stumps should form a straight line during the delivery stride. Bowlers often block off their body with the front foot due to the angle of the run-up with the bowler's momentum directed toward fine leg when bowling to right-hand batsmen. Together with back foot collapse, the bowler is unable to redirect his momentum towards the target and the front leg ends up going across the body. This causes a tremendous amount of stress throughout the lower back and as a result, the torso falls away in order to allow the bowling arm to be redirected toward the stumps (Hurrian and Harmer, 2003).

(e) Long delivery stride – collapsing of the front leg

Bartlett *et al.* (1996) recommends that the delivery stride be approximately 75 – 85% of the bowler's standing height. It is said that the delivery stride is dependent on the approach speed into the delivery stride as well as the physique of the bowler (Bartlett *et al.*, 1996; McGrath and Finch, 1996).

There are three main reasons for the front foot collapsing prior to delivery (Hurrian and Harmer, 2003):

- Back leg collapsing on BFI – the more the back foot collapses, the higher the front leg tends to become and as a result the longer the delivery stride. The long delivery stride will make it more difficult for the bowler to bowl over a solid, braced front leg. The back foot should land close to the popping crease and the front foot should land on the batting crease.
- Approach velocity - Those who approach the crease too quickly will have a shortened delivery stride (Bartlett *et al.*, 1996; McGrath and Finch, 1996).
- Physical fitness and strength – the faster the bowler runs into the wicket, the greater their physical conditioning needs to be in order to withstand the GRFs (Hurrian and Harmer, 2003).

It has been suggested that bowlers adopt a straight front leg technique in order to maximise ball release speed as it provides a stable lower body, which the bowler can use as an effective lever. This could however be injurious, as the knee joint will not be able to play an effective role in the attenuation of impact forces. This results in an increase in stress fractures of the lower back. By flexing the knee, it would reduce the forces in the skeletal structures of the knee and hip joints but might increase the forces in the muscles and tendons. It is said that slight flexion of the delivery leg could decrease vertical and horizontal GRF to 2.0 and 0.3 times the bowlers body weight respectively. Ideally, the bowler is to flex the front knee slightly on landing (attenuating the impact forces) and then to extend to a straight front leg. However, very few cricketers can master this technique (Bartlett *et al.*, 1996). Bartlett *et* al. (1996) also states that a flexed knee might adversely affect the speed of ball release.

(f) Excessive lateral flexion of the torso

The main reason for this is that the upper body is out of alignment with the lower body due to incorrect foot positioning or hip and shoulder alignment (McGrath and Finch, 1996; Hurrian and Harmer, 2003). In order to identify a potential problem Hurrian and Harmer (2003) advise that you record the bowler's action front-on. At the moment of release, draw an imaginary line through the shoulders and measure the angle created with the vertical. The angle should be approximately 45°. It is important to note how much the shoulder angle changes from FFI to release. The greater the angle between the shoulder and the pelvis, the more stress on the lower back. Bowlers should try to keep their heads upright throughout the delivery phase and try to release the ball directly above their front foot. At front foot loading, the force through the body is at its maximum.

(I) Bowling classification

Various methods have been used in order to distinguish between the three different bowling techniques namely side-on, front-on and mixed action. McGrath and Finch (1996) use shoulder and back foot alignment to classify bowling actions, while Gray *et al*. (2003) devised a method using the angle of pelvic-shoulder separation (P_A-S_A).

(i) Side-on

Stretch (2003c) states that the side-on technique requires a relatively slow run-up. Just prior to the delivery stride, the bowler performs a cross-over step to enable the back foot to be placed parallel to the back crease (See Figure 1). A line can be drawn through the back foot, the front foot and the middle stump at the batsmen's end. This ensures that the line of the hips and shoulders is pointing down the pitch.

The shoulder alignment should be less than or equal to 190° and the back foot angle should be less than or equal to 280° where the right hand horizontal line drawn through the leading shoulder parallel with the pitch (McGrath and Finch, 1996). Gray *et al.* (2003) suggests that the P_A-S_A will be less than 20° with the pelvic and shoulder alignments less than 200°.

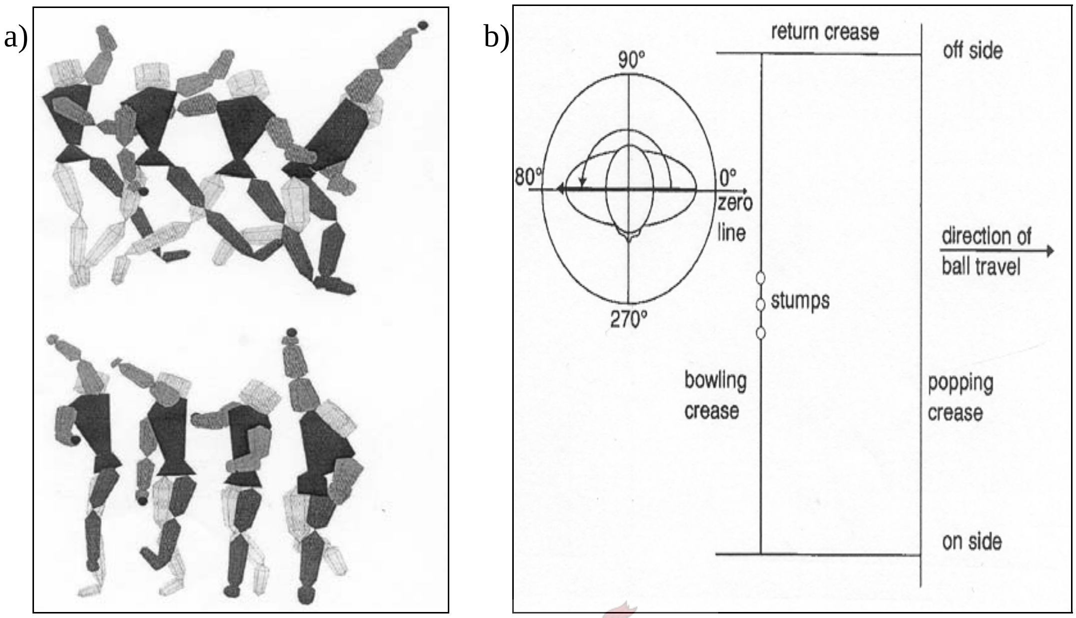

Figure 1: Side-on bowling technique taken from Bartlett *et* al. (1996) a) Depicts body alignment and cross over step from the side view and front view. b) Shows the angle of the shoulders (180º) on BFI.

(ii) Front-on

The front-on technique requires a faster run-up with a more open-chested position at back foot placement (Stretch, 2003c).

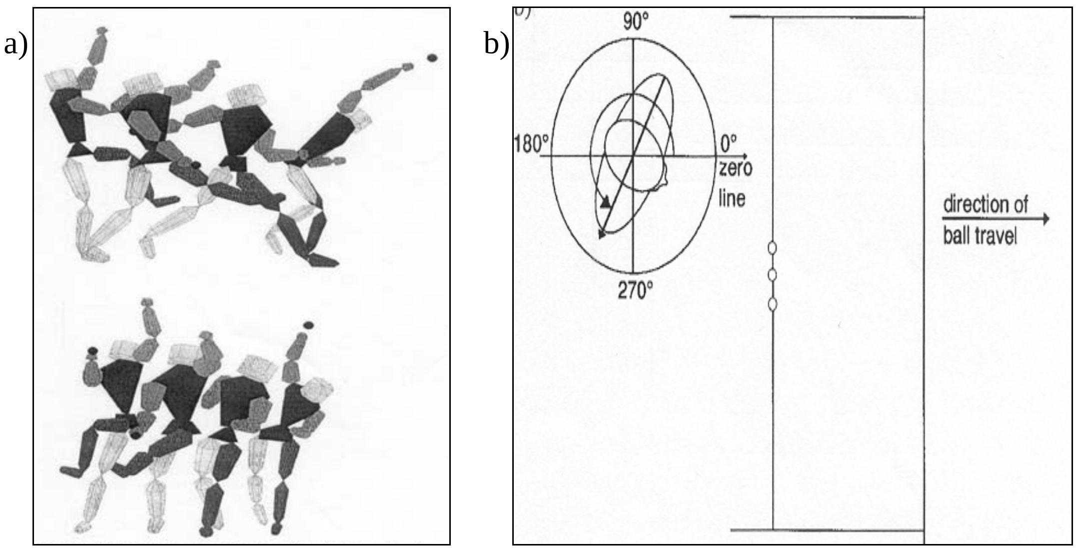

Figure 2: Front-on bowling technique taken from Bartlett *et* al. (1996) a) Depicts body alignment and from the side view and front view. b) Shows the angle of the shoulders (>190º) on BFI.

No cross-over step is performed as the back foot is placed pointing down the length of the pitch with the line of the hips and shoulders pointing towards third slip. Stretch (2003c) urges bowlers not to rotate the upper-body into a more side-on position between back foot and front foot placement. McGrath and Finch (1996) state that the bowlers with a front-on action have a shoulder alignment greater than 190° and a back foot angle of greater than 280° (See Figure 2); while Gray *et al.* (2003) states that the P_A-S_A is less than 20° with the pelvic and shoulder alignments greater than 200°.

(iii) Mixed action

Stretch (2003c) states that the mixed technique is a combination of the side-on and front-on techniques and links this particular technique to lower back injury. Two mixed techniques have been identified namely the side-on mixed technique and the front-on mixed technique.

Figure 3: Depicts the body alignment from the side view and front view of the mixed bowling technique taken from Bartlett *et* al. (1996).

Bowlers present with a side-on mixed technique when their feet land in a side-on position with their feet parallel to the crease and hips aligned down the pitch. Their shoulder alignment changes from a side-on position and BFI to a front-on alignment at FFI. Hips and shoulders are not aligned placing excessive stress on the lower back at BFI, FFI and the follow through. The front-on mixed technique is where the feet land in a front-on position with the back foot pointing down the length of the pitch and the hips pointing towards third slip. However, the shoulder alignment changes from a front-on position at BFI to a side-on alignment at FFI. Hips and shoulders are not aligned and places excessive stress on the lower back during BFI and FFI.

McGrath and Finch (1996) only highlighted the front-on mixed technique where the bowler is front-on at BFI (i.e. >280°) but in an attempt to obtain a more side-on position, the bowler counter-rotates his shoulders. P_A-S_A is greater than 20° at any point between BFI and FFI (Gray *et al*, 2003).

Bartlett *et al*. (1996) states that bowlers continuously using a mixed action are prone to develop abnormal radiological features in the lumbar spine as they place the spine in an awkward position at a time when the GRF are at their greatest. Stretch (2001a) states that bowlers adopting a mixed action are at an increased risk of injury. If bowlers were to adopt a side-on action their bodies would be able to summate the various forces more efficiently (Stretch, 1989) obtaining maximum velocity with minimum strain on the body structures.

(g) General alignment

In an ideal technique, the pre-delivery stride, BFI, FFI, and first stride in the follow through should be in a straight line aiming toward the target (Hurrian and Harmer, 1996).

2.4.2.4 Workload

Gregory *et al.* (2004b) compared work load and injury incidence among 70 fast bowlers between the ages of nine and 21 and found no significant difference between those bowling less than 1 000 balls, those bowling between 1 000 – 3 000 balls and those bowling more than 3 000 balls per season.

The authors acknowledged having failed to analyse the data for confounding variables. Some of the injuries acquired within this study could have been attributed to growth spurt. A decreased bowling injury incidence may be due to the fact that they were bowling on softer English pitches, which offers more force absorption. Bowlers bowling more in the time leading up to the study period may have become injured and therefore bowled less in the study period, exacerbating the injury incidence amongst this group (Gregory *et al*., 2004b). Some of the injuries may have become manifest after the study period yet pertains to its activities. The study did not consider individual bowling spells in the nets or in matches, an important factor when bowlers become fatigued.

The reliability of the results could be questioned as the total workload was estimated. Although there were 70 subjects, the sample comprised a wide variety of age groups (under-13, under-15, under-17, under-19 and senior), making the sample of each age group even smaller. Some injuries that could be more prevalent amongst certain age groups can therefore not be identified.

Dennis *et al*. (2003 and 2004) investigated the relationship between fast bowling workload and injury in first-class cricketers. It was found that injured bowlers bowled more frequently than uninjured bowlers did (Orchard and James, 2002; Dennis *et al.*, 2003). Bowlers should bowl with an average of two to five days rest between bowling sessions; those bowling more or less frequently are at a significantly increased risk of injury. Bowlers who bowled in five or more sessions per week may have been at 4.5 times the risk of sustaining injury (Dennis *et al*. 2004). Bowlers bowling at training more frequently than every six days are at 1.8 times the risk of injury.

Orchard and James (2002) found that hamstring and shoulder injuries had the greatest correlation between high workload and the risk of injury (Table 3). Risk factors were a high number of match overs in the previous week and the number of days of play.

Table 3: The risk of hamstring & shoulder injury in relation to bowling workload

	Average match overs bowled in previous:			
Bowlers who suffered:	Week	Two weeks	Month	Three months
No injury	8	17	34	92
Hamstring injury	17	31	53	137
Shoulder injury	17	31	58	185

* This Table was adapted from McGrath and Finch (1996)

Orchard and James (2004) found that the number of bowling sessions per week correlated with the risk of injury. An English county cricket surveillance revealed that the weekly match workload for first class bowlers in England is almost double than in Australia (Newman, 2003). It also revealed that English first-class cricketers had a higher injury prevalence (12.3%) than the Australians (7.0%) but Newman (2003) suggests that it could be due to the increased number of matches played per week.

Bowlers bowling an average less than 40 deliveries per session were at an increased risk of injury compared to those who bowled more than 40 deliveries per session (Dennis *et al*., 2003). Bowlers are presumably urged to maintain a certain level of conditioning (bowl a minimum number of deliveries) in order to withstand injury. In the injured, it was found that there was a significant increase in the number of deliveries bowled per session in the eight – 21 days prior to injury (Dennis *et al.,* 2004). Dennis *et al*. (2003) reported that injured bowlers bowled on average 70 more deliveries per week than their uninjured counterparts. Bowlers were advised to maintain a workload of between 123 – 188 deliveries per week. An increased risk of injury was displayed when bowlers bowled more than an average of 522 deliveries per 30 day period (Dennis *et al*., 2003).

Bowlers bowling too many overs in a single spell or bowling too many spells during matches or practises predispose themselves to lower back injury (McGrath and Finch, 1996). Once fatigue sets in, bowlers with a perfect technique will start changing their body action to accommodate the fatigue putting the bowler in a high-risk category. McGrath and Finch (1996) reported on a study involving possible biomechanical changes during a 12-over spell in nine bowlers. Although the bowling technique did not vary substantially to draw any conclusive evidence, those who had adopted a front-on technique displayed counter rotation of the shoulders after 12 overs.

Any sudden escalation in bowling workload should be avoided, especially if it is going to be maintained. Bowlers should try to decrease their training workload during periods of high match bowling workload (Dennis *et al*., 2003 and 2004).

Stretch (2003c) advises coaches to become aware of the fact that individuals grow and develop at different rates and that they need to adjust their players' training and competitive workloads to suit their maturity level. Excessive bowling during the player's growth period will lead to injury especially to immature spines.

2.4.2.5 Playing conditions

(a) Surface

Orchard and James (2002) found cricketers to be at an increased risk of injury on harder pitches and suggested that quadriceps strains and injuries to the soft tissue of the lumbar region may be related to ground hardness as well. Concrete offers 0% force absorption, hard turf pitches 35% and grass can offer up to 75% force absorption (Stretch, 2003c). The possibility of injury due to potholes and sprinkler pop-ups needs to be eliminated and the pitch must be carefully prepared ensuring that it is flat and smooth (McGrath and Finch, 1996).

(b) Weather

Cricket is a sport played in summer which means that there is an increased risk of skin cancer, dehydration, heat exhaustion and even heat stroke (McGrath and Finch, 1996). McGrath and Finch (1996) suggest general thermoregulation e.g. wearing appropriate clothing, using sunscreens, maintaining hydration and acclimatisation as a form of injury prevention. Cramps, headaches, dizziness and a lack of co-ordination are symptoms of heat stress that coaches and cricketers need to be aware of. Players who are unfit or overweight are said to be more susceptible to heat illness (McGrath and Finch, 1996). It is advised that cricketers regularly consume fluids to reduce the risk of heat illness and maintain physical and mental performance.

The pitch could also become wet which may allow the ball to bounce erratically endangering the batsmen (McGrath and Finch, 1996). The umpire is able to call the pitch or out-field as unfit for play when it is slippery or wet and affects the foothold of bowlers, fielders and/or batsmen.

2.4.2.6 Level of match

The risk of bowling injury during domestic matches is not significantly different to that of international matches. Orchard and James (2002) stated that the differences that do occur in injury incidence and prevalence may be due to factors such as workload. It was reported that shoulder tendon injuries were more prominent at international level.

2.4.2.7 Bowling first or second in a match and time of match

The relative risk for bowling injury for the team bowling second in a first class match and day-night game is 1.60 (Orchard and James, 2002). It was initially thought to be due to a lack of warm-up or related to fatigue but was later found that possible fatigue from batting in the first innings was not a relevant risk factor (Orchard and James, 2004). No mention was made of the risk of injury for the side batting first.

2.4.2.8 Past history of injury

It is said that previous injury is a strong predictor of current injury in fast bowlers (Stretch, 2003a). Orchard and James (2002) suggest that there is an apparent association between many cricket injuries and a past history of that injury, including muscle strains, knee injuries, shoulder tendon injuries and groin injuries. There is no apparent relationship between past history of a side strain and the recurrence of the injury. There may however be two or more different types: certain side injuries that have an increased risk of incidence while others display a negative correlation.

2.4.2.9 Muscle strength and flexibility

With continuous bowling during the season, a bowler’s lower lumbar vertebrae are inclined to become stiff. McGrath and Finch (1996) say that stiff joints at particular interval levels of the lumbar spine may place extra force on existing hyper-mobile joints at other levels resulting in injury. Tightness in muscles of the pelvis could cause it to tilt anteriorly, increasing lordosis in the lumbar vertebrae. Any decrease in the flexibility of lower back musculature will increase the possibility of back injury.

Poor hamstring or lower back flexibility will predispose the cricketer to intervertebral disc abnormality (Bartlett *et al.*, 1996; McGrath and Finch, 1996). It was found that bowlers with disc degeneration or bulging produced lower sit and reach scores than bowlers with natural vertebral structure (McGrath and Finch, 1996).

The greater the effort the fast bowler has to put into a delivery or bowling spell, the greater the stresses placed on the body and the faster fatigue sets in (Stretch, 2003c). McGrath and Finch (1996) state that a high level of muscle endurance is paramount to staying injury free as fatigue is substantially delayed. Bowlers need to pay particular attention to developing leg, back and trunk strength and flexibility (Stretch, 1989) but too much reliance on upper body strength could result in the bowler bowling too quickly culminating in back injury.

2.4.2.10 Bowling vs. non-bowling side of body

Orchard and James (2002) found that shoulder, groin and knee cartilage injuries are more likely to occur on the bowling side while side-strains, lumbar stress fractures and hamstring injuries are more common on the non-bowling side.

2.4.2.11 Body composition

Excessive body fat is detrimental to cricketing performance and does not contribute to energy production resulting in the body consuming more energy to support this excess weight (McGrath and Finch, 1996). The sum of seven skin-folds (triceps, subscapular, biceps, supraspinale, abdominal, thigh and medial calf) was found to be 66.3 ± 24.2mm amongst Australian state cricketers and 74.7 ± 25.1mm amongst Australian test cricketers (Bourdon *et al.*, 2000). Unpublished data regarding the mean percentage of body fat amongst Victorian state cricketers, was 12.3% with a range of 9.6 – 15.3% (Payne *et al.*, 1987). The average body composition (using three skinfolds: chest, abdomen and thigh as described by Jackson and Pollock) of South African provincial cricketers, measured between the years 2000 - 2002 was 9.3 ± 3.6% (Coopoo and Vallabhjee, 2003).

2.4.2.12 Posture

Any deviations from the normal anatomic relationship between skeletal and muscular systems increase the risk of injury (McGrath and Finch, 1996). McGrath and Finch (1996) suggest that repetitious fast bowling could aggravate scoliosis while a low longitudinal arch could predispose the cricketer to stress fractures of the lumbar vertebrae as the foot is not capable of absorbing high forces at front foot impact. A leg length discrepancy could alter lumbosacral alignment (Motley *et al*., 1998) causing muscle imbalances which could then result in injury.

2.5 BATTING

The aspect of cricket batting has been neglected by sport scientists, as is evident from the lack of reported research (Stretch *et al*., 2000). The batsman must make several decisions once the ball has left the bowler's hand. These include deciding on the line and length of the ball, deciding on whether to move forward or backward to the pitch of the delivery, deciding on whether or not to play a stroke and which stroke to play. These decisions rely predominantly on the reaction time of the batsmen (McGrath and Finch, 1996).

Laboratory measures of visual reaction time indicate that some aspects of high speed ball are impossible to monitor because there is insufficient time for the player to process the unpredictable movements of the ball. It is easy to imagine how a collision type injury can result if the correct protective gear is not worn (McGrath and Finch, 1996).

Bartlett (2003) reported that batsmen do not keep their eye on the ball when batsmen face deliveries up to 44 meters per second (160 kilometres per hour). Their eyes focus on the point of delivery, and then maintain that gaze for the first part of ball flight. A saccade follows, bringing the fovea below the ball, close to where the ball will bounce. This gaze direction is then maintained for a period before and after the bounce. Thereafter, the head and eye move down quickly trying to track the last part of the ball flight. An inexperienced batsman needs at least 200ms more to initiate a saccade than an experienced one. A batsman needs to predict directional changes after the ball bounces from pre-bounce information, either provided during flight or by the bowler's body actions. More experienced batsmen who have a variety of deliveries in their repertoire, discriminate better between deliveries than those without this prior knowledge.

Todd *et al.* (2003) studied the heart rate response as well as the rate of perceived exertion of cricketers batting in both hot and cool environments. It was found that subjects perceived hot and cold conditions to be similar during the first three overs of batting. After three overs, the batsmen's perception of physical exertion in warm conditions collaborated with their heart rates while they tended to under-predict the level of exertion in cold conditions. As expected, the heart rate response in hot conditions proved to be higher than that in cold conditions. The heart rate also increased at a greater rate in hot conditions.

Although batting injuries may not pose the biggest threat to cricketers, it is still responsible for approximately 17% of injuries amongst first-class cricketers (Stretch 2001a) and 29.8% amongst schoolboy cricketers (Stretch, 1995). Batting injuries range from 10.6 – 10.9% of the injuries sustained by Australian first-class cricketers during major matches (Orchard *et al*., 2002; Orchard and James, 2002). As stated previously, it would be inappropriate to compare these statistics with the above-mentioned studies as Orchard *et al.* (2002) and Orchard and James (2002) restrict the definition of injury to that which affects the availability of the cricketer during major matches only. Batting injuries are predominantly to the lower and upper limbs (Stretch, 2001a).

The modern-day batsman needs to achieve an optimal level of fitness, in order to avoid direct injuries of being struck by the ball and indirect and overuse injuries as a result of the repetitive nature of the game as well as possess good technical skills (Stretch *et al.*, 2000). The inclusion of the Pro20 series into South African domestic cricket made an opportunity available for more expansive play in order to increase the number of spectators at local games. One-day internationals (ODIs), although a slightly longer form of the game, adopt a similar approach. It is said that the number of batting injuries increase in proportion as the level of play increases, from domestic to international cricket (Orchard and James, 2002). This could be due to the increased speed of the deliveries faced as well as the pace of the game. Batsmen are advised to place more emphasis on strength and flexibility training than ever before (Stretch, 1993b).

The first batting injury was reported in 1752 when Frederick Louis, the Prince of Wales, died hours after being struck on the head by a ball (Temple, 1982). Six deaths occur in the United Kingdom per year as a result of playing cricket (Payne *et al*., 1987). Orchard and James (2004) however, suggest that there has been a decrease in the number of head and facial injuries in the past 20 years. This could be due to changes in the laws pertaining to short-pitched deliveries or superior protective equipment.

Stretch (1989) suggests that top and middle order batsmen are more prone to impact injuries to the head and upper limbs than lower order batsmen. During the early part of the innings, the ball is new, the bowler is rested and the wicket possesses more bounce making the batsman more susceptible to impact injuries. Although bowlers spend less time batting than batsmen do, they are more prone to hand injuries (Stretch, 1989). This could be due to the fact that they are not as skilled and do not posses the appropriate reactions to deal with fast bowling.

2.5.1 Types of injuries found amongst batsmen

2.5.1.1 Head, neck and face injuries

It is interesting to note that most injuries to the head or face occur as a result of the ball deflecting off the top edge of the bat when the batsman was attempting a hook shot (Stretch, 1991) or as a result of the ball rearing off the pitch. Stretch (1991) found that these injuries were prominent when batsmen were not wearing helmets or wearing helmets with no visor, only earpieces.

Head injuries include concussion (Temple, 1982; Stretch, 1989; Stretch *et al*., 2000), facial lacerations, often requiring stitches (Stretch, 1989, Stretch *et al*., 2000; Orchard *et al.*, 2002), fractured facial bones (Stretch *et al*., 2000; Orchard *et al*., 2002) and neck injuries (Orchard *et al*., 2002; Stretch and Venter, 2005) (See Table 1). Stretch (1993a) specifically reports of eye injuries including retinal detachment and rupture of the globe.

2.5.1.2 Lower limbs injuries

Stretch (1991) suggests that muscle strains occur while running between the wickets or due to overuse and batting for long periods of time. Stretch (1989), Stretch *et al*. (2000) and Orchard *et al*. (2002) have reported quadriceps, hamstring, gastrocnemius and groin strains. Stretch (1989) found tears to the ankle and knee ligaments, foot fractures and contusions to be common amongst batsmen while Orchard *et al*. (2002) found knee cartilage and tendon injuries, lower limb fractures haematomas and lacerations to be present.

2.5.1.3 Upper limbs injuries

Fractures to the distal third of the ulna were reported by Stretch (1989) and Orchard *et al*. (2002) as well as arm lacerations. Phalangeal fractures, dislocations and contusions as well as wrist injuries are prevalent amongst cricketers of all ages (Stretch, 1989; Orchard and James, 2002; Stretch and Venter, 2005).

2.5.1.4 Back and trunk injuries

Stretch (1993a) and Stretch *et al*. (2000) reported injuries to the soft tissue of the abdomen, splenic rupture and fractures of the ribs. Back strains were reported by Stretch (1989) and Orchard *et al*. (2002).

2.6 FIELDING

Research into fielding in cricket is limited compared to that of batting and bowling even though it is said that "catches win matches" (Bartlett, 2003). Previous research has been aimed at the interceptive skill of catching but even this skill varies considerably amongst the various fielding positions. Wicket-keepers and slips often catch the ball below chest height as they intercept the ball coming off the edge of the bat while outfielders often have to contend with the ball falling from above head height (Bartlett, 2003).

Fielding injuries can be sustained while running, diving, catching and throwing the ball (Stretch, 2003b) and account for approximately 33% of the total injuries sustained by first-class cricketers (Stretch and Venter, 2005) and 22.8% of the injuries sustained by schoolboy cricketers (Stretch, 1995). Orchard *et al*. (2002) and Orchard and James (2002) reported that fielding injuries comprise 12.2 – 12.4% of the injuries sustained during major matches in Australian first-class cricket. As previously stated, these figures should be viewed with caution as they are restricted to the authors' definition of an injury which only affects the cricketer's availability during major matches.

Stretch (2001a) suggests that the upper and lower limbs are the most frequently injured sites amongst fielders (35.4% each). Limited overs matches are often decided by a few runs and Stretch (2003a) reports that the fielders are required to dive at full-length in order to stop the ball which often results in injury. The cervical vertebrae experience whiplash as the fielder hits the ground and are therefore susceptible to injury. The fielder then jumps up after diving for the ball and tries to secure a run out placing further strain on the shoulder (Stretch, 2003a) due to the forces involved in throwing long distances (Bartlett, 2003). Orchard and James (2002) suggest that most injuries in amateur players occur during fielding, perhaps due to their inferior techniques.

Orchard *et al*. (2002) found that wicket-keepers had the lowest overall injury prevalence possibly due to their lack of sprinting and long throwing in the field. It could also be attributed to their total lack of bowling and as with batsmen and bowlers, a reluctance to miss games when carrying minor injuries for fear of losing their position in the side. However, damage to the cartilage of the knee can be a serious injury to wicket-keepers due to the stress of prolonged squatting (Orchard and James, 2002).

In a study conducted by Botha *et al.* (2003) it was estimated that wicket-keepers perform approximately 300 squats in a one day game and 700 in a four day match. The wicket-keeper is also expected to sprint to the wicket about 360 times in a four day game, in addition to batting and run-scoring responsibilities. On average, wicket-keepers covered 4486m in a one day match and presented with an average heart rate of 125 beats per minute. They had an average energy expenditure of 436.4 kilojoules. Wicket-keepers have a relatively high work rate which needs to be maintained for long periods of time. Wicket-keepers are urged to incorporate aerobic training (60 – 80% of their heart rate maximum) and explosive exercises, particularly form the squatting position, into their training regime in order to meet match requirements.

2.6.1 Types of injuries found amongst fielders

2.6.1.1 Upper limb injuries

Orchard *et al*. (2002) list shoulder tendon injuries, shoulder dislocations and sublaxations, elbow injures, forearm fractures, wrist and hand injuries as the most common upper limb injuries amongst fielders (See Table 1). Stretch (1989) suggests that shoulder injuries can occur due to cricketers falling on their shoulders or as a result of repetitive throwing. Repetitive throwing can lead to degeneration and inflammatory changes or partial and complete ruptures of the rotator cuff and usually incorporates the biceps tendon (Stretch, 1989). Cricketers can also be susceptible to elbow strains and phalangeal fractures. Hand and wrist injuries occur as a result of being struck by the ball (Stretch, 1989; Orchard *et al*., 2002).

2.6.1.2 Back and trunk injuries

According to Stretch (1993a), Du Toit and Rademan (1987) state that cricketers can predispose themselves to splenic rupture after landing heavily when attempting to field the ball. Orchard *et al*. (2002) found side and abdominal strains common amongst fielders and also reported the presence of lumbar injuries other than stress fractures.

2.6.1.3 Head, neck and face injuries

Orchard *et al*. (2002) has reported the presence of fractures to facial bones as well as facial lacerations while Stretch (1993a) suggests that close in-fielders are susceptible to severe eye injuries. Neck injuries occur as a result of diving to field the ball (Stretch, 2001a; Orchard *et al*., 2002).

2.6.1.4 Lower limb injuries

Stretch and Venter (2005) suggests that acute soft tissue injuries can occur to the lower limbs when a fielder runs after the ball. Orchard *et al*. (2002) identified groin, hamstring and gastrocnemius strains, knee ligament injuries, lower limb fractures, haematomas and lacerations, ankle and foot sprains and heel and achilles injuries amongst fielders.

2.7 HEAD, NECK AND FACE INJURIES

Temple (1982) suggests that injuries to the head, neck and face result in the least amount of time lost from play compared to injuries at other sites, but Stretch (1995) reports that injuries to the head and face are major areas of concern. Stretch (2003a) reported the incidence of head injuries to be as low as 3.1% of the total injuries incurred by first class cricketers, while Temple (1982) reported a high of 25% amongst county cricketers. The seasonal incidence of head, neck and face injuries amongst schoolboys was said to be 19.3% (Stretch, 1995).

The most common head, neck and face injuries found amongst cricketers include concussion, broken nose and cheek bones, lacerations and neck injuries (Stretch, 1989; Orchard *et al*., 2002). Neck injuries, particularly muscle strains and spasms, are thought to arise due to long periods of batting (Stretch, 2001b).

2.7.1 Eye injuries

Jones and Tullo (1986) reported five cases of severe eye injuries sustained in cricket. Three were cases caused by the ball ricocheting off the edge of the bat into the eye. The cricketers sustained lacerations to the eye, requiring sutures;

hyphaema with secondary glaucoma or risk of chronic glaucoma, blow-out fractures of the orbit floor, retinal detachment with multiple retinal holes and globe rupture with the associated fracture of the inferior orbit margin.

It was said that if the cricket ball were to approach horizontally, the brow would offer substantial protection to the eye (Jones and Tullo, 1986). If the ball was to approach obliquely from the side, no protection would be offered and the cricketer would be at risk of sustaining a rupture of the globe. It is recommended that cricketers, particularly batsmen and in-fielders, should wear adequate eye protection.

2.7.2 Dento-facial injuries

Subramanian (2003) suggests that the awkward bounce of some deliveries and the ricocheting of the ball off the edge of the bat could result in a heavy blow to the face. Impact to the dental and facial region could result in soft tissue lacerations, fracture of teeth, loss of teeth and injury to supporting structures, fractures of the mandible and/or maxilla, tempero-mandibular joint injuries and cerebral concussions.

Pre-existing pathology e.g. periodontal or periapical abscess or infection around the third molars can exacerbate injury during a competition and result in non-participation or under-performance of the athlete (Subramanian, 2003). It is therefore encouraged that cricketers undergo pre-event dental screening. Cricketers should also wear helmets with more protection in the dental facial region in the form of the grille.

2.7.3 Helmets to protect against head injuries

During the last two decades the helmet, designed to protect the batsman against impact from a cricket ball, has become standard protective equipment. Helmets have developed from the head-only protection to now incorporate facial protection by means of the grille (McGrath and Finch, 1996). Helmets should reduce anxiety when facing a fast bowler but may increase the risk of injury due to visual impairment, increased bulk mass and disruption to balance and heat dissipation.

McGrath and Finch (1996) suggest that injury can still result, even when a helmet is worn. After the initial force is absorbed and dissipated by the outer shell, the movement of the helmet further reduces the impact energy of the ball until the outer shell strikes the head. As the shell strikes the head, it causes the brain to collide with the interior of the skull resulting in varying degrees of concussion and/or brain damage (McGrath and Finch, 1996; Stretch, 2000).

The helmet can be dislodged while batting resulting in facial fractures (McGrath and Finch, 1996; Subramanian, 2003). These fractures can result in long term morbidity and deformity and may even require hospitalisation and surgery (McGrath and Finch, 1996).

2.8 BACK AND TRUNK INJURIES

Back and trunk injuries are most commonly found in activities requiring repetitive flexion, extension and/or rotation of the spine such as bowling (Foster *et al*., 1989). Burnett *et al*. (1996), McGrath and Finch (1996) and Ranawat *et al*. (2003) state that sustaining a back injury during the adolescent growth period for a young and talented fast bowler prior to their reaching an elite level, could result in the permanent loss of the player if the injury sustained is debilitating. An acute event later on in their careers could result in the completion of the stress fracture and precipitate symptoms (Ranawat *et al*., 2003). Elliottt (2000) suggests that young cricketers presenting with congenital anomalies may find that the rigors of fast bowling are too great and give up bowling.

Bell (1992) suggests that back injuries, whether of bone, intervertebral disc, apophyseal joint or soft tissue, among fast bowlers at elite and club level have reached epidemic proportions. The bowler experiences a series of collisions with the ground in the run-up, at BFI and at FFI, which are transmitted via the foot to the leg and eventually culminates in the lower back (Elliott, 2000). These forces could cause injury to the lower back (McGrath and Finch, 1996) and have been associated with abnormal radiological findings.

Stretch *et al*. (2003) found that between 38 – 47.4% of schoolboy bowlers sustained back injuries, while Orchard *et al*. (2002) reported a low of 19.5% and Stretch (2001b) a high of 24.8% amongst senior first-class cricketers. Approximately 50% of fast bowlers are diagnosed with a stress fracture of the lumbar vertebra (Payne *et* al., 1987).

Foster *et al*. (1989) and Elliott (2000) describe the findings of a study conducted on 82 injury free high performance male fast bowlers with a mean age of 16.8 years. It was reported that 38% of the bowlers had sustained at least one disabling injury, 11% developed stress fractures to lumbar and/or sacral vertebrae while 27% had a soft tissue injury to the back which caused them to miss at least one match. Three of the nine bowlers diagnosed with stress fractures to the lumbar vertebrae were found to be genetically predisposed to pars defects. The fifth lumbar vertebra (particularly the neural arch) was the most vulnerable to stress fractures because of the abrupt changes in the direction of movement between the spinal column and pelvis (Foster *et al*., 1989). In the event of a weak multifidus muscle, the neural arch of this vertebra is subject to even greater bending forces.

With an average age of 16.8 years, the cricketers' intervertebral discs were relatively elastic allowing the intervertebal shear force to reach the facet joints, placing undue stress on the pars interarticularis. Foster *et al*. (1989) reported that as growth cartilage is less resistant to repetitive stresses than adult cartilage, the pars interarticularis was more vulnerable to damage.

Elliott (2000) reports on a study conducted on 20 members of a state fast bowling squad. It was found that 55% of these bowlers presented with defects of the pars interarticularis while 65% of them presented with intervertebral disc abnormalities. All of the bowlers who had experienced back pain during the previous season had evidence of a radiological abnormality.

Stress fractures in the lumbar vertebrae of 18 professional cricketers with an average age of 20.8 years were reviewed by Ranawat *et al*. (2003). Nine cases of bilateral pars interarticularis defects were recorded, five associated with spondylolisthesis. Seven of the nine lesions were on the opposite side to the bowling arm. The 18 cricketers comprised seven opening pace bowlers, six medium pace all-rounders, one spin bowler and four specialist batsmen. The batsmen who were diagnosed with these defects showed that the injury was as a result of bowling at a younger age, prior to specializing as professional batsmen.

In an investigation of 42 cricketers, 174 pars interarticulares were imaged using reverse gantry computed tomography (rg-CT). Forty cases of spondylolysis were identified – 24 complete and 16 incomplete (Gregory *et al*., 2004a).

The lumbar spine, sacro-iliac joint and ribs are prone to stress fractures and ligamentous injury (Leary and White, 2000; Orchard *et al*., 2002; Orchard and James, 2002; Stretch, 2003b). Stretch (1989) and Orchard *et al*. (2002) report of abdominal muscle strains particularly at the insertion of lower ribs often diagnosed as a rib stress fracture. Most of these are overuse injuries associated with bowling and batting for long periods of time, and fielding injuries (Stretch and Venter, 2005). According to Corrigan (1984) fielders can present with a splenic rupture after being struck by a cricket ball (Stretch, 1993a). McGrath and Finch (1996) describe various back injuries including spondylolysis, spondylolithesis, pedicle sclerosis and intervertebral disc degeneration.

2.8.1 Back pain

Fast bowlers with pars interarticularis defects do no always present with lower back pain, while there is also an inconsistent relationship between disc degeneration and back pain (Millson *et al*., 2004). Bell (1992) and *et al*. (2004a) however state that spondylolysis presents with a crescendo-type of lower back pain which is worsened with lumbar extension. Pain is initially felt after bowling then it presents during a spell until the bowler is unable to bowl at all (Gregory *et al*., 2004a).

A fast bowler presenting with a fracture of the pars interarticularis, could suffer an acute breakdown with pain and muscular spasm in the lower back (Ranawat *et al*., 2003). Tenderness is felt in the line of the facet joints on the side opposite the bowling arm but may not be associated with a loss of movement. Bell (1992) suggests that some athletes continue to train in spite of lower back pain which could be potentially debilitating.

Common practice is that if pain exists, the cricketer should not participate in the game or practice (Millson *et al*., 2004). Millson *et al*. (2004) also states that you could use pain and/or radiological evidence from a computed tomography (CT) scan, although it could be quite costly, as a guide to return the cricketer to full participation in fast bowling.

2.8.2 Causes of back pain

The high prevalence of back injuries in young fast bowlers is not due to a single aetiological factor but rather a combination of factors (Foster et al., 1989; Burnett et al., 1996; McGrath and Finch, 1996; Stretch et al., 2003; Stretch, 2003a) including:

2.8.2.1 Inadequate physical and physiological preparation

Although power, flexibility and sufficient aerobic and anaerobic capacities are needed to sustain speed and direction to the fast bowler, it is important to emphasize the principle of specificity of training (Bell, 1992). By observing the principles of progression and overload, the bowler must bowl enough in training to prevent stress injury and breakdown in match play.

Bowlers with a higher level of shoulder depression strength and shoulder horizontal flexion strength were significantly related to back injury as bowlers with greater upper body strength may have exerted higher rotational forces on their spines in an effort to achieve optimal ball velocity (Foster *et al*., 1989). Motley *et al*. (1998) state that in a balanced upright stance, the spinal column along with its ligaments and musculature supports the weight of the upper trunk. Any imbalances in the strength, endurance and extensibility of the muscles of the spine, promotes lumbrosacral malalignment and increases the load on the bony aspects of the spine.

Asymmetries in the para-spinal muscles, quadratus lumborum, psoas, erector spinae and multifidus, were evident in young fast bowlers (Elliott, 2000) and presented with a larger volume on the bowling arm side of the trunk. Elliott (2000) suggests that there is a significant association between stress injuries of the pars interarticularis and asymmetry of the quadratus lumborum (which stabilizes the lumbar spine) of more than 10% on the bowling arm side of the body. Spinal stability is achieved through an appropriate interplay between the large torque producing muscles, rectus abdominus and external obliques, and the multifidus, psoas major, quadratus lumborum and transvers abdominus, the muscles better designed to provide control and stability to the lumbar spine (Elliott, 2000).

Poor abdominal strength and extensibility of the hamstring and hip flexor muscles could lead to lower back pain (Motley *et al*., 1998). Motley *et al*. (1998) are of the contention that any change in the length-tension relationship of the lower extremity muscles with pelvic attachments adversely effects lumbosacral alignment.

2.8.2.2 Postural defects

Bowlers with a low foot arch are more likely to develop stress fractures in their lumbar vertebrae as foot arches are designed to help absorb impact forces (Foster *et al*., 1989; Elliott, 2000). If the foot has a low arch, it will not be able to dissipate the GRF effectively.

2.8.2.3 High physical demands

Although no data is available, it is commonly believed that as fatigue sets in due to continuous bowling, the speed and accuracy of fast bowlers declines after six to eight overs, increasing the risk of injury. Noakes and Durandt (2000) estimated that fast bowlers deliver about 64 deliveries (60 legal and four wides or no-balls) in 40 minutes in a one-day game. During this time, they are expected to run 1.9 kilometres in 5.3 minutes at an average speed of 21.6 kilometres per hour. The delivery action would require 64 seconds of upper body action as well as 64 episodes of lower body deceleration.

2.8.2.4 Biomechanical aspects of the bowling technique

The GRF generated at FFI are transmitted by the bones, tendons and muscle to the knee and hip joints and absorbed by the body, provided that the spine is erect which is the case in the side-on bowling action. The intervertebral compressive forces developed through impact are more likely to be resisted by the bowlers' intervertebral discs. In a lordotic posture or when the spine is hyperextended as with the front-on or mixed bowling action, the facet joints are forced to bear more of this compressive force (Foster *et al*., 1989). Regardless of how fit the cricketer may be, if the bowling technique used involves hyperextension and/or excessive twisting, there is a significant risk of developing back injury (McGrath and Finch, 1996).

A mixed bowling action is characterized by counter-rotation of the shoulders in the transverse plane i.e. bowlers with a shoulder alignment of more than 240° at BFI who attempt to adopt a more side-on position at FFI, and is related to the appearance of spinal pathology in the thoraco-lumbar spine (Foster *et al*., 1989; Burnett *et al*., 1996; Elliott, 2000; Orchard and James, 2002). Continuous bowling with a mixed action will lead to accelerated disc degeneration and could also result in more serious degenerative changes such as a pars interarticluaris defect (Burnett *et al*., 1996).

Bowlers who deliver the ball from a greater height develop significantly more stress fractures than those who bowled from a lower height (Foster *et al*., 1989; Elliott, 2000). Bowlers releasing the ball from a lower height, flexed their knee joint at impact to assist in the dissipation of GRF and decrease the likelihood of sustaining back injury (Foster *et al*., 1989; Elliott, 2000; Elliott and Khangure, 2002).

2.8.2.5 Escalation in workload

Motley *et al*. (1998) states that a sudden increase in training intensity or frequency can lead to lower back pain. Back injury may be related to the repetitive stress of bowling too many overs in any single spell and/or bowling too many spells. A sudden increase in bowling intensity associated with match play may also be particularly relevant (Bell, 1992).

2.8.2.6 Overuse

Overuse injuries generally occur to the lower spine (McGrath and Finch, 1996). Athletes who train excessively, often train in a neuromuscularly fatigued state and attempt skills beyond their physical capabilities, develop training-induced muscle strength and extensibility imbalances (Motley *et al*., 1998). Motley *et al*. (1998) states that these factors further reduce the athlete's ability to attenuate the kinetic energy of jump landings and twisting movements. This promotes a greater dependence on the non-contractile structures (bone and capsuloligamentous structures) for postural maintenance.

The most severe overuse injury, particularly for the fast bowler, is said to be the development of abnormal radiological features in the lumbar spine. Repetitive activity places pressure on the neural arch and facet joints of the pars interaticularis making it vulnerable to micro or stress fractures as it is unable to absorb the repeated shocks resulting in fatigue failure (Bell, 1992; Motley *et al*., 1998; Elliott, 2000 and Stretch *et al*., 2003). If these factors are present during a growth spurt, the risk of sustaining an overuse injury is further increased (Motley *et al*., 1998). In young sportsmen, the intervertebral discs are relatively elastic and forces are more readily transmitted to the facet joints. Complete ossification of the neural arch may not have occurred and growth cartilage is less resistant to repetitive stress than adult cartilage making young bowlers more susceptible to back injury (Bell, 1992). Athletes who train at a high intensity in excess of 24 hours per week increase their risk of developing a pars defect (Motley *et al.,* 1998).

2.8.3 Types of back injury

2.8.3.1 Spondylolysis and spondylolithesis

Spondylolysis is defined as a single or double fracture of the pars interarticularis (area of the vertebral arch between the superior and inferior facet) caused by a stress reaction (Stretch, 1989; Bell, 1992; McGrath and Finch, 1996; Gregory *et al*., 2004a). Foster *et al*. (1989) states that spondylolysis is often encountered in Australian fast bowlers.

The pars interarticularis stress reaction results in a vulnerable pivot being formed between the vertebral body and the posterior apophyseal joints (Stretch, 1989; Bell, 1992; McGrath and Finch, 1996; Gregory *et al*., 2004a). The stress response of the pars interarticularis will rarely be a result of acute trauma but suggests the presence of a genetically predisposed weak point of the pars (Gregory *et al.,* 2004a). Motley *et al*. (1998) found that this genetic predisposition can lead to stress fractures, even from the impact forces of normal gait. Some cases of spondylolyses may result from dysplasia with failure of normal ossification (Gregory *et al*., 2004a).

Stress fractures usually occur on the contralateral side to the bowling arm as a result of repetitive rotation and hyperextension of the back (Stretch, 1989; Stretch *et al*., 2003;Gregory *et al*., 2004a) while Elliott (2000) found that unilateral fractures occur on the opposite side to the bowling arm in about 80% of cases. Gregory *et al*. (2004a) suggests that incomplete stress fractures develop more frequently on the left than on the right side of the spine. This could be due to the fact that there are more right handed fast bowlers than there are left handed fast bowlers. Pain occurs in the lower lumbar region or is localized in one side of the spine, radiating to the legs or buttocks after continuous stress to the back (Stretch, 1989).

Gregory *et al*. (2004a) found that 85 - 95% of fractures occurred at L5 and 5 - 15% at L4 with the proximal levels affected more rarely. Incomplete fractures were spread more evenly throughout the lowest three lumbar levels amongst cricketers but the most common site was L4 where 43.8% of incomplete lesions were found (Gregory *et al*., 2004a).

Unilateral fractures tend to be incomplete and bilateral fractures tend to be complete (Gregory *et al*., 2004a). It was said that once a spondylolysis has become complete there is instability in the vertebral ring leading to increased stress on the contralateral pars interarticularis which then tends to fracture as well (Gregory *et al*., 2004a).

Bilateral spondylolysis may allow the forward displacement of the upper vertebrae and separation of the anterior aspects of the vertebra from its neural arch resulting in spondylolisthesis (Gregory *et al*., 2004a). McGrath and Finch (1996) report that spondylolisthesis may also be due to the elongation of the pars interarticularis.

Ranawat *et al*. (2003) describes five types of spondylolisthesis:

1. Dysplastic with associated congenital abnormality of the upper sacrum and the arch of the lumbar vertebra
2. Isthmic with a defect in the pars interarticularis
3. Degenerative due to long standing intersegmental instability
4. Traumatic due to fractures in areas of the posterior elements other than the pars interarticularis
5. Pathological due to generalized or localized bone disease

Early diagnosis of a stress reaction in the pars interarticularis may prevent its progression to spondylolysis or spondylolisthesis (Bell, 1992). However, if early detection is not carried out, a fibrous or non-union could result, increasing the likelihood of recurrence three to four years later (Stretch *et al*., 2003).

The movements of hyperextension, lateral flexion and thoracic lumbar rotation in combination with a jerk force occurring when the fast bowler lands during his delivery stride, are all major aetiological factors in the development of spondylolysis and spondylolisthesis (Foster *et al*., 1989; Elliott, 2000; Ranawat *et al*., 2003; Ranawat and Heywood-Waddington, 2004; Gregory *et al*., 2004a; Millson *et al*., 2004).

Spondylolysis and spondylolisthesis in young bowlers could also be related to tightness in the hamstring muscles (Elliott, 2000). Drezner and Herring (2001) has found that tight hamstring muscles can cause a posterior pelvic tilt. This places the back extensors at a mechanical disadvantage and makes the spine less resilient to axial loads. Motley *et al*. (1998) suggests that the spinal posterior ligamentous system is shortened. When the spine is forced into hyperextension and rotation while bowling, the posterior ligamentous structure is placed under undue stress resulting in a pars interarticularis stress reaction on the neural arch.

In a study on 20 members of a state fast bowling squad, Elliott (2000) found the incidence of spondylolysis to be 39% while the incidence of spondylolisthesis was said to be 19%. Ranawat and Heywood-Waddington (2004) found that spondylolysis is present in more than 50% of young fast bowlers, symptomatic or asymptomatic, and suggests that it probably developed before skeletal maturity when most players are all-rounders.

The incidence of spondylolysis among those who engage in fast bowling during their childhood and adolescence, appeared to be three to four times higher than generally occurs in a caucasian population (Elliott, 2000). Higher inter-segmental joint forces were said to be the cause of this tissue breakdown.

Millson *et al*. (2004) suggests that it is difficult to differentiate between symptomatic spondylolysis and acute or subacute stress fractures from asymptomatic chronic spondylolysis as there appears to be dissociation between pain and spondylolyis as measured by a CT scan.

(a) Hereditary and associated factors

Spondylolysis and spondylolythesis are virtually unknown at birth but their prevalence increases with age between six and 40 years (Bell, 1992; McGrath and Finch, 1996; Gregory et al., 2004a). The incidence of spondylolysis amongst the general population is around five to six percent but the incidence is much higher in sportsmen participating in sports involving repetitive flexion, rotation and hyperextension of the lumbar spine (Bell, 1992; Elliott, 2000). Spondylolithesis is said to be asymptomatic in four – six percent of adults (Gregory *et al*, 2004a).

Millson *et al*. (2004) suggests that certain bowlers and racial groups may have a genetic predisposition to spondylolysis. This predisposition could be the explanation for stress fractures seen on a CT scan of asymptomatic individuals.

Bell (1992) found the incidence of spondylolysis to be less common in African-Americans; explaining the relative immunity to spondylolysis amongst West Indian fast bowlers of that time.

(b) Incorrect bowling technique

Cricketers bowling with a mixed action, where the bowler is front-on at BFI but in an attempt to obtain a more side-on alignment, excessively counter-rotates (more than 40°) the shoulders to decrease shoulder alignment (line joining the acromion processes) in the transverse plane at FFI, are more susceptible to spondylolysis due to the increased hyperextension and lateral flexion of the spine (Bell, 1992; Elliott and Khangure, 2002). The side-on action allows for more effective force summation due to its additional rotational movement decreasing the risk of injury (Bell, 1992).

2.8.3.2 Intervertebral disc degeneration

An intervertebral disc can be described as a body which is hydrated with fluid (McGrath and Finch, 1996). Degeneration occurs when it is progressively converted to an anhydrous body (McGrath and Finch, 1996; Elliott and Khangure, 2002). More extensive degeneration can occur when the peripheral component of the disc extends beyond the margin of the vertebrae, also known as premature ageing (McGrath and Finch, 1996; Elliott and Khangure, 2002). Elliott (2000) found the incidence of disc abnormalities (degeneration or premature aging) among 24 young fast bowlers to be 21%. The disc abnormalities occurred predominantly between L1/L2 and L5/S1 (Elliott, 2000) while Burnett *et al*. (1996) reported that degeneration is most common at L5/S1, L2/L3 and L4/L5.

Disc degeneration generally starts during the second decade of life and is known to increase naturally with age (Burnett *et al*., 1996; Elliott and Khangure, 2002). The increase is more pronounced amongst fast bowlers, where mechanical loading of the lumbar region occurs during the bowling action (Elliott and Khangure, 2002). It was reported that the incidence of disc degeneration increased from 21% to 65% at 13 and 18 years respectively, and was reported as high as 70% in retired elite fast bowlers. Burnett *et al*. (1996) suggests that subjects with disc degeneration are symptomatic or asymptomatic. Elliott and Khangure (2002) stated that although the degeneration of an intervertebral disc is not as severe as an abnormality of the pars interarticularis, it may cause pain and alter the distribution of forces on the vertebrae.

The exact cause of disc degeneration still remains controversial (Burnett *et al*., 1998). Early suggestions have implied that torsion alone causes disc degeneration, but has since been refuted. Elliott and Khangure (2002) suggested that combinations of repetitive loading such as axial rotation, forward flexion and high compressive forces in hyperextension, as found in the mixed bowling technique, may cause spine pathology. Bowlers using a front-on or side-on action had significantly lower levels of lumbar disc degeneration than those bowling with a mixed action (Elliott and Khangure, 2002).

2.8.3.3 Pedicle sclerosis

Pedicle sclerosis is an increase in bone density of the pedicle, pars interarticularis and occasionally the posterolateral margin of the vertebrae (McGrath and Finch, 1996). Elliott (2000) suggests that it indicates a physiological stress reaction of the pedicle or pars interarticularis resulting in abnormal radiology.

2.8.4 Radiology

In a radiological investigation conducted on 10 young fast bowlers (15 – 22 years) presenting with back pain, Stretch *et al*. (2003) found that eight subjects presented with normal radiographs while two had evidence of sclerosis. A single photon emission computed tomography (SPECT) bone scan showed an increased uptake in all subjects. The rg-CT scans showed no fracture in three subjects, partial fractures in three subjects, complete fractures in two subjects and old, bilateral fractures in two subjects. It is suggested, following this study, that a X-ray, SPECT bone scan and rg-CT scan be used when making a diagnosis.

The CT scan is the most sensitive imaging procedure to visualize cortical bone injuries but it is insensitive to acute or subacute stress reactions of the bone

(Ranawat *et al*., 2003). CT scans are said to have relevance in the acute or subacute setting, where there is a proven bone stress reaction on an isotope or MRI scan showing an area of increased bone turnover, metabolism or oedema. A CT scan could also be used in the follow up of a positively diagnosed injury or to ascertain whether a fracture had developed within a reacting area and to assess the progression of healing and union of a positively diagnosed acute or subacute fracture (Millson *et al*., 2004). Advanced injuries are said to have a decreased likelihood of complete radiological healing (Millson *et al*., 2004).

Pars defects are more likely to cause back pain in fast bowlers under the age of 21 years and are poorly shown on a MRI (Burnett *et al*., 1996). A bone stress reaction could however manifest as the body's adaptive response to added stress associated with the biomechanics of bowling or could be genetic in origin and not be related to the lower back pain experienced at all.

Gregory *et al*. (2004a) suggests that spondylolisthesis can be identified on plain radiography and says that rg-CT scans can be used to identify morphological abnormalities in the pars interarticularis and characterize them as complete or incomplete fractures. A non-invasive and radiation free MRI scan can be used to detect intervertebral disc abnormalities (Burnett *et al*., 1996).

2.8.5 Spinal shrinkage

An investigation into the amount of spinal shrinkage amongst eight cricketers due to the presences of compression and shear forces during bowling was undertaken by Reilly and Chana (1994). Fast bowlers are known to absorb about three times their body weight with every foot contact of the run-up and then experience a GRF of approximately five times their body weight at BFI and FFI during the delivery stride. The absorption of these forces together with the lateral flexion, extension, rotation and compression of the vertebral column during the delivery stride, makes fast bowling a traumatic activity.

An increased risk is associated with repetitive practise and an extended competitive season. It was noted that the average spinal shrinkage after bowling one delivery every 30 seconds for 30 minutes from a run-up of 14 metres, was 2.30 ± 1.58mm. Bowlers who were inverted at 50° for five minutes prior to bowling displayed a reduced stature by 0.38 ± 1.9mm after bowling. Gravity inversion, whereby the bowler is suspended from his ankles, is used in order to extend the normal spine length. Gravity inversion at 50° on its own, increased stature by 2.66mm.

The subjects' perceived their rating of suppleness to increase the longer they bowled (Reilly and Chana, 1994). They suggested that a exercise duration of 30 minutes may have been insufficient to note and acute down-turn in perceived suppleness while skeletal muscle stiffness or soreness tends to have a delayed onset.

2.8.6 Injuries to the trunk

Potts and Hollingsworth (2003) report that the less serious, nonetheless debilitating injuries to the thorax, appear to be under-presented in press than their relative frequency in play might actually suggest. The thorax refers to the region between the neck and the diaphragm, bound by the sternum, costal cartilage, ribs and thoracic vertebrae. When looking at the data recorded by 12 of the 18 county cricket physiotherapists, it revealed a total of 50 significant injuries to bowlers which resulted in players being unavailable for selection. Injuries to the thorax accounted for 24% of the injuries recorded. The most common injuries recorded were muscle tears particularly intercostal tears and costoiliac impingement.

It is interesting to consider how the lack of sternal support, particularly on the 11^{th} and 12^{th} ribs, might magnify the frequency and significance of muscle tears. Potts and Hollingsworth (2003) suggest that due to the high frequency of muscular injury, players were not always fully conditioned or had not undertaken appropriate preparation prior to injury. Physiotherapists attributed 25% of thoracic injuries to a lack of warm-up.

Orchard and James (2002) and Orchard *et al*. (2002) state that side strains are unique to fast bowlers and affect a very high percentage of fast bowlers at least once in their careers. It does not however appear to have a high recurrence rate over the course of a bowler's career. Side strains generally occur on the non-bowling side of the body and the majority are strains of the abdominal insertions on to the lower ribs. Orchard *et al*. (2002) believes that side strains are often diagnosed as rib stress fractures instead of muscle strains. Side strains are more likely to occur in players who had bowled more than 20 overs in the previous week and are strongly related to bowling speed. Orchard and James (2002) believe that there are different varieties of side strain, some are highly recurrent and/or related to overuse whereas others are related to speed and/or are a once-off injury.

Humphries and Jamison (2004) found that no clinical description of a bowler's side strain, or anatomical pathology thereof, had been defined in the literature. They agreed with Orchard and James (2002) in that the injury appears to be unique to cricket bowlers, although similar injuries were found amongst javelin throwers. Injury to the trunk is a common and serious injury in first class cricket and ten cases were observed in pace bowlers (Humphries and Jamison, 2004).

The most notable features were that the injury consistently occurred on the non-bowling arm side of the body, the positive side flexion test and the high rate of previous similar injury. The injury seemed to occur when the bowler's non-bowling arm was pulled down from a position of maximum elevation with some lateral trunk flexion during the final delivery action but it was not possible to determine whether the injury occurred at the start, in the early or mid-phase of this action.

Pain was said to have occurred in the mid-axillary line, over one or more of the lowest four ribs at the attachment of the internal and external obliques and transverse abdominus. The area of maximum pain, correlated well with the area of maximum tenderness. Bowlers returned to competitive bowling on average, 29.7 days after sustaining the injury. History of previous side strain is an important risk factor.

2.9 UPPER LIMB INJURIES

Temple (1982) first reported that the finger is the most vulnerable site of injury with injuries presenting as fractures, dislocations and contusions. Ligament and joint sprains are also likely to occur (Leary and White, 2000). Injuries to the phalanges and metacarpals are predominantly impact injuries sustained while batting or fielding a ball (Stretch, 1989). Injuries to the glenohumeral joint are common and usually affect the supporting muscle, tendon or joint. These injuries are sustained while fielding (particularly throwing), bowling and as a result of overuse (Stretch, 2001b). Orchard *et al*. (2002) and Orchard and James (2002) identified the following injuries to be common amongst cricketers: shoulder tendon injuries, shoulder dislocations and sublaxations, elbow injuries, forearm fractures, arm lacerations and haematomas, wrist and hand injuries and upper limb stress fractures. Tendonitis of the shoulder was another injury identified by Leary and White (2000). Upper limb injuries account for approximately 19.2 – 29.4% (Leary and White, 2000; Orchard and James, 2002) of injuries sustained by first-class cricketers and 24.6% amongst schoolboy cricketers (Stretch, 1995).

2.9.1 Hand Injuries

The hands and fingers are important for the skills of the game of cricket. Repeated trauma to the hand, fingers and thumbs could lead to either an operative option or an extended period off the game, which could also result in the early onset of osteoarthritis (Dhage *et al*., 2003). Hand injuries are common in cricketers at all levels but most occur in amateur players while fielding (Orchard and James, 2002). Hand injuries as a result of batting, increases in proportion as the level of play increases. Orchard and James (2002) suggest that this could be due to the superior fielding skills of elite players and the increased speed of the balls faced when batting.

Some of the worst injuries occur while fielding rather than in batting (Belliappa and Barton, 1991; Constantinides *et al.*, 1996; Dhage *et al*., 2003). With the ball being delivered at speeds of up to 160 kilometres an hour and returned off the bat at equal or greater speeds, it is not surprising that the bare hands of the fielder are particularly vulnerable. Fielders do not wear any protective equipment making them even more susceptible to impact injuries (Dhage *et al*., 2003).

Macgregor (2003) identifies the potential for forced hyperextension of the fingers, hand and wrist resulting in injury. Fractures of the base of the middle phalanx with dorsal dislocation of the proximal interphalangeal (PIP) joint are common (Belliappa and Barton, 1991). The PIP joint is particularly vulnerable due to the relatively long proximal and distal lever arms which transmit lateral and torque stresses to a hinge joint which has no appreciable lateral mobility.

Despite wearing protective gloves, the hands of the wicket-keeper are also frequently injured due to the repeated impact of the ball causing recurrent collateral ligament damage leading to symptomatic degeneration of the distal interphalangeal (DIP) joints of the index and little fingers.

Dhage *et al*. (2003) found 36 injured cricketers amongst one hundred club, recreational or semi-professional cricketers who presented with 57 new injuries. The percentage of wicket-keepers injured (44.4%) were more than all-rounders (37.7%), batsmen (33.3%) and bowlers (28.5%). This could be expected as wicket-keepers are subjected to every ball delivered by the bowler, provided it is not hit by the batsman, almost every ball thrown in by fielders and balls faced while batting. All-rounders however had the highest relative injury incidence (the number of all-rounders injured in relation to the number of all-rounders in the sample group) and could be attributed to the fact that they are expected to cover every possible activity in the game.

Of the 36 players injured, 29 were injured while fielding, three while batting and four players while keeping wicket. Fielding just within 30 metres from the bat comprised 48.3% of the injuries sustained, followed by slips (24.1%), close in-fielders (20.7%) and boundary fielders (6.9%). Sprains accounted for 15 of the injuries, there were 14 fractures, five lacerations and two dislocations.

Constantinides *et al*. (1996) reported an unusual cricket injury whereby the ball hit the end of the distal phalanx of the thumb of a fielder, resulting in a longitudinal fracture of the proximal phalanx. The fracture split both articular surfaces and the shaft into two symmetrical halves in the sagittal plane. There was a step in and separation of the articular surfaces. The fracture was reduced and internally fixed with lag screws.

Injury rates are not high enough to suggest that poor protective equipment is being worn by elite batsmen or that fielders should wear more protective equipment (Orchard and James, 2002).

2.9.2 Shoulder injuries

The shoulder complex consists of five articulations, the glenohumeral, sternoclavicular, coracoclavicular, acromioclavicular and scapulothoracic joints, making it the most complex joint in the body (Aginsky *et al*., 2004). The glenohumeral joint lacks bony stability, comprising only the humeral head which attaches to the glenoid cavity of the scapula forming a ball-and-socket joint. Stability, provided by glenohumeral ligaments, glenoid labrum, shoulder capsule and rotator cuff muscles, is said to be sacrificed for increased mobility (Aginsky *et al*., 2004).

Shoulder injuries occur in players who have bowled a high number of overs in last three months and those with a past history of shoulder injury (Orchard and James, 2002). Shoulder injuries almost always involve the shoulder of the bowling arm resulting in tendon pathology, particularly of the rotator cuff tendons. Orchard and James (2002) report that shoulder injuries are more common in spin bowlers than fast bowlers and suggest that shoulder instability may be a contributing factor.

Fast bowlers have a high incidence of shoulder injuries as the nature of fast bowling requires the arm to be rotated at around 6 000°.s^{-1} (Aginsky *et al*., 2004). Front-on bowlers are particularly susceptible to injury due to their faster run-up and faster arm action which places more stress on the shoulder joint. When the bowler delivers the ball, the internal rotators are concentrically contracted in order to accelerate the arm while the external rotators are contracted eccentrically in order to decelerate the arm after ball release (Aginsky *et al*., 2004). Imbalance between the agonist and antagonist groups is one of the major risk factors for developing shoulder injuries such as dislocation and impingement, with deficiency in external rotator strength possibly resulting in an injury. During the acceleration phase the external rotators are contracted eccentrically in order to decelerate and control the arm. Any external shoulder rotation weakness could contribute to impingement syndrome. Aginsky *et al*. (2004) states that if the relative strength of the internal rotators was greater than that of the external rotators, it would indicate a decreased deceleration of the internal rotator which may cause the prime movers (anterior deltoid and pectoralis major) to superiorly translate the humeral head into the subacromial space resulting in the impingement of the rotator cuff tendon. Shoulder hypermobility in the anterior capsule as indicated by an increase in external rotation and general laxity of the glenohumeral joint of the shoulder, may be a risk factor in the development of an impingement injury (Aginsky *et al*., 2004).

The fast bowler needs to decelerate the arm effectively from 6 000°.s^{-1}, resulting in an increase in the peak torque forces. To achieve high ball delivery speeds the external eccentric forces must be great enough to balance these concentric and eccentric contractions with a relationship between dysfunction and injury. Fast bowlers should follow a specific shoulder strengthening and flexibility programme to reduce the risk of injury. During the acceleration phase of the bowling action, the external rotators are eccentrically contracted in order to decelerate the arm. Any weakness in the external rotators could lead to impingement syndrome. Aginsky *et al*., (2004) found that a greater relative strength of the internal rotators compared to the external rotators indicates decreased deceleration of the internal rotation. This could lead to the migration of the humeral head resulting in a decreased subacromial space causing impingement of the rotator cuff tendon. Fast bowlers are therefore advised to strengthen their external rotators to about 66% and 100% of the internal rotator concentric and eccentric strength respectively (Aginsky *et al*., 2004).

Thrower's shoulder, the degeneration and inflammatory changes or partial and complete rupture of the rotator cuff, usually the muscle of the biceps tendon, is a common injury amongst cricketers (Stretch, 1989). Salam and Eyres (1989) reported the occurrence of Clay Shoveller's fracture but stated that it occurs to a lesser degree to thrower's shoulder (Stretch, 1993a).

Drescher *et al.*, (2004) reported the first case of little league shoulder syndrome in a cricket player where the lateral part of the proximal humeral epiphysis of the right shoulder was widened. The throwing mechanism of cricketers requires a whip-like action of the arm which places repetitive traction strain on the shoulder and elbow joints. The proximal humeral growth plate of a young person consists of cartilage and an impulse of the whole arm exerts strain at this weak location.

It was reported that many athletes lack adequate muscular strength to dynamically stabilise the shoulder and it is therefore recommended that they undergo resistance exercise and a throwing program with a long toss component as well as post throwing scapular stabilisation and rotator cuff exercises. This cricketer was advised to abstain from all throwing for 12 weeks and from fast bowling until closing of the proximal humeral epiphyseal plate.

De Beer (2003) conducted a review of shoulder injuries amongst professional cricketers and found a lack of anterior stability to be most common cause of shoulder injury. Labral tears and rotator cuff impingement were found to be the second greatest cause of injury while SLAP (superior labrum anterior to posterior) lesions, rotator cuff tears, pectoralis major rupture, thoracic outlet syndrome, acromio-clacicular degeneration, HAGL (humeral avulsion of the gleno-humeral ligament) lesions and latissimus dorsi ruptures were reported to a lesser degree.

Bowling itself did not contribute to anterior stability but rather repeated throwing, which led to stretching of the anterior capsule and secondary anterior instability (De Beer, 2003). One case of a Bankart lesion was reported due to a fall on an outstretched arm when diving for a catch while the other cases of instability were due to laxity. The majority of the remaining injuries reported were due to the overhead throwing action. The rupture of the pectoralis major occurred while bench pressing while the rupture of the latissimus dorsi occurred during bowling.

Bell-Jenje (2003) identified several potential shoulder injury risk factors amongst South African academy cricket players including player speciality (where bowlers are more prone to injury), a history of previous injury to the same shoulder, weak scapular stabilisers, decreased glenohumeral internal rotation, scoliosis and leg length difference of 1.0 cm or more.

2.10 LOWER LIMB INJURIES

First-class cricketers are most vulnerable to lower limb injuries (Leary and White, 2000) Leary and White (2000) report the prevalence of lower limb injuries at a low of 44.9% while Stretch (2001b) reports the prevalence at a high of 50%. The prevalence of lower limb injuries amongst schoolboy cricketers is reported as 22.8% (Stretch, 1995). Many lower limb injuries occur due to impact from the ball, stress injuries associated with repetitive movements (Stretch, 1989), bowlers tramping in footmarks on the pitch in their delivery stride and follow-through, and running between the wickets (Stretch, 2001a). Hamstring, quadriceps (Orchard *et al*., 2002, Stretch, 2001b; Leary and White, 2000), calf strains (Orchard *et al*., 2002, Leary and White, 2000; Stretch, 1993a) and adductor strains all affect cricketers and appear to affect both sides of the body without absolute discrimination (Orchard *et al*., 2002).

Hamstring strains or tears may be related to relative weakness, a past history of injury and related to a short-term high workload (a high number of overs in the week before injury), while quadriceps strains are more common early in the season and may be related to harder and drier grounds (Orchard *et al*., 2002, Orchard and James, 2002; Stretch, 2003a). Orchard and James (2002) suggest that adductor and groin strains may be related to the preferred “turning side” when running between wickets. Injuries to the patella femoral joint are primarily caused by bowling and overuse (Stretch, 2003a) with muscle strains and ligament tears being the most common injuries reported (Stretch and Venter, 2005).

Leary and White (2000) reported that ligament and joint sprains, tendonitis and contusions occur to the knee. Orchard *et al.* (2002) and Orchard and James (2002) on the other hand, suggest that knee ligament injuries are relatively uncommon in cricket and report that they occur while playing football as part of cross-training drills. Knee cartilage injuries are one of the few serious injuries that tend to affect the wicket-keeper and possibly occur due to the stress of prolonged squatting (Orchard and James, 2002).

Ankle and shin injuries are often caused by sliding into the fence while trying to prevent a boundary (Orchard *et al*., 2002; Orchard and James, 2002) but can be prevented by using a rope or marked line rather than a solid fence to demarcate the area. Leary and White (2000), Orchard *et al*. (2002) and Stretch (2001b) report of ankle sprains, impingement, ligament tears, contusions and haematomas. Orchard *et al*. (2002) reported of fractures (other than stress fractures) to the lower limb, lower limb haematomas and lacerations, shin soft tissue overuse injuries and heel and achilles injuries.

2.10.1 Lower limb stress fractures

Stretch (1989), Orchard et al. (2002) and Rizvi (2003) recorded stress fractures to the metatarsals, fibula and tibia. Rizvi (2003) noted that right arm fast bowlers were prone to stress fractures in their left lower leg and ankle region while left arm fast bowlers were prone to stress fractures in their right lower leg and ankle region i.e. in the side opposite to the bowling arm. Contributing factors included hard playing surfaces, improper bowling mechanics, overtraining and malnutrition in growing athletes from developing countries. Rizvi (2003) reported that after an educational programme was implemented for coaches, a change in infrastructure whereby softer grounds and practise pitches were developed, and the impartation of sound training techniques by a physical trainer and nutritional advice with the emphasis on a high calcium intake, the number of lower limb stress fractures were noticeably reduced.

2.10.2 The sliding stop

The sliding stop made its way into the game of cricket due to the game's increased competitiveness over the last few years where games are won or lost by one run (Von Hagen *et al.*, 2000). Acute meniscal injuries to the knee are rare in cricket but can occur when performing the sliding stop incorrectly. The correct way to perform the sliding stop is where the right handed thrower chases the ball slightly to his left hand side. When in range the fielder will slide feet first with the right leg extended and the left leg flexed at the knee to 90° under the right leg forming a figure four. The fielder slides on his left buttock and hip area and the left hand is used to steady and balance. As the ball is picked up in the right hand, the right foot engages the ground and the momentum of the slide combined with a push from the left hand brings the fielder upright and then into a position to throw the ball (Von Hagen *et al*., 2000).

If the cricketer fails to engage his right foot with the ground to allow his momentum to bring him upright or to use his left hand sufficiently enough to push himself up, it may result in an injury. Von Hagen et al. (2000) suggests that the sliding stop should either be discouraged or coached appropriately in order to avoid unnecessary injury.

2.11 SUMMARY

The first definition of injury was given by Stretch (1993a) and stated that an injury was defined as any physical damage that occurred during a match, practise or training session and prevented the player from completing that specific match, practise or training session. Orchard *et al*. (2002) added structure to the definition and defined an injury as that which prevents a player from being fully available for selection in a match or during a match, causes a player to be unable to bat, bowl or keep wicket when required by the rules or the team's captain. A similar definition was used by Newman (2003) although not as specific as that of Orchard *et al*. (2002). Newman (2003) defined an injury as that which prevents a player from full participation in training or playing for more than one day even if there is no game or formal training planned for that day. As can be seen by the various injury definitions given by Stretch

(1993a), Orchard *et al*. (2002) and Newman (2003) there is a need for a standardised injury definition so that accurate comparisons can be made between all cricket playing nations.

It can however be stated that the average match injury incidence amongst Australian first-class cricketers was 32.3 per 10 000 man-hours played (Orchard and James, 2006), 15.3 per 10 000 man-hours played by English first-class cricketers (Newman, 2003) and 40.6 per 10 000 man-hours played by West Indian first-class cricketers (Mansingh *et al*., 2006). The seasonal injury incidence amongst first-class Australian cricketers was reported by Orchard and James (2006) as 16.3 and amongst English first-class cricketers, by Newman (2003) as 10.8. The average seasonal incidence amongst South-African first-class cricketers, although calculated differently, was reported as 2.1 injuries per player per season.

During very early injury studies, it was found that the finger was the most vulnerable site for injury (Temple, 1982; Payne *et* al., 1987; Stretch, 1989). It would appear however that the most vulnerable site for injury is now the lower limb (Newman, 2003; Orchard and James, 2004; Stretch and Venter, 2005; Mansingh *et al*., 2006). The decrease in vulnerability of the fingers could be attributed to improved protective gear as well as improved training techniques with a greater focus on hand-eye coordination and reaction time.

Lower limbs accounted for 28.0 – 49.1% of injuries amongst first-class cricketers (Newman, 2003; Orchard and James, 2004; Stretch and Venter, 2005; Mansingh *et al*., 2006) while the back and trunk (20.8 – 28.0%) and upper limbs (20.6 – 28.0%) were injured at proportionately similar rates. The head, neck and face region were the least injured (4.2 – 12.0%) anatomical regions of the body (Newman, 2003; Orchard and James, 2004; Stretch and Venter, 2005; Mansingh *et al*., 2006).

Bowlers, in particular fast bowlers, were the most prone to injury (Foster *et al*., 1989; Stretch, 1993a; Bartlett *et al*., 1996; Elliott, 2000; Leary and White, 2000; Orchard *et al*., 2002; Newman, 2003). Stretch and Venter (2005) identified the prevalence of bowling injury to be approximately 40% amongst South African first-class cricketers and found the back and trunk to be the most vulnerable anatomical region. Overuse injuries are on the increase and Stretch *et al*. (2003) advises both players and coaches to become more aware of their training and match workloads.

Injury rates to batsmen, approximately 17% to first-class South African cricketers (Stretch and Venter, 2005), are not high enough to suggest that poor protective equipment is being worn (Orchard and James, 2002). Stretch (1989) suggests that bowlers or lower order batsmen are more prone to hand injuries than top or middle order batsmen, possibly due to the fact that they are less skilled and go not posses the appropriate reactions to deal with fast bowling.

Fielding injuries which account for approximately 33% of all injuries sustained by South African first-class cricketers (Stretch and Venter, 2005), can be acquired while running, diving, catching and throwing the ball (Stretch, 2003a). Stretch (2001a) found the upper and lower limbs to be most prone to injury amongst fielders.

Club cricket players are said to present with more injuries than semi-professional players (Dhage *et al*., 2003). While club cricket is still played seriously, the cricket skills and level of training is found to be inferior to that of the semi-professional players. Semi-professional players develop a wider range of more refined skills which may help to reduce the likelihood of injury. Cricketers under the age of 24, were found to be more prone to injury than their older counterparts (Stretch *et al*., 2003).

The next chapter incorporates the methodology used to collect the data and statistical procedures utilised to interpret and compare data.

CHAPTER THREE

MATERIALS AND METHODS

CONTENT

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3.1 INTRODUCTION

In this chapter, a detailed description is given of the sample group used as well as the method of data collection so that other researchers would be able to emulate the study at a later date. All forms of consent required have been specified, be it verbal or written. Copies of the questionnaires used have been incorporated and definitions of terms have been given where applicable.

3.2 SUBJECTS

The population consisted of 196 cricket players representing all 16 provincial teams in the under-19 Coca-Cola Khaya Majola cricket week played in Pretoria from 16 - 20 December 2004. The teams included: Boland, Border, Border Kei, Easterns, Eastern Province, Free State, Gauteng, Griquas, Kwa-Zulu Natal, Kwa-Zulu Natal Inland, Limpopo, Mpumulanga, Notherns, North West, South Western Districts and Western Province.

3.3 CONSENT

The research proposal was presented to the UCBSA who provisionally accepted the proposal but asked that confirmation be made by the Managing Director of Amateur Cricket South Africa. The researcher contacted the managing director and requested consent (Appendix I). Consent was then given but it was suggested that the researcher contact each provincial manager or coach to set up interviews. Contact details were emailed to the researcher who then proceeded with further telephonic consent. Consent was formally obtained from all 16 provincial teams participating in the cricket week in Pretoria. The researcher had obtained a fixture list from the UCBSA and had arranged to speak to the various teams within the first three days of the competition, 16 – 18 December 2004, while they were batting. Coaches were assured that the two batsmen batting at the time, as well as the next two in, would not be disturbed. Data would be obtained from these players at a time convenient to them.

3.4 DATA COLLECTION

Interviews were conducted with players while their team was batting, or after the day's play. The researcher personally guided each cricket player through a questionnaire regarding training and injury (Appendix II) to clarify any uncertainties that may have arisen. Data was collected retrospectively and the cricket players were asked to recall all injuries from June 2003 to May 2004.

An injury was defined as any physical damage that occurred during a match, practise or training session and which prevented the player from completing the match, practise or training session (Stretch, 1995). The questionnaire was designed to obtain the following information: i) anatomical site of injury, ii) month of injury, iii) diagnosis of injury, iv) cause of injury, v) whether it was a recurrence of a previous injury and vi) whether the injury recurred during the season.

Injuries were classified as acute, being of rapid onset, chronic, of prolonged onset and acute-on-chronic where a cricketer presents with increased symptoms of a chronic injury (Stretch and Venter, 2005). The incidence of injury was expressed as a percentage of the total. Injuries were grouped according to the anatomical region injured: i) head, neck and face, ii) upper limbs, iii) back and trunk and iv) lower limbs. The injuries were classified according to whether they were sustained during batting, bowling, fielding or other activities including gym and fitness activities. The number of injuries in each phase was then expressed as a percentage of the total number of injuries to allow for comparison between the phases of play during which the injuries were sustained.

Questions regarding handedness while batting and bowling were also asked. The cricketers involved in bowling were asked to give an approximation of the number of overs bowled during training in order to gauge individual workloads. Various questions were also asked regarding training specificity.

A questionnaire was handed out to all 16 coaches (Appendix III) and was designed to see the level of coaching qualifications achieved by them and their level of understanding of basic training principles. The coaches' questionnaire was personally handed to them. All coaches asked if they could complete the questionnaire in their own time; the researcher therefore did not have an opportunity to define terms if there was any confusion.

3.5 DEFINITION OF TERMS

It should be said that when the researcher guided each cricketer through the questionnaire, the definitions below were used to ensure that all players had a correct understanding of the terms used. It was therefore used to ensure a standardised method of data collection.

A pre-season program is one in which training takes place at a moderate intensity with the main aim being sport specific training. Cricketers train hard in order to achieve baseline fitness, appropriate for cricket, and maintain muscle strength. Sports vision as well as hand-eye coordination are also important attributes of pre-season training (Vallabhjee *et al.*, 2003).

Aerobic endurance is a measure of the heart's ability to pump oxygenated blood to working muscles as well as the muscles' ability to take up and use the oxygenated blood during exercise (Powers and Dodd, 1999). Cricketers can improve aerobic endurance by taking a 30 – 60 minute jog. By establishing a certain level of aerobic endurance, the cricketer will delay the onset of fatigue.

Anaerobic endurance is the ability to repeatedly perform short bursts of speed required by fielders chasing a ball or batsmen running between the wickets. Cricketers will be able to improve their anaerobic endurance by practicing to run between the wickets or by completing several sets of short sprints.

Hand-eye coordination is seen not only as a function of the integration of visual and motor systems but the dominance of the visual system. As the eyes receive visual stimulus, the brain needs to instruct the hands to respond appropriately. If the stimulus is not received timeously or the hand is too slow in reacting, the batsman may miss-hit the ball or fielder may fumble the ball (Naidoo *et al.*, 2003). Cricketers were asked if they practised short catches or hitting the ball up into the air off the bat etc.

Reaction time refers to the delay between receiving visual stimulus and the execution of the motor response to the challenge (Vallabhjee *et al.*, 2003) e.g. ball drops. Two players stand approximately five metres apart. One player drops the ball from an outstretched hand while the other player accelerates and attempts to catch the ball before the second bounce. One's reaction time is directly related to their level of hand-eye coordination.

Agility can be defined as the body's ability to change position quickly and accurately (Vallabhjee *et al.*, 2003) e.g. practicing turns while running between wickets, running zig-zags.

Balance may be defined as the maintenance of a state of equilibrium during physical activity (Vallabhjee *et al.*, 2003). Balance is often dependent on core-stability and one's ability to transfer weight equilaterally. Balance exercises can include standing on one leg where the cricketer is asked to perform various movements e.g. picking up a ball from the ground without falling over.

Core stability refers to the stabilization of the lumbar-pelvic region and is essential for spinal support in all rotational activities related to cricket. The lumbar-pelvic region is where the body's centre of gravity is and forms the crucial link between the upper and lower body (Vallabhjee *et al.*, 2003). Core stability exercises include bridging, static cycling, leg raises etc.

Static stretching is a form of stretching that slowly lengthens the muscle to a point where further movement is limited, the stretch is generally held for 20 to 30 seconds. (Powers and Dodd, 1999). This form of stretching is most often used at the end of the training session or match.

Dynamic stretching is a form of explosive stretching where the muscle is rapidly lengthened and then shortened through a specified range of motion. This form of stretching is most often used during the warm-up e.g. butt-kicks.

3.6 STATISTICAL ANALYSIS

The Centre for Statistical Consultation at Stellenbosch University used Statistica 7.1 to compute univariate statistics and frequency distributions. The seasonal incidence was calculated using all reported injuries. The Chi-square test was used to determine significant relationships between occurrences of injuries and various other variables. Due to the assumption of independent observations by the Pearson Chi-square test, only singular injuries were considered. This means that even though a cricketer presented with two injuries, only one injury was considered for comparative statistics. Comparisons of this study with previous studies were made by testing for significant differences in proportions.

The next chapter presents the data collected in the above-mentioned ways and analysed according to the methods described. The results are discussed and compared, where applicable, to other research.

CHAPTER FOUR
RESULTS AND DISCUSSION

CONTENT

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4.1 INTRODUCTION

One hundred and ninety six cricketers (94.2% of the projected population of 208 cricketers) present at the Coca-Cola Khaya Majola under-19 Cricket Week completed the questionnaire with the aide of the researcher. All 196 of these cricketers, consisting of 126 all-rounders, 24 batsmen, 26 bowlers and 20 wicket-keepers, have played provincial school cricket, with 24 of them having represented their senior provincial teams and 19 having played nationally at an under-17 or under-19 level. They had a mean age of 17.6 ± 0.7 years, just one year younger than the lower limit of group that Stretch (2003b) identified as the more injury prone group (19 – 24 year olds) amongst senior provincial cricketers.

Only 54.1% of the cricketers reported that they followed a pre-season program but several cricketers did report that they were involved in cricket throughout the year (either playing indoor cricket or following a winter cricket program). During the season, 21% of the players spent 1 - 5 hours practicing and training for cricket per week; 68% spent 6 – 10 hours per week while 22% spent more than 10 hours practising and training per week (See Table 4).

Table 4: The role of the cricketers and their weekly training loads.

	1 - 5 hours	**6 - 10 hours**	**11 – 15 hours**	**15 - 20 hours**	**Total**
Bowler	7	16	3	0	26
Batsman	9	12	2	1	24
All rounder	22	92	10	2	126
Wicket-keeper	4	12	4	0	20
Total	42	132	19	3	196

Sixty seven cricket injuries were reported by the respondents. Seven players reported that they sustained two injuries during the season. The seasonal incidence of injury amongst this group is 34.2%. Surprisingly, no injuries were sustained to the head, neck and face region while 34.3% were sustained to the upper limbs; 34.3% to the lower limbs and 31.3% to the back and trunk. Almost 72% of injuries occurred during matches, 14.9% occurred gradually due to the repetitive stresses sustained during matches and practices, 11.9% occurred during practice and 1.5% of the injuries occurred during other forms of training.

The majority of injuries (40.6%) reported were quite severe and took the cricketers more than 21 days to recover (See Table 5). Thirty-six percent of injuries allowed the cricketers to return to play within seven days of acquiring the injury.

Table 5: Severity of injuries and the activities in which they occurred.

	Not given	**1 - 7 days**	**8 - 21 days**	**> 21 days**	**Total**
Batting	1	6	1	2	10
Bowling	0	8	9	17	34
Fielding	2	8	5	7	22
Other	0	1	0	0	1
Total	3	23	15	26	67

Fifty-eight (86.6%) of the injuries were reported as being first time injuries while only nine injuries (13.4%) were due to the recurrence of a previous injury. Bowling accounted for 50.7% of the injuries, while fielding accounted for 32.8%, batting accounted for 14.9% and the remaining 1.5% occurred while warming-up or training.

4.2 A COMPARISON OF SOUTH AFRICAN INJURY PROFILES

The principal finding of this study shows that the seasonal incidence of injury for the current study is 34.2% which is significantly ($p<0.05$) lower than the seasonal incidence (49.0%) found amongst the schoolboys of Stretch (1995). There are various possibilities for the significant difference found. These include:

- A difference in the sample populations used. Stretch (1995) conducted a study on cricketers from the Border, Eastern and Western Cape regions, playing for their schools' first teams while the current study looked at all the provincial, under-19 cricketers. The survey may not give an adequate representation of the injury profile of schoolboy cricketers.
- Susceptibility to injury. If a player is more injury-prone than another, he would have spent a considerable amount of time on the injury list negatively affecting his chances of being selected for his school's team let alone the provincial team.

- Fear of the impact the information will have on national team (SA schools/Colts) selection. One of the primary reasons for hosting the Coca-Cola Khaya Majola under-19 Cricket Week, is to name the SA schools team thereby acting as a stepping stone for senior provincial team selection: to scout promising new talent.
- Loss of position within the team. Due to the nature of the game, players often fight to keep their places in the squad and might report that they continued playing even though they were injured. One of the South African cricketers continued playing in a test against England in January 2005, after having sustained a fracture in his left hand. Although admired by many for his courageousness, it entices our young cricketers to follow suit.

An average injury rate of 2.1 injuries per player per season is seen amongst senior provincial cricketers (Stretch & Venter, 2005) which is once again significantly higher ($p<0.01$) than that seen amongst schoolboy cricketers (34.2% in the current study and 49.0% in Stretch, 1995). One of the major differences between schoolboy cricket and first-class cricket is the presence of a team physiotherapist or doctor. When one such person is available, the player would immediately seek medical advice as it is readily available to him. This could however pose another problem, that of injury over-representation. In other words, cricketers might experience slight discomfort and although not serious, be left out of the team as a precautionary measure.

Senior cricket (provincial and national) particularly ODIs and the pro20 series, is a spectator sport. Spectators flock to the grounds to see big hits, fast deliveries and brilliant fielding. All of these characteristics of the senior game, cause players to strive even harder. Players often strive so hard that it leads to injury. The amount of cricket played and time spent training by senior cricketers is far different to that of schoolboy cricket. Senior cricketers can play one, three, four and five day cricket, playing between 90 and 110 overs per day. Schoolboy cricketers only play one-day cricket, a maximum of 100 overs per day. Senior cricketers only have about three days to recover before their next match whereas schoolboy cricketers generally have six days to recover unless they are playing in a tournament. The amount of cricket played and time allowed for recovery can be directly related to the incidence of injury.

At schoolboy level, very few cricketers specialize as either batsmen or bowlers. This can be seen by the fact that there are almost five times as many all-rounders (126) compared to batsmen (24) and bowlers (26) in the current study. Stretch (1995) found approximately double the number of all-rounders (50) compared to batsmen (25) and bowlers (24) in his study. It would appear that versatility is advantageous to schoolboy cricketers although all-rounders are thought to be more susceptible to injury than batsmen and bowlers as the total impact on their bodies is far greater. Figure 4 shows that there is no significant difference ($p>0.05$) in the injury rate between all-rounders, batsmen and bowlers although bowlers (33.3%) presented with slightly more injuries than the all-rounders (32.0%) and batsmen (25.0%). The difference seen in the current study could be attributed to an under-reporting of injury or players still playing even though they are injured (e.g. a player still batting even though he is not allowed to bowl). For the purpose of this comparison, wicket-keepers were regarded as batsmen.

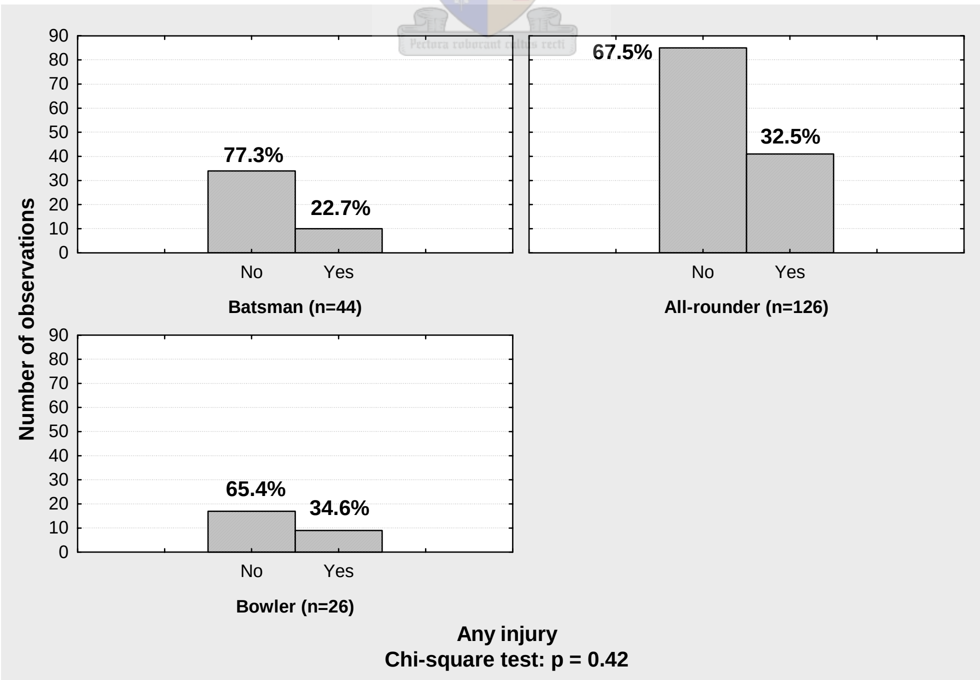


Figure 4: The injury incidence of all-rounders, batsmen and bowlers.

A summary of the anatomical site of injuries and phase of play in which it occurred, is given in Table 6. The majority of injuries occurred while bowling (50.7%) which is similar to the percentage of bowling injuries sustained by schoolboy cricketers (47.4%) recorded by Stretch (1995). Although the proportion of bowling injuries sustained by senior provincial cricketers (40.0%) (Stretch and Venter, 2005) is lower than that of both schoolboy studies, it is not significantly different. The total number of batting injuries reported by Stretch (1995) (29.8%) was significantly higher than that found in the current study (14.9%) and could be directly related to the number of head, neck and face injuries sustained while batting in Stretch (1995). The proportion of injuries sustained while fielding were very similar amongst the schoolboys of the current study (37.8%) and the senior provincial cricketers (33.0%) of Stretch and Venter (2005). Although the schoolboys of Stretch (1995) sustained proportionately lower injuries while fielding (22.8%) it was not statistically significant.

The most significant difference ($p<0.01$) seen is with the comparison of head, neck and face injuries between the schoolboys of Stretch (1995), 19.3% and the current study (0.0%). This could be attributed to the fact that the wearing of helmets while batting at indoor and outdoor sessions has only recently been made compulsory at under-19 level. Only 5.1% (10) of this sample reported that they did not wear helmets when given the option. A significant difference ($p<0.05$) was also found amongst senior provincial cricketers where 5.0% of the injuries were sustained to the head, neck and face. This could be attributed to the added speed and accuracy of senior bowlers and the rate at which the ball comes off the bat. The number of back injuries were significantly lower ($p<0.01$) amongst senior provincial cricketers. This could be attributed to the fact that their technique is more efficient to that of schoolboys. Their epiphyseal plates have had an opportunity to fully mature and ossify making force absorption so much more efficient. Cricketers of the current schoolboy study presented with significantly more ($p<0.05$) upper limb injuries (34.3%) than the senior provincial cricketers (23.0%). This could be attributed to the more inferior reaction times of schoolboys when compared to senior cricketers. There were significantly more ($p<0.05$) lower limb injuries amongst senior provincial cricketers (49.0%) than

Table 6: The anatomical site of injuries and phase of play in which it occurred. Values represented in the table are percentages of the total number of injuries sustained.

ANATOMICAL SITE AND PHASE OF PLAY															
	BATTING			**BOWLING**			**FIELDING**			**OTHER**			**TOTAL**		
UPPER LIMBS	1.8	1.5	3.9	5.3	7.5	4.4	17.5	23.9	14.2*	0.0	1.5	0.6	24.6	34.3	23.0*
BACK & TRUNK	7.0	3.0	3.2	26.3	26.9	13.0**	0.0	1.5	4.3	0.0	0.0	2.4	33.3	31.3	23.0
LOWER LIMBS	3.5	10.4	8.8	14.0	16.4	21.8	5.3	7.5	13.2	0.0	0.0	5.2	22.8	34.3	49.0*
HEAD, NECK & FACE	17.5**	0.0	1.1	1.8	0.0	0.8	0.0	0.0	1.3	0.0	0.0	1.8	19.3**	0.0	5.0
TOTAL	29.8*	14.9	17.0	47.4	50.7	40.0	22.8	32.8	33.0	0.0	1.5	10.0*	100.0	100.0	100.0

Results are delineated as follows: Stretch (1995), current study & Stretch and Venter (2005).
*$p < 0.05$; **$p < 0.01$

Table 7: A comparison between the recovery time of injuries sustained in the Stretch (1995) study and the current study. Values represented in the table are percentages of the total number of injuries sustained.

RECOVERY TIME						
	1-7days		**8-21days**		**>21days**	
UPPER LIMBS	15.8	17.2	7.0	3.1	1.8*	14.1
BACK & TRUNK	17.6	7.8	8.8	10.9	7.0	12.5
LOWER LIMBS	10.5	10.9	7.0	9.4	5.2	14.1
HEAD, NECK & FACE	19.3**	0.0	0.0	0.0	0.0	0.0
TOTAL	63.2**	35.9	22.8	23.4	14.0**	40.7

Results are delineated as follows: Stretch (1995), current study.
Note that the recovery time for injuries were only reported in 64 cases in the current study.
*$p < 0.05$; **$p < 0.01$

amongst schoolboys of the current study (34.3%). This was attributed to the high proportion of injuries sustained while warming up, cooling down and training at the gym.

When looking at the average recovery time from injuries sustained (Table 7), it must be noted that 40.6% of the injuries sustained in the current study were so severe that it kept the cricketer out of the game for 21 or more days. This is significantly ($p<0.01$) more than the proportion seen in the schoolboy study of Stretch (1995), 14.0%. The majority of the cricketers in Stretch (1995) recovered within eight days of sustaining injury, significantly ($p<0.01$) quicker than in the current study. The proportion of injuries that took between eight and 21 days to recover, were similar between both schoolboy studies.

Figure 5 shows a breakdown of injuries sustained over the various months of the year. Cricketers in the current study were more susceptible to injuries over the December/January period when most of their high intensity matches were played in competitions such as the Coca-Cola Khaya Majola under-19 Cricket Week. There is a tendency for these cricketers to be more susceptible during their pre-season, in September, and towards the end of their season in April. Injuries were also sustained by cricketers in their so-called “off-season” and can be attributed to the winter cricket programs hosted by schools and clubs.

In the schoolboy study by Stretch (1995) it was found that their injury incidence peaked in the middle of their season when most players are returning to school and cricket after the summer holidays. Coaches often expect cricketers to continue training throughout the holidays but very few seem to have the self-discipline to do so. These cricketers are expected to be a certain level of fitness for the competitive phase which lies ahead of them. If they are not fit enough, they are predisposed to injury.

Senior provincial cricketers are more susceptible to injury at the start of their competitive season (Stretch and Venter, 2005). The risk of injury tapers gradually over the season but rises again towards the end of the competitive season when the players often experience over-training and even burnout.

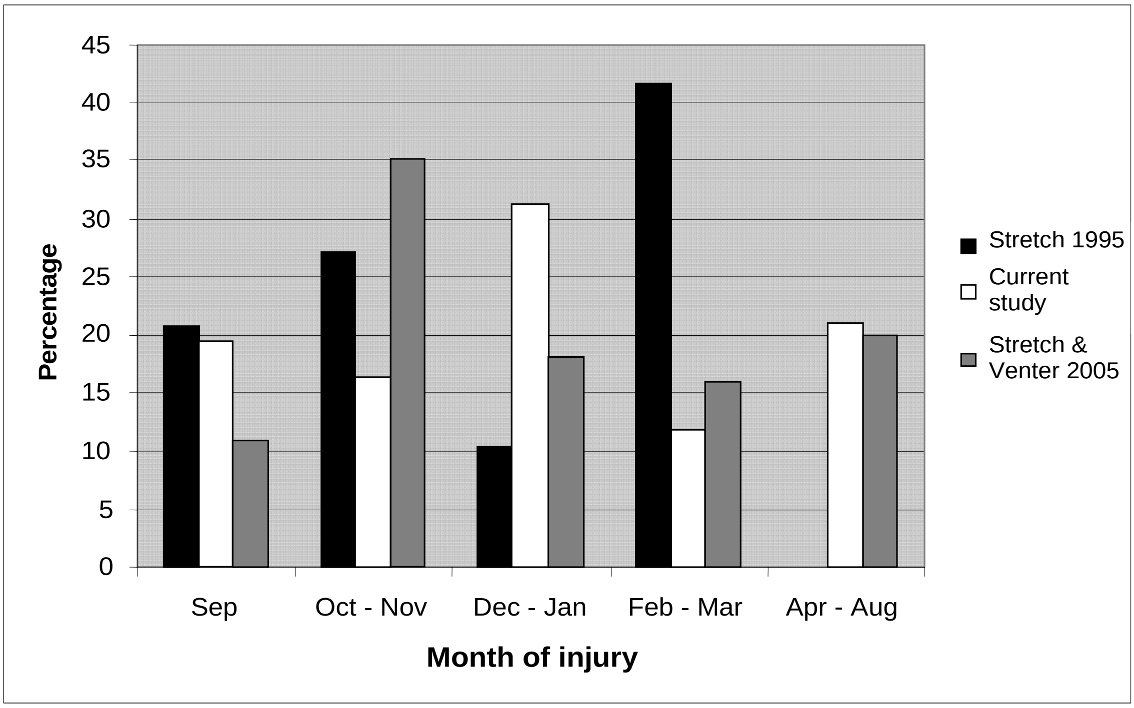


Figure 5: A graph depicting the monthly proportion of injuries in the current study, Stretch (1995) and Stretch and Venter (2005).

4.3 BOWLING INJURIES

Bowling, fast bowling in particular, is the major cause of injury amongst cricketers (Foster *et al.,* 1989; Stretch, 1993a; Bartlett *et al*., 1996; Elliott, 2000; Leary and White, 2000; Orchard *et al.,* 2002; Newman, 2003). It is no different in this study where the bowling injury comprises 50.7% of the total number of injuries reported. Where this is the highest incidence to be reported in a study, it is still similar to the proportion of bowling injury (47.4%) seen in the schoolboy study conducted by Stretch (1995). Stretch and Venter (2005) reported that the incidence of bowling injuries amongst South African first-class cricketers was 40.0%, 45.2% amongst Australian first-class cricketers (Orchard and James, 2006) and 28.0% amongst West Indian first-class cricketers (Mansingh *et al*., 2006). The prevalence of bowling injury to English county cricketers was 5.6% (Newman, 2003).

The 34 bowling injuries reported in this study occurred primarily as a result of overload in the run-up (1), delivery stride (20) and follow through (3). During the run-up, delivery stride and follow-through, the cricketer has to hyperextend, laterally flex and rotate the trunk in an attempt to position the body to achieve maximum delivery speed. These actions place the spine at an increased risk for injury (Stretch, 1989; Elliott, 2000; Millson *et al*., 2004; Ranawat and Heywood-Waddington, 2004). Injuries were also acquired due to overuse (1), on the release of the ball (5) as well as the misplacement of the front foot on FFI (4). Stretch (1989) and Elliot (2000) report that the fast bowler experiences peak vertical forces of up to five times the cricketer's body weight and peak horizontal deceleration forces of up to twice the cricketer's body weight at FFI of the delivery stride. It is therefore understandable that if the correct biomechanics are not executed during delivery, injury could result as the forces are transmitted via the foot to the leg and lower back (Stretch, 1989). A brief diagnosis of bowling injuries can be seen in Figure 6.

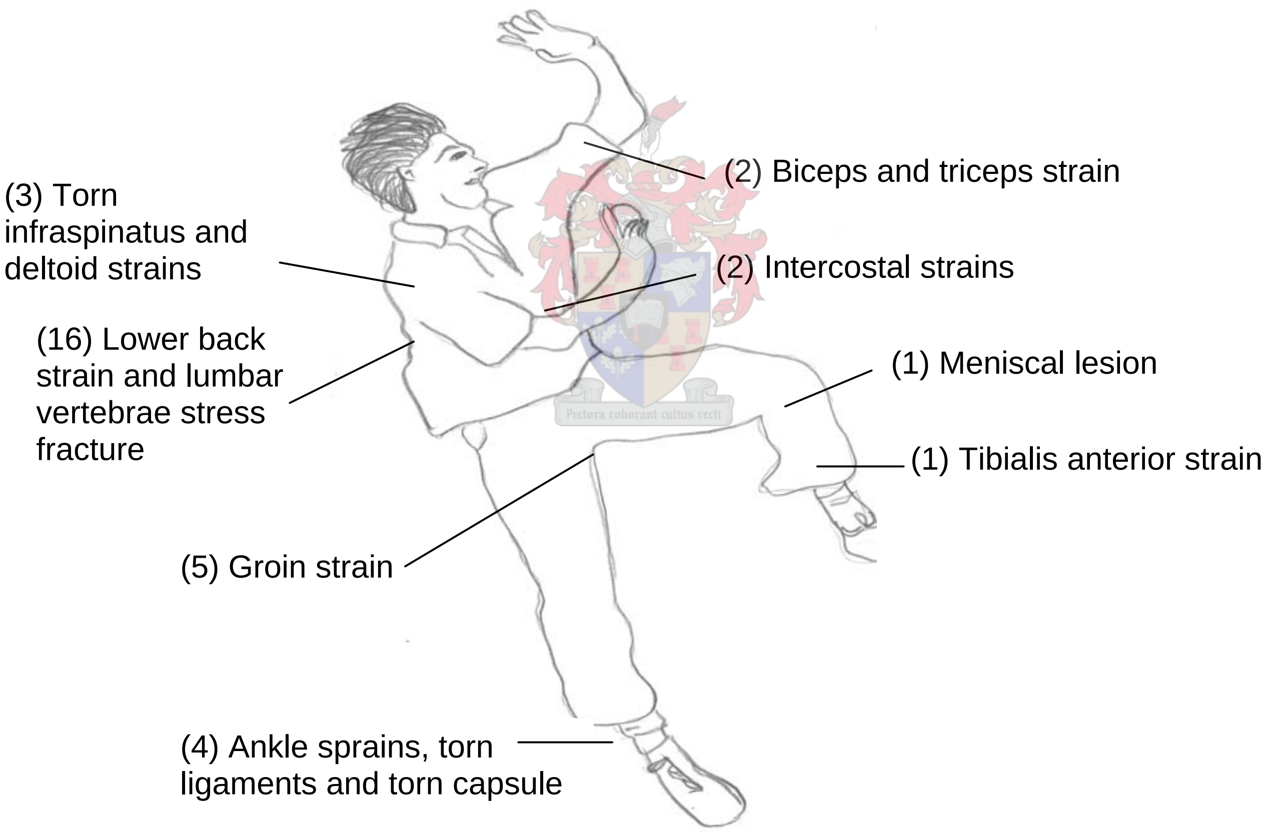


Figure 6: Summary of injuries acquired while bowling.

Stretch (2001b) suggests that the lower limb is the anatomical region most likely to be injured by fast bowlers. Stretch and Venter (2005) found the average prevalence of lower limb injuries amongst fast bowlers to be 21.8%. Although slightly higher than that found in Stretch (1995) namely 14.0%, and the current study (16.4%), it was not significantly different (p>0.05). In this study, the back and trunk (26.9%) was found to be most prone to injury. This was similar to that found in Stretch (1995) namely 26.3%. Only 13.0% of injuries reported by senior provincial cricketers were back and trunk injuries as a result of bowling. One could therefore assume that schoolboys are more susceptible to back and trunk injuries than senior first-class cricketers as their spines have not fully matured.

Groin strains are said to be the most common injury amongst fast bowlers (Bartlett *et al*., 1996; Orchard and James, 2002; Orchard *et al*., 2002; Newman, 2003; Stretch and Venter, 2005). Wear and tear of the articular cartilage is found to be prevalent amongst straight leg bowlers (Bartlett *et al*., 1996; Orchard *et al*., 2002; Orchard and James, 2002). Bartlett *et al*. (1996) and Orchard and James (2002) have recorded incidences of ankle ligament sprains as well as tibialis anterior strains. Various soft tissue injuries to the lumbar region have been reported by Orchard *et al*. (2002) and Orchard & James (2002). Shoulder tendon injuries are the most common upper limb injuries amongst bowlers (Stretch, 1989; Orchard & James, 2002; Orchard *et al*., 2002). Bartlett *et al*. (1996) makes special mention of rotator cuff strains and impingement.

4.3.1 Type of bowling and injury incidence

In a study conducted by Gregory *et al*. (2002) it was found that fast bowlers were more prone to ankle (8.6%) and knee injuries (11.4%) while spin bowlers, particularly wrist spinners, were more susceptible to shoulder injuries (11.9%). There was no significant difference in the injury prevalence of the lower back between spin bowlers (2.4%) and fast bowlers (5.7%). In the current study, only 33.3% of all bowlers reported injuries.

According to Figure 7, there were however significantly more fast bowlers injured (26.4%) than spin bowlers (8.7%) ($p < 0.05$). In Gregory *et al*. (2002) the authors subdivided spin bowlers into wrist and finger bowlers whereas in the current study, spin bowlers were subdivided into leg and off spinners. No comparison could therefore be made between the prevalence of shoulder injuries amongst wrist spinners reported in Gregory *et al*. (2002) and the shoulder injuries reported in the current study. Due to the small number of bowling injuries sustained by spin bowlers (4), no direct comparison could be made with fast bowlers and their susceptibility to injury of various anatomical sites.

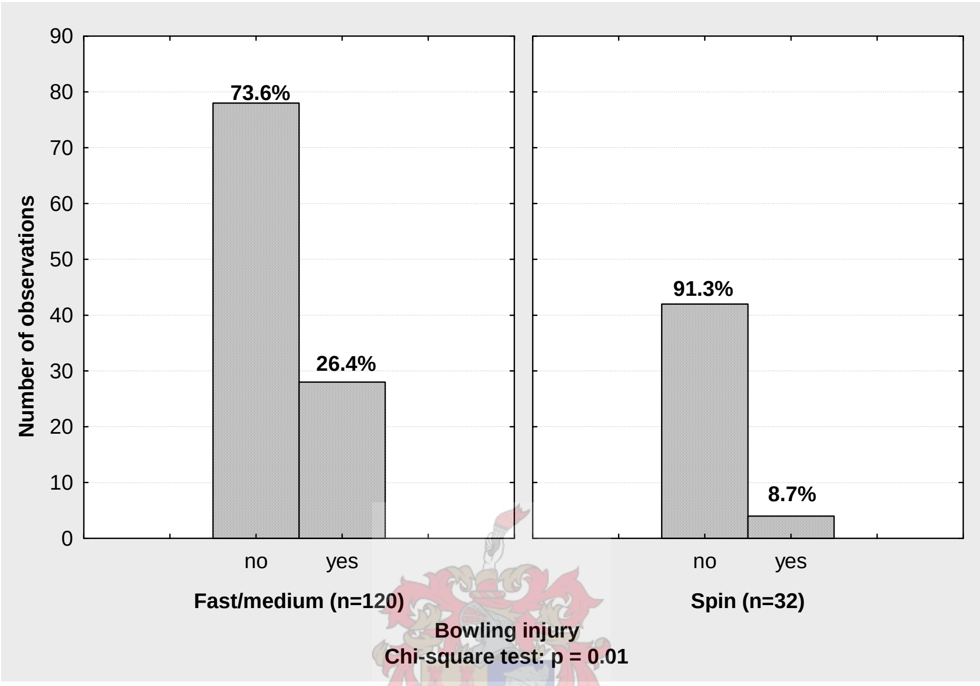


Figure 7: Injury incidence between fast and spin bowlers.

4.3.2 Fast bowling technique and injury

The ideal bowling technique is one where a side-on approach is adopted (Stretch, 1989). The bowler is said to be able to summate the forces acting on his body more efficiently, obtaining a maximum velocity with minimum strain on bodily structures. Bowlers adopting a mixed action are at an increased risk of injury (Stretch, 2003b). Bartlett *et al*. (1996) states that bowlers continually using a mixed action are more prone to abnormal radiological features in the lumbar region as the spine is placed in an awkward position at a time when the GRF's are at their greatest.

In Figure 8 it can be seen that slightly more bowlers adopting a mixed action (32.0%) sustained injury compared to those adopting either a front-on (25.8%) or side-on (24.0%) technique. There was however no significant difference (p > 0.05) in the injury prevalence between bowlers adopting either action.

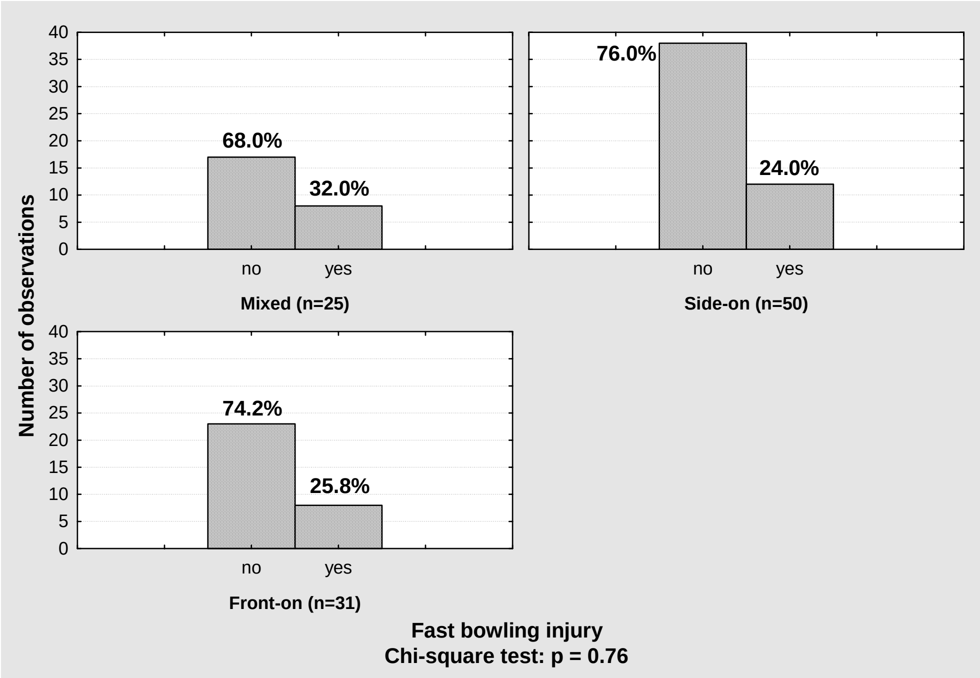


Figure 8: Fast bowling injury incidence of the side-on, front-on and mixed action techniques.

According to Bartlett *et al*. (1996), very few bowlers manage to position their back foot parallel to the popping crease which would adversely affect the alignment of their hips and shoulders throughout the delivery stride. In the current study, bowlers were asked to personally identify which bowling technique they used. This subjective angle could have led to a misinterpretation of their bowling classification and could therefore impact the injury incidence of the various bowling techniques. Caution will therefore need to be exercised when analyzing the above-mentioned data.

4.3.3 Bowling workload and the incidence of injury

Several studies have been conducted on bowling workload and the incidence of injury (Orchard and James, 2002; Dennis *et al*., 2003 and 2004). The general consensus being that those who bowl most are more prone to injury. Bowlers are urged to take two to five days rest between bowling spells, those bowling more than five times per week are at a 4.5 times greater risk of sustaining injury. Dennis *et al*. (2004) states that those bowling more frequently than every six days, are said to be at 1.8 times the risk of injury. None of the bowlers in the current study had two or more rest days in between bowling sessions, in fact 33 of the bowlers reported not having any rest days in between bowling sessions.

Hamstring and shoulder injuries are said to be correlated to bowling workload (Orchard and James, 2002). Due to the small number of injuries reported in the current study, no comparison could be between workload and the incidence of hamstring and shoulder injury.

No research was found on the correct number of overs to be bowled in a spell but it was found that those adopting a front-on technique, bowling a 12-over spell, displayed counter-rotation of the shoulders placing undue pressure on the lumbar region (McGrath and Finch, 1996). In the current study, cricketers were not asked to keep a log book of the total number of overs bowled in a spell or session so the totals recorded, should be viewed with caution. According to Figure 9, 14 bowlers reported bowling less than five overs in a spell, of which only 3 (21.4%) sustained injuries. A total of 125 bowlers reported bowling 5 - 10 overs in a spell, 22.4% of which sustained injuries while only 7.7% of bowlers bowling more than 10 overs in a spell, sustained injuries. Although bowlers bowling five- to 10-over spells sustained proportionately more injuries than those bowling less than five or more than 10 overs, no significant difference was found ($p > 0.05$).

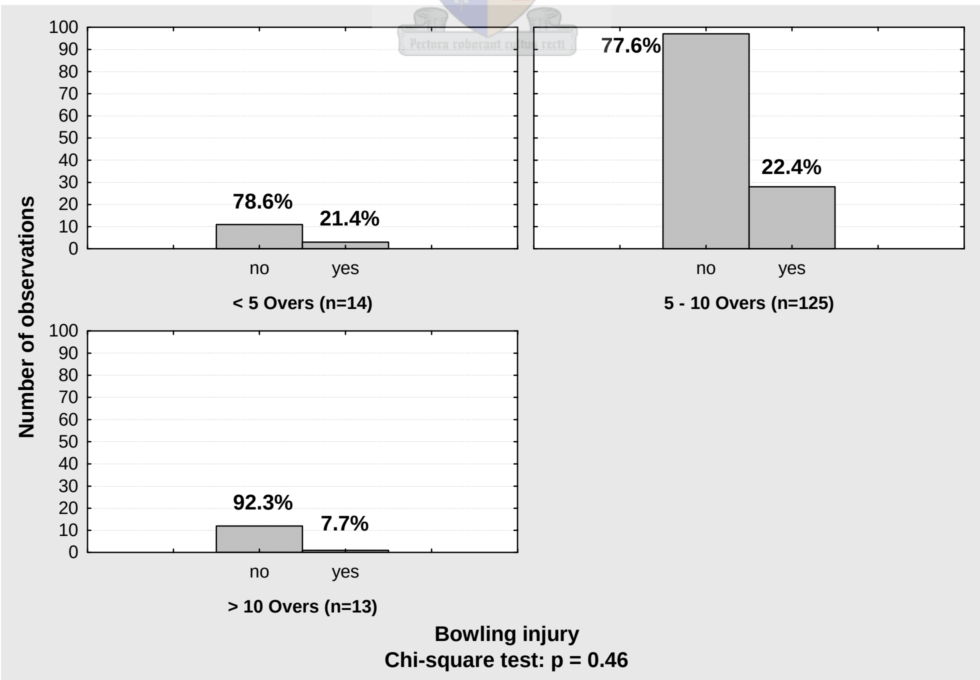


Figure 9: Fast bowling injury incidence in relation to the average number of overs bowled in a single spell.

As stated previously, bowlers with a higher workload are more prone to injury than their team-mates with a lesser workload (Orchard and James, 2002; Dennis *et al*., 2003). It was found however that bowlers bowling less than a total of 40 deliveries in a session were more prone to injury than those bowling more than 40 deliveries in a session (Dennis *et al*., 2003). As seen in Figure 10, bowlers bowling less than 10 overs in a session sustained proportionately more injuries (26.5%) than those who bowled 10 - 14 overs per session (20.8%) and 15 or more overs (17.1%), although the difference measured was not significant ($p>0.05$). It is interesting to note that Dennis *et al*. (2003) found that injured bowlers, in his study, bowled approximately 70 more deliveries per week than their uninjured counterparts. In the current study, the injury prevalence decreased slightly with bowlers bowling 15 or more overs in a single session. The decrease was however not significant ($p>0.05$). It must be reiterated that bowlers were not asked to keep any record of their bowling workload so the workloads described above are mere approximations of their training workloads.

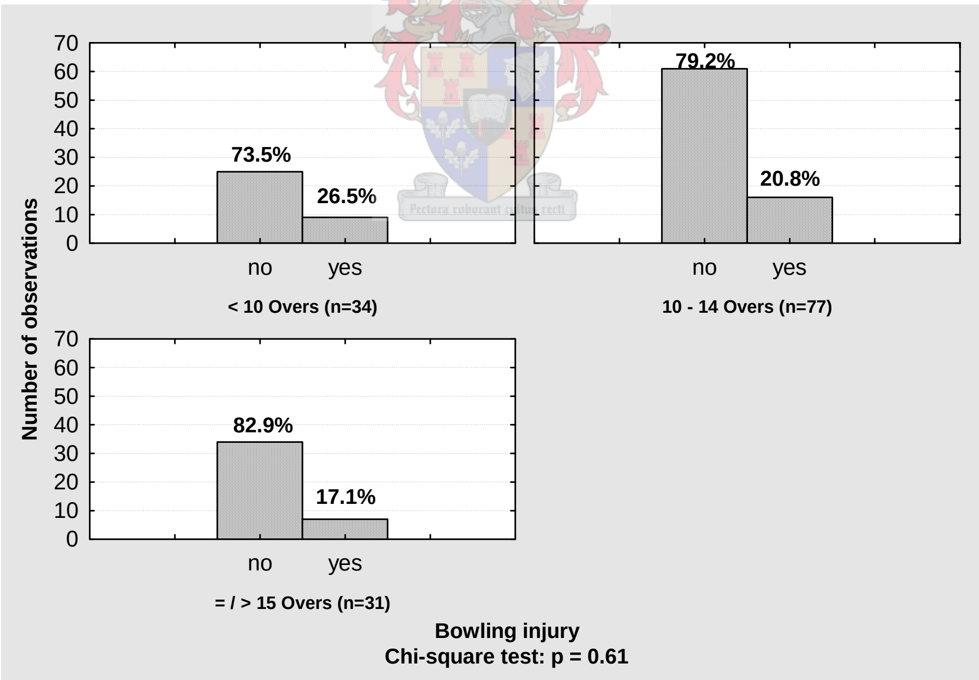


Figure 10: Fast bowling injury prevalence in relation to the average number of overs bowled per session.

Bowling, particularly fast bowling, as identified by Foster *et al*. (1989), Stretch (1993a), Bartlett *et al*. (1996), Elliott (2000); Leary and White (2000), Orchard *et al*. (2002) and Newman (2003) as the leading cause of injury amongst most cricketers, was again found to be the major cause of injury in the current study. Bowling injuries in the current schoolboy study, as in Stretch (1995), comprised mostly back and trunk injuries (26.9% and 26.3% respectively) while South African first-class bowlers were more prone to lower limb injuries (21.8%) while bowling.

Although no significant difference was found in the injury incidence of the various fast bowling techniques, it is felt that bowlers adopting a mixed action would be more susceptible to injury compared to those adopting a side-on or front-on technique. Statistical analysis of the current study may have supported this theory if qualified coaches and/or biomechanists had identified all fast bowlers' bowling action.

As bowlers present in the current study estimated their average bowling workload, no conclusions could be drawn to support or disprove theories relating to the ideal bowling workload albeit per session, per week or per month. No measurements were taken to assess body composition or flexibility; again no comparison could be made with regards to these variables.

4.4 BATTING INJURIES

Batting can be quite hazardous considering that the ball could be travelling up to 160 kilometres per hour (44.4 metres per second). With a pitch length of 17 metres, the batsman would have to react within approximately 383 hundredths of a second in order to respond appropriately to the specific line and length of the ball. Despite this, Stretch *et al*. (2000) has identified a lack of scientific research into batting.

Batting has been identified as the phase of play with the lowest injury prevalence amongst first-class South African cricketers, 17.0% (Stretch and Venter, 2005); Australian first-class cricketers, 20.8% (Orchard and James, 2006); and West-Indian first-class cricketers, 20.0% (Mansingh *et al*, 2006). Newman (2003) found the prevalence of batting injury to be 1.8% amongst

English county cricketers. According to the schoolboy study by Stretch (1995), batting injuries comprised 29.8% of the total injuries sustained which was significantly higher ($p<0.05$) than those sustained in the current study (14.9%). Top and middle order batsmen are said to be more prone to impact injuries of the head and upper limbs than lower order batsmen (Stretch, 1989). This is attributed to the fact that top and middle order batsmen face the new ball on a bouncy wicket, bowled by bowler who is well rested. It was however mentioned that lower order batsmen are more susceptible to hand injuries as they do not possess the skill and reaction time of the top order batsmen. Of the three impact injuries sustained by the batsmen in the current study, one was to the hand of a number eight batsmen. The other two injuries impacted the lower limbs.

The game of cricket, along with the various forms of protective equipment, has evolved tremendously since the first batting injury was recorded in 1752 when Frederick Louis was struck on the head by a ball (Temple, 1982). The wearing of batting helmets, even by junior provincial cricketers has become compulsory in recent times. This could have contributed to the fact that no head, neck or face injuries were reported in the current study. It would be ludicrous if one thought that the helmet was the answer to preventing all future head, neck and face injuries, especially considering that not all helmets are of the same quality as was evident in Stretch (2000). Impact to the helmet with the ball is likely to result in a certain amount of concussion or brain injury and can cause the helmet to become dislodged, resulting in fractures (McGrath and Finch, 1996; Subramanian, 2003).

In the current study, 10 batting injuries were reported and occurred as a result of direct impact from the ball (3), running between the wickets (3), playing a shot (2) and overuse following long spells out in the middle (2). A brief diagnosis of the injuries can be seen in Figure 11.

In the current study, it was found that the lower limbs (10.4%) were the anatomical region more prone to injury, a proportion similar to that found by Stretch and Venter (2005) amongst senior provincial cricketers (8.8%). In the schoolboy study by Stretch (1995) it was found that the head, neck and face (17.5%) were significantly more inclined to become injured ($p<0.01$) while injuries to the back and trunk comprised 7.0% of the total number of injuries reported. The proportion of back and trunk injuries sustained by first-class cricketers, 3.2% (Stretch and Venter, 2005) was similar to that of the current study, 3.0%.

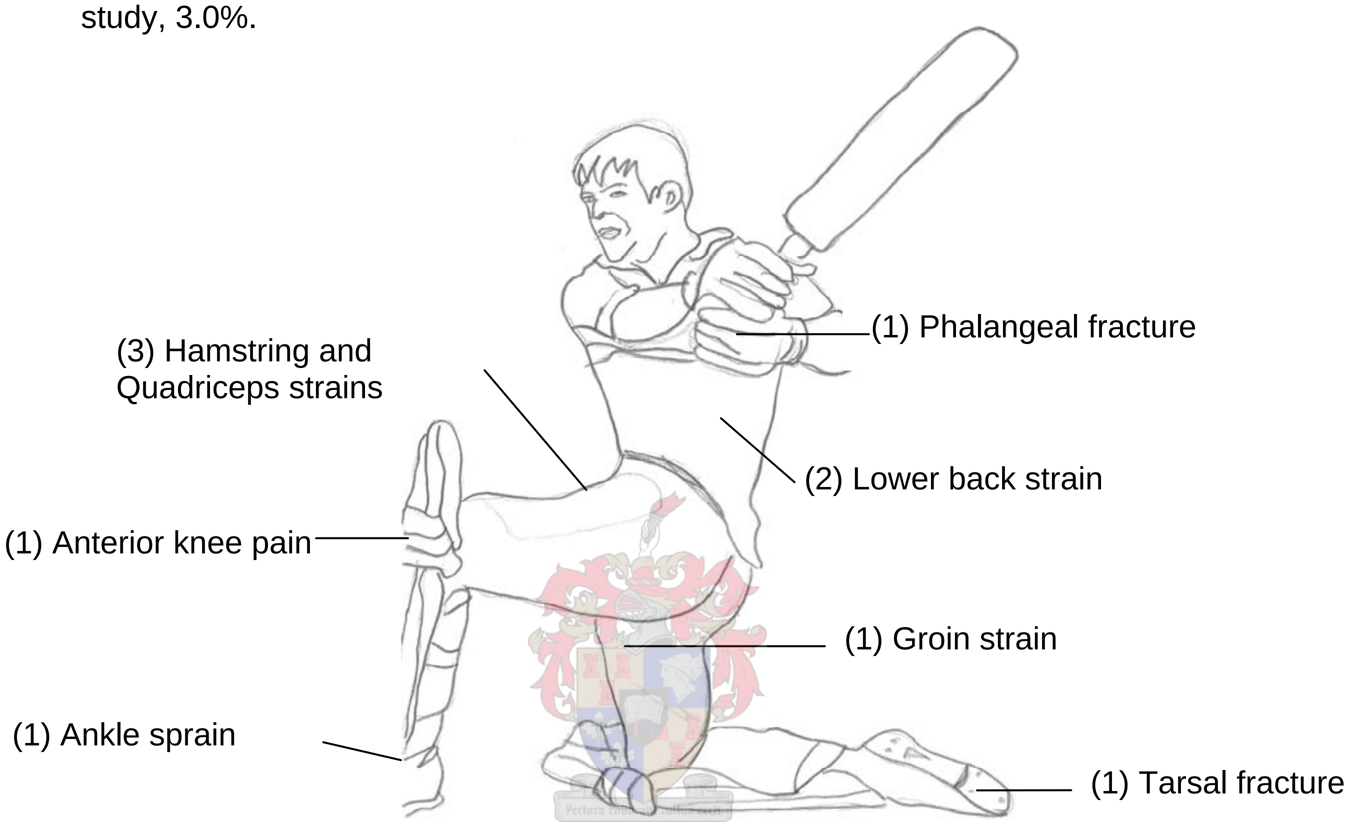


Figure 11: Summary of injuries acquired while batting.

Muscle strains to the quadriceps, hamstring and groin acquired while running between the wickets, have been reported by Stretch (1989, 1991), Stretch *et al*. (2000) and Orchard *et al*. (2002). Stretch (1991) reported on injuries sustained due to overuse or from batting for long periods of time. Foot and ankle injuries had been documented by Stretch (1991) while Orchard *et al*. (2002) described injuries to the tendon and cartilage of the knee. Impact injuries to the hand have been identified by Stretch (1989), Orchard and James (2002) and Stretch and Venter (2005).

The proportion of batting injuries and incidence of lower limb injuries amongst them appeared similar amongst the schoolboys of the current study and South African first-class cricketers. Although no significant difference ($p>0.05$) was found between injuries to the upper and lower limbs, back and trunk, there was a significant difference ($p<0.01$) in the number of head, neck and face injuries sustained by the schoolboys of Stretch (1995) and the current study. Even though no head, neck and face injuries were sustained in the current study, batsmen are urged to continue following precautionary measures to prevent or minimize these injuries.

4.5 FIELDING INJURIES

Fielding is quite a complex phase of play as it comprises various skills including running, diving, catching and throwing. Stretch (2003a) suggests that diving at full-length can predispose the fielder to whiplash as he hits the ground. The art of getting to one's feet and throwing the ball into the stumps can place further strain on the shoulder due to the forces involved in throwing (Bartlett, 2003; Stretch, 2003a). There are also various positions in which to field and some can be more specialized such as wicket-keeping, slips and short-leg. Research into fielding is, however, limited, compared to that of bowling and batting, even though some research has been aimed at the skill of catching (Bartlett, 2003).

Fielding was found to be the second leading cause of injury amongst West Indian first-class cricketers, 44.0% (Mansingh *et* al., 2006), South African first-class cricketers, 33.0% (Stretch and Venter, 2005) and Australian first-class cricketers (Orchard and James, 2006). The prevalence of total fielding injuries was found to be 2.2% amongst English county cricketers (Newman, 2003). In the current study, fielding injuries were sustained by 32.8% of those injured.

The upper limbs are more prone to injury than any other anatomical region and are responsible for 14.2% of injuries sustained by fielders (Stretch and Venter, 2006). This was significantly less ($p<0.05$) than the proportion of upper limb injuries found in the current study (23.9%). Upper limb injuries to fielders comprised 17.5% of the total number of injuries sustained by the schoolboy cricketers in Stretch (1995). The incidence of lower limb injuries in the current study (7.5%), were similar to that of the South African first-class cricketers, 13.2% (Stretch and Venter, 2005) and that of the schoolboy cricketers (5.3%) in Stretch (1995).

The majority of the 21 fielding injuries occurred from direct impact from the cricket ball (7) when cricketers attempted to take a catch, from diving to catch the ball and landing incorrectly (4), chasing after the ball (4) and trying to stop the ball along the ground (4). Other injuries occurred as a result of overloading the shoulder on ball release when throwing (1) and overuse from throwing (1). A brief diagnosis of fielding injuries can be seen in Figure 12.

Injuries sustained to fielders in the current study were similar to those reported by other researchers. The presence of hand injuries has been well documented (Stretch, 1989; Orchard *et al*., 2002). Stretch (1989) stated that repetitive throwing could lead to degenerative and inflammatory changes in the shoulder complex. Partial and complete ruptures of the rotator cuff as well as the biceps tendon have been identified (Stretch, 1989; Orchard *et al*., 2002).Orchard *et al*. (2002) found that forearm fractures, groin strains and ankle sprains were common amongst Australian first-class cricketers. Cricketers of all ages need to become more aware of the apparent threat of injury while fielding.

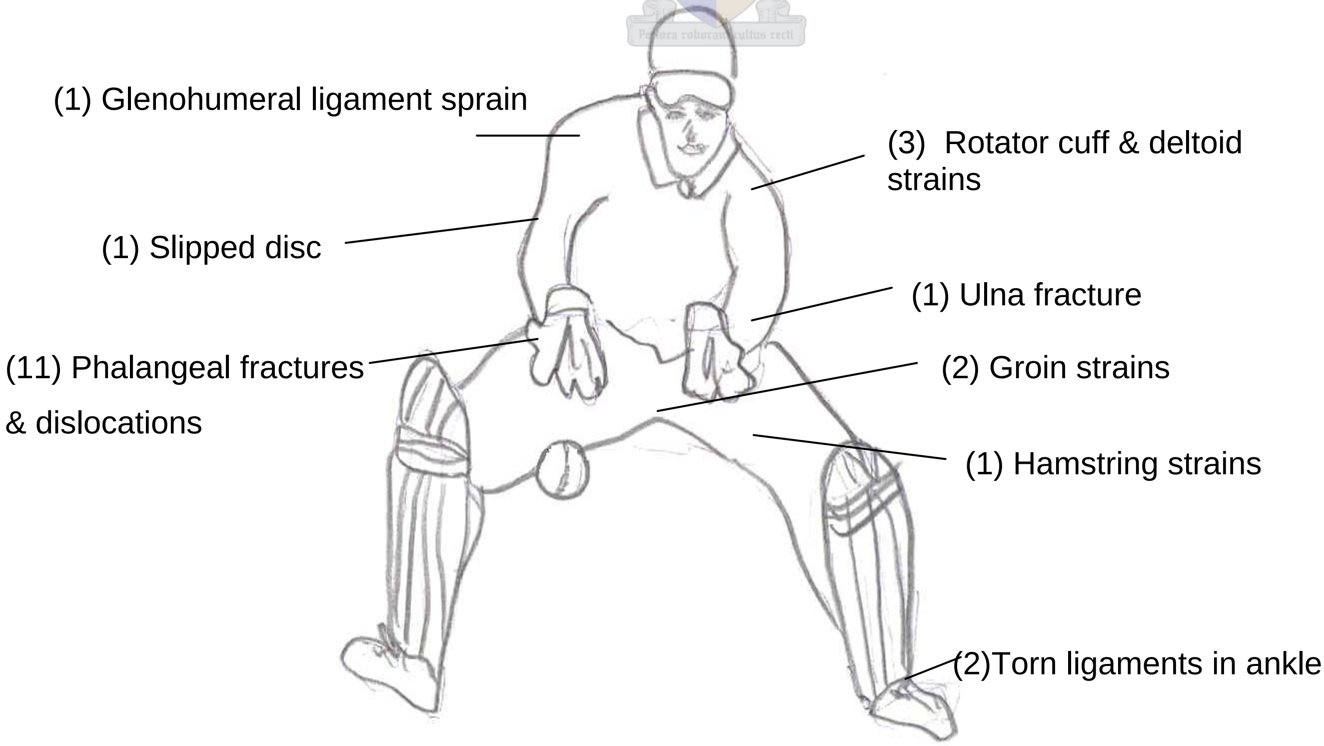


Figure 12: Summary of injuries acquired while fielding.

4.6 COACH'S FEEDBACK

Of the 16 coaches present at the Coca-Cola Khaya Majola Cricket Week, only nine had returned the questionnaire distributed to them during the Cricket Week. Three of the coaches had attained a level three coaching certificate; two had attained a level two coaching certificate while only one had attained a level one coaching certificate. The coaches were asked several questions pertaining to their understanding of training and training principles. The results are summarized below.

Three of the nine coaches correctly defined the term "periodization". In layman's terms, periodization refers to the process of structuring training into phases. It was interesting to note that seven coaches reported that they followed a structured pre-season program but only six of them defined the correct means to achieve the goals of a pre-season program. Five coaches defined the differences between pre-competitive and competitive phases correctly while three of them did not answer the question. One of the coaches stated that he focused more on technical skill training during the competitive phase rather than the pre-competitive phase. The majority (77.8%) of the coaches stated that they successfully altered training intensity during the season but only 44.4% described the correct way to alter training intensity in the pre-competitive and competitive phases. Training intensity should taper just prior to competition or matches while cricketers are advised to train at a relatively high intensity in the pre-competitive phase. Three of the coaches reported that they did not follow any specific program for the transition period while only one of the coaches following a transition period reported that he incorporated a form of cross-training into his program.

Coaches were asked to describe a typical training session but only one did so appropriately while another stated that the training sessions were designed by a biokineticist. Three teams trained together twice a week, two teams trained together three times a week while another three teams trained together four times a week. One of the teams did not respond to that question.

Aerobic and anaerobic endurance, muscular strength and endurance, power and flexibility (both static and dynamic) were under-reported in general training sessions. This could mean that the coaches are not fully aware of the importance of physical fitness to the cricketer. If cricketers were to develop and maintain a good level of aerobic endurance, they would be inclined to fatigue at a much slower rate making them more alert and responsive on the field. A good level of aerobic endurance is also said to improve the rate of recovery after training and matches. Hand-eye coordination, reaction time, agility, speed and balance were reported in high proportions. It is not known whether the terms are fully understood by the coaches though.

All nine teams represented were said to undergo comprehensive warm-ups prior to training and matches. All but one coach stated that they concluded training sessions and matches with a cool down comprising mainly of stretching and a few cross-training drills e.g. touchies, handball.

It would appear that coaches at provincial under-19 level only have the bare essential knowledge of fitness and training specific to cricket. Coaches familiar with the more scientific terminology reported that they either had a background in sport science or had contacts with someone who specializes in sport science.

4.7 SUMMARY

Cricketers of the current study displayed a seasonal incidence of injury of 34.2%. Although one of the lowest incidences recorded, it was felt that the number of injuries reported for the 2003/2004 season was under-reported. As found in numerous other studies, bowling was the leading cause of injury, followed by fielding and batting. The number of injuries sustained in each phase of play, were similar to that seen amongst South African senior provincial cricketers. The proportion of batting injuries acquired by the schoolboys of Stretch (1995) was significantly higher than that found amongst the schoolboys of the current study; presumably due to the number of head, neck and face injuries sustained by this group. The number of back and trunk injuries sustained while bowling were similar amongst both groups of schoolboy cricketers but significantly ($p<0.01$) less than that found amongst senior provincial bowlers. It was interesting to note that the number of injuries to the upper limbs was significantly higher ($p<0.05$) than that seen amongst senior provincial cricketers while the number of lower limb injuries was significantly lower ($p<0.05$).

It would appear as though the cricketers of the current study acquired an injury profile similar to that of senior provincial cricketers although the number of back and trunk injuries and injuries to the upper limbs possibly indicate inferior skills to the more senior players.

The following chapter is designed to conclude the study as well as present various recommendations for decreasing the prevalence of certain injuries. It will give basic training guidelines and other advice to be used by coaches.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATIONS

CONTENT

p.

5.1 INTRODUCTION

A total of 196 cricketers completed the injury questionnaire with only 67 injuries reported for the 2003/4 season. The seasonal incidence of injury in the current study was therefore 34.2%. This is significantly ($p<0.05$) lower than that of the previous study (49.0%) conducted by Stretch (1995). There were no injuries to the head, neck and face region while 34.3% were sustained to both the upper and lower limbs, and 3.3% of the injuries were sustained to the back and trunk. Approximately 72% of injuries were reported during matches, 14.9% occurred gradually, 11.9% were sustained during practices and 1.5% of injuries occurred during other forms of training e.g. gym. The majority (40.6%) of injuries were severe enough to prevent cricketers from playing matches or training for more than 21 days. There were 58 first time injuries while nine injuries were a recurrence of a previous injury. Bowling accounted for 50.7% of injuries, fielding 32.8%, batting 14.9% and the remaining 1.5% occurred while warming-up or training.

It should be stated that one of the provincial teams reported having sustained one injury, while their coach stated that his team had been plagued by injury all season. The author therefore suggests that the total number of injuries were under-reported by the respondents, possibly due to a fear of the impact the information could have on national team (SA schools/Colts) selection and a possible loss of position in their provincial teams.

During the compilation and analysis of the data presented in the current study, several researchers responsible for cricket injury surveillance in their countries compiled a report defining a universal method of data collection, analysis and interpretation (Orchard *et al*., 2005). The principal findings and guidelines are presented below.

5.2 METHODS FOR UNIVERSAL CRICKET INJURY SURVEILLANCE

It has been said that ongoing injury surveillance is necessary in order to minimize future injury sustained while playing cricket (Orchard *et al.*, 2005). In order for injury surveillance to be compared between the different countries, six authors J. Orchard (Australia), D. Newman (England), R, Stetch (South Africa), W. Frost (New Zealand), A. Mansingh (West Indies) and A. Leipus (India) came together to set up a universal method of cricket injury surveillance. The authors felt so strongly about establishing a uniform method of injury surveillance that the article was published in the following, highly reputable journals: Journal of Science and Medicine in Sport, British Journal of Sports Medicine, South African Journal of Sports Medicine and the New Zealand Journal of Sports Medicine. The following guidelines and definitions were presented:

- A cricket injury is defined as any injury or medical condition that a) prevents a player from being fully available for team selection for a major match or b) occurred during a major match causing the player to be unable to bat, bowl or keep wicket. This includes a batsman who is unable to bat at his usual position or requires the use of a runner, a wicket-keeper who must hand over the gloves, and a bowler who is unable to finish bowling an over or complete his usual complement of overs.
- A cricketer is said to have recovered from an injury when he returns to full, unrestricted participation in at least one match.
- A recurrent injury is one in which an injury is sustained to the same side and body part and of the same injury type as a previous injury from which the cricketer has already fully recovered.
- A season is generally referred to as a six-month period in which all international and domestic cricket matches are played, but due to the ever-changing length of season due to overseas tours, researchers are advised to accurately define the season in question. It can be added though that northern hemisphere seasons generally run from 1 April – 30 September while southern hemisphere seasons generally run from 1 October - 31 March.
- A team will consist of 12 players and can either be an international or domestic team that plays in major matches including Tests, domestic first-class matches, ODIs and domestic one-day matches.

- A squad is a pre-selected group of 25 cricketers consisting of bowlers (a player who bowled on average more than five overs in matches during the previous two seasons), wicket-keepers (those who kept wicket in at least 50% of matches played during each season) or batsmen. All-rounders do not have to be incorporated as all bowlers are required to bat.
- Exposure time is an estimated amount of time that a player is exposed to injury. Total hours of exposure for a team playing in a 50-over match is estimated as 43.3 hours while a team playing in a five day match playing 90 overs per day is exposed to injury for approximately 195 hours.
- Match injury incidence is defined as the number of injuries occurring in major matches and could be sub-divided into a match incidence with a time-based denominator, or batting and bowling match incidence with a delivery-faced (per 10 000 balls) or -bowled (per 1 000 overs) denominator.
- The seasonal injury incidence is the total number of injuries occurring per squad per season. This includes injuries sustained while training, playing matches and those of gradual onset.
- Injury prevalence takes the average number of squad members not available for selection through injury or illness for each match into consideration, divided by the total number of squad members i.e. the numerator is missed player games, while the denominator is the number of games multiplied by the total number of squad members.
- The injury surveillance coordinator should note who is not selected due to injury, unavailable due to national team commitments, selected as twelfth man, not selected, or rested, and when they are not available through suspension or personal reasons.

If all cricket-playing countries adopt the methods of injury surveillance reported above, global comparisons of injury rates could be identified, compared and monitored. This could, however, pose huge difficulty in surveying the injury profile of schoolboy cricketers as they play very few provincial matches together and come from a number of different schools. Injury surveillance of Australian amateur cricketers is said to be problematic as the level of medical staffing is less consistent at this level (Orchard and James, 2006). Injury surveillance at first-class level is said to be rather costly as good medical records and records of player participation need to be kept and passed on. According to Orchard and James (2006) the structure of a national contract in Australia is such that it allows basic injury details to become public knowledge. Privacy laws in favour of uncontracted players, however, do not allow for comprehensive data collection amongst amateur cricketers unless prior consent has been given. Injury surveillance could only be seen as beneficial if a long-term ongoing project were implemented (Orchard and James, 2006).

5.3 PREVENTION OR MINIMIZATION OF INJURIES

5.3.1 Bowling injuries

As stated previously, bowling injuries are a serious threat to cricketers accounting for just less than half of all injuries reported by either schoolboy or first-class cricketers (Stretch, 1995; Stretch and Venter, 2005; Orchard and James, 2006). Various factors leading to bowling injury have been identified by Stretch (1993a) and include:

- A sudden and drastic increase in the length of bowling spells during a match as opposed to the amount of bowling usually performed in training.
- Attempts to bowl too quickly placing undue force on the body.
- Captains who over-bowl a bowler who is performing well in a match.
- A bowler returning for a subsequent bowling spell without adequate recovery from a previous bowling spell.
- A sudden increase in the number of matches played.
- Inadequate warm-up before starting a bowling spell.
- Return to match play too soon after injury, not reaching a match-readiness state.

Captains and coaches are urged not to over-bowl their bowlers, particularly at the beginning of a season (Stretch, 1989). Orchard and James (2002) have identified a further risk for bowling injury, that being bowling second rather than first in a match, which is possibly due to fatigue or a lack of warm-up. Bowlers bowling second in a first class match are said to be at 1.6 times the risk of injury. Bowling second in ODIs showed no disadvantage in day games but there was a significant increase in the risk of injury when bowling second in a day-night game (Orchard and James, 2002). The greatest risk for bowling injuries is speed and workload with fast bowlers at a 12 times higher risk of injury than the spin bowlers with the lowest risk.

a) Bowling workload

Various recommendations have been made by the UCBSA with regards to bowling workload, although it does not appear to have been successfully implemented at schoolboy level considering the enormous workloads reported above. The recommendations made can be seen in Table 8.

Table 8: Bowling workloads recommended by the UCBSA*

Age group	Matches	Practices	Maximum no. of matches & practices in 1 week
Under-12	**2 spells of 4 overs** with a one hour break in-between	**2 * 30 min practise sessions per week** 5 min short run-up at a reduced pace 20 min match pace, supervised 5 min bowling technique development	3
Under-16	**2 spells of 6 overs** with a one hour break in-between	**2 * 40 min practise sessions per week** 5 min short run-up at a reduced pace 25 min match pace, supervised 10 min bowling technique development	3
Under-19	**3 spells of 6 overs** with a one hour break in-between	**3 * 40 min practise sessions per week** 5 min short run-up at a reduced pace 25 min match pace, supervised 10 min bowling technique development	4
Senior	**Maximum of 3 spells of 8 overs** with a one hour break in-between	**3 * 60 min practise sessions per week** 10 min short run-up at a reduced pace 40 min match pace, supervised 10 min bowling technique development	4

*The table was adapted from Stretch (2003b).

It has been suggested that bowlers maintain a daily logbook of the number of overs bowled at training or during matches. An example of a page from the logbook can be seen in Table 9. The idea is that the player keeps a record of the total number of overs bowled. If it does not look similar to the suggested workload given above, bowler should be able to discuss it with the coach who should immediately address the matter. The bowler should ask the coach to sign the logbook to ensure that he too has an idea of the workload undertaken by the bowler. By using the logbook, it is easy to calculate the weekly, monthly and seasonal workload that could facilitate data collection for various research projects.

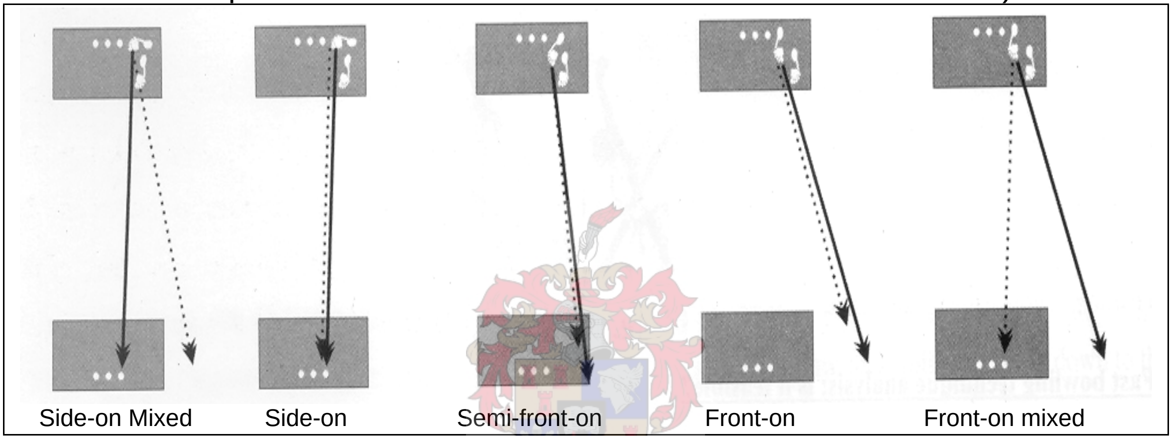
b) Fast bowling technique

Bowlers and coaches are advised to pay special attention to bowling technique and attempt to develop a side-on bowling action (Stretch, 1989). Bell (1992) stated that bowling with a side-on action allowed for more efficient force summation as the additional rotational movement decreased the risk of injury. Bowlers bowling with a mixed action were prone to abnormal radiological features (Bartlett *et al*., 1996).

A very basic fast bowling technique analysis has been established by Stretch (2003c). The coach or bowling analyst is required to film at least four of the bowler's normal deliveries. If it is thought that the bowler has adopted either a front-on or mixed bowling action, a brief explanation of foot and shoulder positions should be given in an attempt to get the bowler into a more side-on approach. The bowler is to be filmed bowling two deliveries which he feels follows the definition of a side-on delivery. The bowler's normal action is to be viewed several times to ensure that an accurate assessment is made. The analyst should then mark the position of the back and front foot as well as hip alignment on the diagram provided (see Figure 13). The footage of the normal bowling action should again be analyzed and then the shoulder alignment should be marked on the diagram provided. Hip and shoulder alignment should be compared in order to determine which bowling action is used. Before the analyst recommends which technique to use, he should view the footage of the so-called classical side-on action as some bowlers will find it easier to adjust their foot position while others will find it easier to adjust the positioning of their shoulder alignment. The analyst can complete the diagnosis and identify key-points to be addressed before making the required changes to the bowling action.

Fault correction should ideally be done at an early age before too much motor memory has set in. Motor memory, which includes motor programs and recall schemas, is a form of long-term memory where you store an understanding of how to perform motor skills that you have learnt through participation (Bressan, 2002). Before making technique changes, Stretch (2003c) advised that a strength training program be implemented to focus on back and trunk strength. Once the bowling analyst has decided on which bowling action to use, the bowler will have to go back to basics in order to implement these changes.

Figure 13: Diagrams used for bowling analysis (The solid line shows the line of the hips while the dotted line shows the line of the shoulders).



Taken from Stretch (2003c)

First–class bowlers should regularly be screened and should undergo an annual biomechanical assessment and MRI of the lumbar spine (Orchard and James, 2002). The MRIs are however rather costly so will only be used by those who can afford to do so. Bowlers are also advised to keep an exact record of their bowling workload to analyse their risk of injury (Orchard and James, 2002 and Mansingh *et al*., 2006). Stretch (1989) suggests that bowlers develop leg, back and trunk strength and flexibility and should ensure that their bowling boots are able to absorb the tremendous forces generated at FFI in the delivery stride. Bowlers should be given adequate time to warm-up before being called on to bowl in match or training situations (McGrath and Finch, 1996).

c) Intervention of back injuries

Back injuries amongst young fast bowlers in particular are of great concern to researchers. Stretch (1995) reported that back and trunk injuries to bowlers accounted for 26.3% of all injuries reported by schoolboy cricketers. In the current study, back and trunk injuries accounted for 26.9% of the total injuries recorded. It is therefore essential to describe methods of early intervention for back and trunk injuries (Stretch *et al*., 2003).

The majority of lumbar fractures will stabilize within approximately three months if adequate rest is given, if bowlers follow a comprehensive rehabilitation program, modify their technique and limit their workloads (Elliott, 2000; Ranawat *et al*., 2003; Stretch *et al*., 2003). A pseudo-joint and osteophyte formation may also occur representing the adaptation of the lumbar spine, which could be advantageous to the bowler if the bowler were to undergo an intensive trunk and pelvic stabilization program, as excess spinal joint movement would not be beneficial without adequate muscle control (Millsom *et al*., 2004).

Elliott (2002) advised that the bowler rest completely until acute symptoms of back pain have subsided, and follow this with three months of graduated exercise without bowling. Rehabilitation should focus on retraining precise co-contraction patterns of the deep trunk muscles, transverse abdominus and multifidus, correct any muscular imbalances, and then adopt a general strengthening program for the spine to ultimately increase stability and functional ability.

A specialized bowling coach should analyze the bowler’s technique to assess whether the spine is being placed under any provocative stresses and then supervise a reintroduction program to bowling over the subsequent months (Ranawat and Heywood-Waddington, 2004). Elliott and Khangure (2002) suggests the use of an education and coaching intervention where players and coaches are informed of the correct biomechanics of bowling and the science behind training etc.

5.3.2 Batting injuries

Batting injuries can be minimized in various ways by using the appropriate protective equipment. Stretch (2000) found that only helmets lined by multi-density ethylene vinyl acetate (EVA) offered enough protection when hit by a cricket ball. Low density EVA did not absorb sufficient energy to prevent excessive force from being applied to the head. Batsmen are also encouraged to wear helmets with full visors to minimize dento-facial injuries (Stretch, 1989; Subramaniam, 2003). It was found that dento-facial injuries could also be minimized by wearing a custom-laminated mouth-guard that separates the head of the condyle from the temporal fossa (Subramanian, 2003). The space caused by the mouth-guard acts as a buffer so that the force of the blow will not be transferred to the base of the skull, and also decreases the rate and severity of cerebral concussion.

Batsmen are advised to practise running between the wickets wearing full protective gear so as to minimize the risk of muscular strain when running between the wickets in matches (Payne *et al*., 1987). Stretch (1989) also urges batsmen to practice on pitches similar to the ones that they are likely to use in a match. Batsmen should be kept warm and stretch continually as they wait to go in to bat (McGrath and Finch, 1996).

5.3.3 Fielding injuries

As previously stated, there is a severe lack of research into fielding in cricket (Bartlett *et al*., 1996), making the recommended strategies for injury prevention or minimization that much harder. It has been shown that the use of the boundary fence has led to many lower limb injuries (Orchard *et* al., 2002; Orchard and James, 2002) but this can be prevented by using a boundary rope instead of solid fencing to demarcate the area.

Cricketers are advised to pay special attention to fielding and catching techniques (Mansingh *et al*., 2006). McGrath and Finch (1996) suggest that cricketers should not be asked to throw the cricket ball over long distances until the shoulder is properly warmed up. Injuries to the cervical vertebrae caused by whiplash when diving to stop the ball can be decreased by teaching the correct diving and landing techniques (Stretch, 2003a). The use of specialised coaches and protective equipment, such as soft mats, is necessary in this regard.

5.4 WARM-UPS AND COOL-DOWNS

Warm-ups are said to be essential in the reduction of injury incidence, particularly musculoskeletal injuries, although the effect of a comprehensive warm-up on the injury incidence of cricketers has not yet been researched (McGrath and Finch, 1996). McGrath and Finch (1996) advised that cricketers take part in a 10 minute warm-up routine before training or playing a match. Football cross-training drills, commonly seen amongst Australian and South African cricketers, should be undertaken with great caution as they have been identified as a risk factor for injury (Orchard and James, 2002). Cricketers do however need variety in their training but alternatives such as volleyball that offer a lower risk of injury should rather be implemented. McGrath and Finch (1996) advise a five-minute cool-down period, which incorporates stretching, at the end of a training session or match.

5.5 CLOSING

Potential risk factors for injury have been identified and it has been suggested that the injury profile of cricketers may be reduced through continuous educational processes that focus on all the physical, training, mental and technical components necessary for success in a sport like cricket (Stretch and Venter, 2005). Stretch and Venter (2005) suggested that a more comprehensive evaluation be made into the risk factors involved in batting and fielding injuries.

It is recommended that players with a history of injury undergo a musculoskeletal evaluation during the off-season to identify any underlying problems (Stretch, 2001b). Another evaluation should be made during the pre-season to ascertain whether the inherent problem areas have been addressed. This should be followed by a further evaluation in the in-season to ensure that the cricketer is following the prescribed maintenance program. The author of the current study suggests that where possible, every cricketer should undergo a musculoskeletal evaluation and be given a personalized training program, specific to his needs and his particular role in the team. Mansingh *et al*. (2006)

stated that the early detection and management of injuries is imperative to the reduction of the impact that injuries will have on team dynamics.

The author suggests that a concerted effort be made to start up an injury database amongst amateur cricketers, particularly those representing their provincial teams at under 14, 16 and 18 levels etc. The author intends to initiate a coaching intervention program whereby coaches are taught how to train cricketers correctly and to minimize injuries, and perhaps re-evaluate the UCB level one, two and three coaching certificates.

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APPENDIX I

Dear 11 August 2004

C/O

THE PREVALENCE AND NATURE OF INJURIES AMONGST SOUTH AFRICAN SCHOOLBOY CRICKETERS

The Biokinetics centre at the Department of Sport Science, Stellenbosch University, is currently investigating the prevalence and nature of cricket injuries amongst schoolboy cricketers. Dr. R. Stretch has done a great deal of research on the epidemiology of cricket injuries amongst senior cricketers and we have found that there is a lack of data regarding schoolboy cricketers, the last study having been completed in 1990.

In our discussion with Mr. Henry on 4 August 2004 we have identified a need for player profiling of all amateur cricketers. We have thus far conducted a pilot study of the prevalence and nature of cricket injuries amongst schoolboy cricketers. Results have been attached, and we have come to the conclusion that further research needs to be done in order to gain a broader perspective of current injury trends and the possible causes thereof. This data could immediately impact on the development of cricket in South Africa. Identifying the most prevalent injuries amongst schoolboys and preventing or minimizing their occurrence could result in a sharp decrease in the prevalence of injuries amongst our senior cricketers, providing that they stay informed about as well as follow the correct training procedures.

We hereby request permission to collect the necessary data at the Khaya Majola Coca cola under-19 cricket week to be held in Pretoria from 16 – 20 December 2004. Data will be collected by means of a questionnaire, at a time that is convenient to the teams and/or the coach. The questionnaire will be completed individually and should take no more than five minutes per player. All information will be treated confidentially and participation will be voluntary.

With the aid of the head coaches for amateur cricket and other staff, we would be able to set up a test battery in order to profile amateur cricketers completely and in the process future team selections and talent identification easier. We have the means to run a database for the profiles of all amateur cricketers; meaning that player profiles would be readily available to those who need it. Dr. M. Kidd of the Centre for Statistical Consultation at Stellenbosch University will set up the database.

Thanking you in anticipation of your response. Should you have any queries, do not hesitate to contact me on or via e-mail:

Kind regards

Natashia Milsom	Prof J. G. Barnard
(Researcher)	(Head of Biokinetics)

APPENDIX II

APPENDIX III

STELLENBOSCH UNIVERSITY COACHES' TRAINING PROTOCOL QUESTIONNAIRE

Name.. Coaching Qualifications........…………....…..
School.. Highest level attained……………………….
Telephone no.............................

What do you understand by the term periodization?...
....
....
....
....
....

Do you follow a specific pre-season program? Yes [] No []

What does your program entail?..
....
....
....
....
....

Do you alter the intensity at all? Yes [] No []

Describe..
....
....

How does your program change between the pre-competitive and the competitive phase?...
....
....
....
....

Do you prescribe any activities for the transition phase? Yes [] No []

Describe..
....
....

Have you prescribed a gym program for the cricketers? Yes [] No []

Describe a typical training session ....
....
....
....
……………………………………………………………………………………
……………………………………………………………………………………

Mark aspects addressed in training:

Hand-eye coordination	[]	Reaction time	[]	Agility	[]
Flexibility (Static)	[]	Flexibility (Dynamic)	[]	Speed	[]
Anaerobic endurance	[]	Aerobic endurance	[]	Power	[]
Balance/proprioception	[]	Muscular strength and endurance			[]

Could you elaborate on your warm-up routine...
....
....
....
....

Do you cool down after the session? Yes [] No []

Describe..
....

How manydays so they train per week?...

Do you have separate days for fitness, fielding , nets and a middle practise or do you do all in one?..
....

How many competitions do you compete in and which competitions are they?
....

When was the team's first game?...

Additional information...
....
....
....
....
....
....
....
....
....
....
....
....
....
....

Table 9: Example of a bowling logbook

NAME			**SURNAME**			**SCHOOL**			**COACH**	
	Sunday	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sub-total**	**Total**	**Sign**
WEEK 1 Date______	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	**Practice**______ **Match**________		
WEEK 2 Date______	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	**Practice**______ **Match**________		
WEEK 3 Date______	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	**Practice**______ **Match**________		
WEEK 4 Date______	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	**Practice**______ **Match**________		
WEEK 5 Date______	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	**Practice**______ **Match**________		
WEEK 6 Date______	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	**Practice**______ **Match**________		
WEEK 7 Date______	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	**Practice**______ **Match**________		
WEEK 8 Date______	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	**Practice**______ **Match**________		
WEEK 9 Date______	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	**Practice**______ **Match**________		
WEEK 10 Date______	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	**Practice**______ **Match**________		
WEEK 11 Date______	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	**Practice**______ **Match**________		
WEEK 12 Date______	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	**Practice**______ **Match**________		
WEEK 13 Date______	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	Practice______ Match________	**Practice**______ **Match**________		

* Taken from Stretch (2003c)

STELLENBOSCH UNIVERSITY, CRICKET INJURY REPORT FORM - COCA COLA KHAYA MAJOLA CRICKET WEEK 2004

Player:			**Contact no.:**	
DOB:			**Province:**	

Role in team:	Fast bowler		Medium pace		Off spinner		Leg spinner	
	Batsman		Wicket-keeper					
Batsman:	Right hand		Left hand		No			
Bowlers:	Right hand		Left hand					
	Side on		Front on		Mixed			
No of overs bowled on the trot								
No of overs bowled per session								
Rest days betw bowling spells								
Fielding position:								

Protective gear:	Helmet		Chest pad		Box		Elbow guard	
	Thigh (Outer)		Thigh (Both)		Gloves		Pads	

Highest level:	Provincial academy		Province 'B'		Province		National academy	
	National		International		Other (Specify)			

Cricket injuries:	
Mechanism:	
Diagnosis	
By whom:	

Month of injury:	January		February		March		April	
	May		June		July		August	
	September		October		November		December	

Team when injured:	School		Club		Provincial academy		Province 'B'	
	Province		National academy		National		International	
	Other (Specify)							

Occurrence:	One day match		3/4/5 day match		Practise		Gradual onset	
	Other (Specify)							

Activity:	Batting		Bowling		Fitness		Fielding	
	Throwing		Catching		Gym			
	Other (Specify)							
Injured while bowling, what type of boot was being worn								
How far into the activity did the injury occur?								

Nature of injury	Fracture		Muscle		Joint		Ligament	
	Open wound		Tendon		Fascia		Stress fracture	
	Cartilage		Dislocation		Nerve			
	Other (Specify)							

	1st time injury		Recurrent: Previous		Recurrent: Present			
	Acute		Chronic		Gradual onset			

Time out of game								
Practise	1-3 days		4-7 days		8-14 days		15-21 days	
	21 + days							
Matches	1-3 days		4-7 days		8-14 days		15-21 days	
	21 + days							

		HEAD, CERVICAL SPINE & F		
Anatomical Site:	Ear		Eye	
	Chin		Cheek	
	Nose		Mouth	
	Other (Specify)			
Diagnosis	Fracture		Unconciousness	
	Eye injury			
Surgery	No		Yes	
		UPPER LIMB		
Anatomical site	Sternoclavicular joint		Clavicle	
	Humerus		Radius	
	Wrist		Metacarpal	
	Soft tissue (Specify)			
Diagnosis	Fracture		Bursitis	
	Lateral epicondylitis		Sublaxation	
	Medial epicondylitis		Dislocations	
	Rotator cuff			
	Ligament			
Surgery	No		Yes	
		THORACIC AND LUMBAR SPINE .		
Anatomical Site:	Thoracic spine		Lumbar spine	
	Sternum		Abdominals	
	Other (Specify)			
Diagnosis	Spondylosis		Spondylolysis	
	Stress fracture		Facet joint	
	Nerve			
	Muscle strain/tear			
	Other (Specify)			
Surgery	No		Yes	
		LOWER LIMB		
Anatomical site	Hip joint		Groin	
	Quadriceps		Hip adductors	
	Patella		Tibia	
	Calf		Ankle	
	Metatarsals		Tarsal	
	Soft tissue (Specify)			
Diagnosis	Nerve			
	Muscle strain/tear			
	Ligament			
Surgery	No		Yes	

Training	Pre-season program		Static stretching	
	Hand eye coordination		Balance	
	Agility		Reaction time	
	How many days a week do you practise?			

This questionnaire was adapted from the one u

ACE			
Cranium		Temple	
Eye brow		Cervical vertebrae	
Lips			
Laceration			
Other (Specify)			
Specify			
Elbow joint		Acromioclavicular joint	
GH joint		Ulna	
Phalanges			
Other (Specify)			
Impingement			
Nerve			
Tendon			
Muscle strain/tear			
Other (Specify)			
Specify			
& TRUNK			
Sacro-iliac joint		Ribs	
Soft tissue (Specify)			
Spondylolisthesis		Disc lesion	
Pedicle sclerosis			
Tendon			
Ligament			
Specify			
Femur		Hamstring	
Hip abductors		Knee	
Fibula		Achilles tendon	
Heel		Talus	
Phalanges			
Other (Specify)			
Tendon			
Meniscus			
Other (Specify)			
Specify			
Dynamic stretching		Core stability	
Aerobic endurance		Anaerobic endurance	
Gym (Personal)		Gym (Coach / PT / Bio)	
How long is each session?			

sed by Dr R. Stretch