

**THE EFFECT OF A PREVENTION PROGRAMME ON THE
RUGBY INJURIES OF 15- AND 16-YEAR OLD SCHOOLBOYS**

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First available photo of a PUK (North-West University) rugby team, 1911.

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Abstract

The effect of a prevention programme on the rugby injuries of 15- and 16-year old schoolboys

Background: The negative side of rugby participation is the danger it presents to health in the form of injuries. Most school coaches, advocates of talent development and selectors put a high priority on implementing programmes to develop bigger, stronger, faster and more skillful rugby players who can excel at their sport. These programmes however, do not place enough emphasis on the prevention of injuries.

Aims: The primary aim of the study was to determine the effect of an approved injury prevention programme on the incidence (injuries per 1000 player hours) of rugby injuries (overall, intrinsic and extrinsic injuries) of 15- and 16 year-old schoolboys, over a two-year period. A further aim was to measure the effect of an approved injury prevention programme on the selected anthropometric, physical and motor and biomechanical and postural variables of all the groups involved in this study over a period of two years. Originating from these aims, a sub-aim of this study was to use information from this study to provide modifications – if necessary – to the current prevention programme in order for it to be effectively applied at high-school rugby level.

Design: A non-equivalent experimental-control group design with multiple post-tests was used for the investigation.

Subjects: The subjects were 120 schoolboy rugby players. The subjects came from two secondary schools in the North West province of South Africa. Both schools were schools with a tradition of excellence in rugby. Players who participated in the experimental injury prevention programme were the year 2004, 15- and 16-year old elite A teams. The B teams acted as controls.

Method: Players were tested over a two-year period. During each of the two years there were three testing occasions where all players were tested: pre-season, during the mid-season break and at the end of the season. The results of these tests were used to monitor changes in anthropometric, physical and motor and biomechanical and postural variables in various stages of the training programme. At the end of every evaluation, deficits were identified in the performance of all players in the experimental group and the prevention programmes were planned accordingly. Players in the experimental group received exercises to address the specific deficits identified.

Rugby injuries were screened and injury data collected through the use of weekly sports-medical clinics.

Results: Differences and changes in *extrinsic injury incidences* in this study could not be attributed to the effect of the prevention programme, and as a result injury trends related to *overall injury incidences* were inconsistent when the experimental groups were compared to the matching control groups. However, the prevention programme did have a positive effect on the *intrinsic injury incidence* of both experimental groups during the study period.

The following moderate or highly practically significant *anthropometric* changes occurred when inter-group comparisons for the two year period were considered: triceps skinfold ($d=0.8$ among 16-year olds), subscapular skinfold ($d=0.5$ among 16-year olds), midaxillary skinfold ($d=1.3$ among 15-year olds), calf skinfold ($d=1.3$ among 16-year olds), humerus breadth ($d=1.4$ among 15-year olds), femur breadth ($d=0.5$ among 15-year olds), fat percentage ($d=0.5$ among 16-year olds) and mesomorphy ($d=1.3$ among 15-year olds). However, these anthropometric changes may be due to other factors, such as the natural growth phase of boys, rather than the effect of the prevention programme.

During the inter-group comparisons of *physical and motor* components, moderately or highly practically significant improvements were recorded in the vertical jump ($d=0.8$ for 15-year olds and $d=1.5$ for 16-year olds), bleep ($d=0.7$ for 16-year olds), pull-ups ($d=0.6$ for 15-year olds) and push-up tests ($d=1.5$ for 15-year olds and $d=1.1$ for 16-year-olds) of the

experimental groups considering the total two year period. From the results it was clear that in practice, the prevention programme significantly improved only four of the 11 physical and motor components over the two-year period and that these improvements often occurred in only one of the age groups involved.

The inter-group comparison of *biomechanical and postural* variables revealed numerous moderately and highly practically significant improvements in both age groups, over the total two-year period. All in all the prevention programme provided the experimental groups with a more balanced (closer to ideal) dynamic mobility, core stability and postural symmetry.

Conclusion: It could be concluded that the present prevention programme did not have a practically significant effect on the incidence of *overall rugby injuries* and *extrinsic rugby injuries* of 15- and 16-year old schoolboys over a two-year period. However, in practice, the prevention programme did have a significantly positive effect on the incidence of *intrinsic rugby injuries* of 15- and 16-year old schoolboys over a period of two years. It could be concluded that the prevention programme did not have a practically significant effect on the *anthropometric components* of 15- and 16-year old schoolboys over a two-year period. Seeing that the prevention programme had a moderately or highly practically significantly effect on only four of 11 physical-and-motor components over the two-year period, and that these improvements often occurred in only one of the age groups involved, it could be concluded that the prevention programme did not significantly affect *the physical and motor variables* of 15- and 16-year old schoolboys over a two-year period. Finally the conclusion could be drawn that in practice the prevention programme significantly improved the *biomechanical and postural variables* over a period of two years. This improvement in biomechanical and postural status may be responsible for the decrease in intrinsic injury incidence. Information from this study was used to provide modifications to the tested prevention programme in order for it to be effectively applied at high school rugby level.

Key words: 15- and 16-year old, anthropometric, biomechanics, injury, overuse, physical and motor, posture, prevention programme, rugby, schoolboy

Opsomming

Die effek van 'n voorkomingsprogram op die rugbybeserings van 15- en 16-jarige skoolseuns

Agtergrond: Die negatiewe sy van deelname aan rugby is die gevaar wat rugbybeserings vir gesondheid inhou. Die meeste afrigters by skole, voorstanders van talentontwikkeling en keurders plaas hoë prioriteit op die implementering van programme om groter, sterker, vinniger en vaardiger rugbyspelers te ontwikkel wat kan uitblink in genoemde sportsoort. Hierdie programme plaas egter nie genoeg klem op die voorkoming van beserings nie.

Doelwitte: Die primêre doelwit van die studie was om die effek van 'n goedgekeurde beseringvoorkomingsprogram op die insidensie (beserings per 1 000 spelerure) van rugbybeserings (totale, intrinsieke en ekstrinsieke beserings) by 15- en 16-jarige skoolseuns te ondersoek oor 'n tydperk van twee jaar. 'n Verdere doelwit was om die effek van 'n goedgekeurde beseringvoorkomingsprogram op geselekteerde antropometriese, fisiek-motoriese en biomeganiese en posturale veranderlikes te meet, by al die betrokke groepe oor 'n tydperk van twee jaar. Voortspruitend uit hierdie doelwitte was 'n sub-doel om die inligting van die studie te gebruik om wysigings aan die beseringvoorkomingsprogram aan te bring – indien nodig – sodat die program effektief op hoërskoolrugbyvlak toegepas kan word.

Ontwerp: 'n Nie-ekwivalente, eksperimentele kontrolegroepontwerp met veelvoudige na-toetse is gebruik vir die ondersoek.

Ondersoekpopulasie: Die proefpersone was 120 hoërskoolrugbyspelers. Die seuns is afkomstig vanaf twee sekondêre skole in die Noordwes-Provinsie. Beide skole is skole met 'n tradisie van uitmuntendheid in rugby. Rugbyspelers wat aan die eksperimentele beseringvoorkomingsprogram onderwerp was, was in die jaar 2004, onderskeidelik, in 15- en 16-jarige, elite A-spanne. Die B-spanne het gedien as kontrolegroep.

Metode: Toetsing het plaasgevind oor 'n tydperk van twee jaar. Alle spelers is drie maal getoets tydens elk van die twee jaar: gedurende die voorseisoen, mid-seisoen en einde van die seisoen. Die resultate van hierdie toetse is gebruik om veranderings in die spelers se antropometriese, fisiek-motoriese en biomeganiese en posturale komponente te monitor, gedurende verskeie stadiums van die oefenprogram. Na elke evaluering is tekortkominge in die prestasie van al die spelers in die eksperimentele groepe geïdentifiseer, sodat aanpassings aan die beseringvoorkomingsprogram daarvolgens beplan kon word. Die spelers in die eksperimentele groep het oefeninge ontvang om die geïdentifiseerde tekortkominge aan te spreek.

Data aangaande rugbybeserings is ingesamel gedurende die ondersoek van spelers se beserings, deur gebruik te maak van weeklikse sportmediese klinieke.

Resultate: Tydens intergroepvergeliking tussen die ooreenstemmende eksperimentele en kontrolegroepe in hierdie studie kon die verskille en veranderinge sigbaar in die insidensie van *ekstrinsieke beserings* nie toegeskryf word aan die effek van die voorkomingsprogram nie en gevolglik was beseringstendense met betrekking tot die insidensie van *totale beserings* inkonsekwent. Gedurende die duur van die studie het die beseringvoorkomingsprogram egter wel 'n positiewe effek op die insidensie van *intrinsieke beserings* onder beide eksperimentele groepe gehad.

Tydens intergroepvergelikings met betrekking tot die twee jaar periode het die volgende matig en hoogs prakties betekenisvolle *antropometriese* veranderinge voorgekom: trisepsvelvou ($d=0.8$ by 16-jariges), subskapulêre velvou ($d=0.5$ by 16-jariges), mid-aksillêre velvou ($d=1.3$ by 15-jariges), kuitvelvou ($d=1.3$ by 16-jariges), humerusbreedte ($d=1.4$ by 15-jariges), femurbreedte ($d=0.5$ by 15-jariges), vetpersentasie ($d=0.5$ by 16-jariges) en mesomorfie ($d=1.3$ by 15-jariges). Hierdie antropometriese veranderinge het egter waarskynlik as gevolg van ander faktore plaasgevind – soos die natuurlike groeifase van seuns – eerder as gevolg van die effek van die beseringvoorkomingsprogram.

Die volgende matig en hoogs prakties betekenisvolle verbetering is bereken tydens die intergroepvergelyking van *fisiek-motoriese* komponente met betrekking tot die twee jaar periode: vertikale sprong ($d=0.8$ by 15-jariges en $d=1.5$ by 16-jariges), bleep ($d=0.7$ by 16-jariges), optreкке ($d=0.6$ by 15-jariges) en opstote ($d=1.5$ by 15-jariges en $d=1.1$ by 16-jariges). Uit hierdie resultate is dit duidelik dat die beseringvoorkomingsprogram slegs vier van die 11 fisiek-motoriese komponente prakties betekenisvol verbeter het oor 'n tydperk van twee jaar en dat hierdie verbetering dikwels net by een van die twee betrokke ouderdomsgroepe voorgekom het.

Verskeie matig en hoogs prakties betekenisvolle intergroepverskille het voorgekom in albei ouderdomsgroepe tydens die vergelyking van *biomeganiese en posturale* veranderlikes met betrekking tot die totale twee jaar lange periode. In geheel het die beseringvoorkomingsprogram gelei tot 'n meer gebalanseerde (nader aan ideaal) dinamiese mobiliteit, kernstabiliteit en posturale simmetrie onder die eksperimentele groepe.

Gevolgtrekking: Die gevolgtrekking word dus gemaak dat die huidige beseringvoorkomingsprogram, oor 'n tydperk van twee jaar, nie 'n prakties betekenisvolle effek gehad het op die insidensie van *totale rugbybeserings* en *ekstrinsieke rugbybeserings* onder 15- en 16-jarige skoolseuns nie. In die praktyk het die beseringvoorkomingsprogram egter wel 'n betekenisvol positiewe effek op die insidensie van *intrinsieke rugbybeserings* onder 15- en 16-jarige skoolseuns oor 'n tydperk van twee jaar tot gevolg gehad.

Die gevolgtrekking kan gemaak word dat die beseringvoorkomingsprogram nie 'n prakties betekenisvolle effek op die antropometriese komponente van 15- en 16-jarige skoolseuns tot gevolg gehad het nie, die twee jaar in ag genome. Siende dat die voorkomingsprogram slegs vier van die 11 *fisiek-motoriese* komponente matig of hoogs prakties betekenisvol geaffekteer het oor 'n tydperk van twee jaar, asook dat hierdie verbeterings dikwels in slegs een van die twee betrokke ouderdomsgroepe voorgekom het, kan die gevolgtrekking gemaak word dat die voorkomingsprogram nie 'n prakties betekenisvolle effek gehad het op die fisiek-motoriese komponente van die betrokke 15- en 16-jarige skoolseuns oor 'n periode van twee jaar nie. Laastens is daar tot die gevolgtrekking gekom dat die effek van die

voorkomingsprogram gelei het tot 'n prakties betekenisvolle verbetering in die *biomeganiese en posturale* veranderlikes, oor 'n tydperk van twee jaar. Laasgenoemde verbetering in biomeganiese en posturale status is moontlik verantwoordelik vir die verbetering sigbaar in die insidensie van intrinsieke beserings. Inligting voortspruitend uit die studie is gebruik om die getoetste voorkomingsprogram te wysig, sodat die program effektief op hoëskoolrugbyvlak toegepas kan word.

Sleutelwoorde: 15- en 16-jaar oud, antropometries, besering, biomeganika, fisiek en motories, oorgebruik, postuur, rugby, skoolseun, voorkoming

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List of abbreviations

ACC	Accident Compensation Cooperation
ACSM	American College of Sports Medicine
ANOVA	Analysis of variance
ASEP	American Sports Education Program
ASIS	Anterior superior iliac spine
BF	Body fat
BMPE	Biomechanical and postural evaluation
CHIRPP	Canadian Hospitals Injury Reporting and Prevention Program
Db	Body density
HWR	Height weight ratio
IRB	International Rugby Board
ISAK	International Society for the Advancement of Kinanthropometry
ITB	Iliotibial band
L	Left
L3,4	Third, fourth lumbar vertebrae
MSE	Mean square error
NAIRS	National Athletic Injury Registration System
NCAA	National Collegiate Athletic Association
NZ\$	New Zealand Dollar
NWU	North-West University
NZRFU	New Zealand Rugby Football Union
PSIS	Posterior superior iliac spine
Q-angle	Quadriceps angle
R	Right
RIPP	Rugby Injury and Performance Project of New Zealand
rm	repetition maximum
ROM	Range of movement/Range of motion
SARFU	South African Rugby Football Union
SD	Standard Deviation
SIJ	Sacroiliac joint
SISA	Sport Information and Science Agency
SKF	Skinfold
TA	Achilles tendon
TLF	Thoraco-lumbar fascia
T1	Year 2004 pre-season physical assessment
T2	Year 2004 mid-season physical assessment
T3	Year 2004 end-of-season physical assessment
T4	Year 2005 pre-season physical assessment
T5	Year 2005 mid-season physical assessment
T6	Year 2005 end-of-season physical assessment
T9	9 th thoracic vertebra
SLR	Straight leg raise
VMO	Vastus medialis obliquus

VMO-L Vastus mediales obliquus-lateralis
VO₂ oxygen consumption
VO_{2max} maximal oxygen uptake

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PROBLEM STATEMENT AND RESEARCH AIMS OF THE STUDY

- 1.1 Introduction
 - 1.2 Problem statement
 - 1.3 Research aims
 - 1.4 Hypotheses
 - 1.5 Research method
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-

1.1 INTRODUCTION

Sport is an important force throughout the modern world. Sports programmes, sports studies, dedicated sports channels, sports pages, sports supplements in newspapers and specialist sports magazines have become increasingly prominent (Weinberg & Gold, 1999; Horne *et al.*, 2000). The promotion of sports programmes during the last three decades has had a significant impact on sports participation (Horne *et al.*, 2000). Common benefits from participation in sport are improved physical and mental health, improved fitness, increased pleasure and relaxation (Neely, 1998; Vanden Auweele *et al.*, 1999; ACSM, 2000). Because of all this, most children participate in organised sports from an early age (Micheli, 1983; Armstrong & Welsman, 1997; Caine & Maffulli, 2005). Among children, the popularity of sport increases from as early as 9 years (Malina & Bouchard, 1991).

Sports players nowadays become professionally involved in sport at a younger age than a few years ago (Baker, 2001). It is clear that to excel in sport the young athlete of today is forced to train longer, more intensively and earlier in life. In the past, "overuse" injuries were the curse of the adult athlete and were not seen to any noticeable degree in the child (Micheli, 1983). However, hours of practising the same movements cause gradual wear and tear on

specific parts of the body and can cause an overuse injury (Harvey, 1983). This, combined with the immaturity of their musculoskeletal systems, may actually cause the young athletes of today to be at a higher risk of these overuse injuries (Price *et al.*, 2004). In addition to these overuse injuries, today's young athlete also runs an increased risk of sustaining trauma injuries, should he/she decide to participate in a contact sport. This may be the reason why large numbers of youths worldwide have been moving away from contact sports to less physical and less dangerous sports (Wilson, 2000). In countries such as South Africa, New Zealand and Wales, this presents a problem as contact sports like rugby¹ enjoy some of the highest participation levels and priority (Quarrie *et al.*, 1995; SISA, 1995; Nicholas, 1997).

It is apparent that, as well as improving physical and mental health, sport can also present a danger to health in the form of accidents and injuries (Van Mechelen *et al.*, 1992). This negative side of sports participation is especially true for contact sports, which are plagued by a high injury incidence (Gabbett, 2004). Data on injury rates across the spectrum of health indicate that injuries have an important impact on both morbidity and mortality (Jones & Knapik, 1999). The cost of absenteeism and medical care of sports injuries is considerable (Lysens *et al.*, 1991). Unwanted socio-economic consequences of sports injuries are loss of function, cessation or reduction in training, medical costs of treatment, absence from school/work and a loss in productivity (Sandelin *et al.*, 1987; Guyer & Ellers, 1990; Neely, 1998; Van Mechelen *et al.*, 1992). These apparently inevitable "side-effects" are undesirable for the sports participant, as well as for the employers, education and society as a whole (Lysens *et al.*, 1991).

All sports, however, have an inherent risk of injury (Armsey & Hosey, 2004). But which sport is the most dangerous? Estimates from several studies (Dixon, 1993; Fuller & Drawer, 2004) are that rugby often has the highest injury incidence and overall costs when compared to other sports codes. In previous years, concerns about increases in rugby injury incidence, the costs of rugby injuries and the long-term effects of these injuries have surfaced in all the major rugby-playing countries (Taylor & Coolican, 1987; Dixon, 1993; Noakes & Du

¹ When the word rugby is mentioned in this study, Rugby Union is implied (unless otherwise stipulated).

Plessis, 1996). Subsequently, it is no coincidence that many people believed that rugby had become too dangerous for their children (Noakes & Du Plessis, 1996). There are even those who believe that the game should be banned (Noakes & Du Plessis, 1996). In 2003, the team doctor of the South African national rugby team, Uli Schmidt, also expressed these beliefs by commenting that "Rugby is breaking our young men. It would be criminal of me to advise parents to allow their sons to play rugby." His reason for this comment was that "the game has changed too much" (De Bruin, 2003:3).

1.2 PROBLEM STATEMENT

Rugby is considered one of the largest sports in the world (Rigg & Reilly, 1988; Hughes & Fricker, 1994). Competitions like the World Cup, Super 12, Six Nations and Tri Nations have sparked unprecedented media coverage of the sport (Coetzee, 1999). In South Africa, rugby is regarded by many as the "national sport" (Burke; 1998; Holtzhausen, 2001). At the beginning of the new millennium, rugby in all countries is being confronted by several important challenges, the biggest being professionalism (Botha & Neethling, 1999). Injuries may make a difference amounting to a considerable amount of money to in the case of the professional rugby player and coach (Botha & Neethling, 1999; Garraway *et al.*, 2000).

Unfortunately the incidence rate of rugby injuries is still increasing (Targett, 1998; Garraway *et al.*, 2000; Holtzhausen, 2001). Etiologic factors related to rugby injuries can be roughly divided into two.

The *first etiologic factor* is the development of revolutionary, scientific training methods in the second half of the twentieth century (Botha & Neethling, 1999). Nowadays players are subjected to long seasons and spend more time improving fitness, strength and speed through very specific and advanced training programmes (Wilson, 2000; Holtzhausen, 2001; Hattingh, 2003). A rise in intrinsic (or overuse) injuries is the result of this increased training load (Noakes & Du Plessis, 1996). Chronic overuse injuries previously seen mainly among runners are now becoming more common among rugby players (Hattingh, 2003). Holtzhausen (2001:88) recorded that 80% of the chronic overuse injuries among professional rugby union players in South Africa were of severe nature.

The *second etiologic factor* related to rugby injuries is the way the game itself has changed. Increases in the number of tackles, rucks per player and average weight per player are all developments characteristic of the modern-day game (Wilson, 2000; Quarie *et al.*, 2001). In conjunction with the above, the nature of the game has changed from a contact sport to a collision sport where the body has to absorb more impact (Wilson, 2000; Holtzhausen, 2001). The main result of these modern-day changes to the game itself is an increase in the number of extrinsic (external to the player) or trauma injuries.

The tendency of an unacceptable rise in injury epidemiology (both intrinsic and extrinsic injuries) among senior rugby players is also visible at South African school level (Roux, 1992; Lee & Garraway, 1996; Jakoet, 2002). Early research has already reported rugby to be the most dangerous sport in which South African (Roux, 1992), English (Briscoe, 1985) and Australian (Taylor & Coolican, 1987) schoolboys participate.

Like their senior counterparts, schoolboy rugby players today are forced to train harder and spend more time practising and playing rugby. As early as 1988, Maffuli and Helms (1988:1405) agreed that because of increased pressure to deliver world class sports performances, children would have to start intensive exercise programmes before the age of 16 years.

In South Africa a national rugby week for 16-year old schoolboys has recently been added to the existing week for 18-year old schoolboys (SARFU, 2003). Furthermore, today many South African school teams face stiff pre-season games in the new Super-16 competition for secondary schools. Consequently schoolboys now experience more pressure to be competitive. The pressure to perform has reached a level where talented boys are increasingly being offered large bursaries to play for prestigious schools. This, together with teams sponsored by major companies, are part of a multi-million rand school rugby industry (KaMathanda, 2002). Additionally, players with potential are sometimes contracted even before they leave school (Burke, 1998). Cumulatively, the additional training and playing time, as well as pressure to perform at school level, will certainly contribute to a rise in injury epidemiology (Silver, 1978; Kersey & Rowan, 1983; Strydom, 1992).

In light of the above, it is important to determine which schoolboy rugby players are most at risk of injury. Research has shown that the majority of sports injuries among boys are sustained during as well as shortly after their growth spurt (Caine *et al.*, 1989; Stanitski, 1989). This most aggressive growth period of most boys begins around the age of 11 or 12 years, and only ends around 15 or 16 years of age (Malina & Bouchard, 1991; Gallahue & Ozmun, 1995). Thus, it makes sense that schoolboy rugby players could be at an increased risk of injury during and shortly after this age. This is consistent with research that suggests those boys who have the highest risk of injury are the 15- to 19-year old A-team rugby players (CHIRPP, 1995; Noakes & Du Plessis, 1996).

Additionally, these schoolboys are most vulnerable to injuries early in the season, and again after the mid-season recess (Sparks, 1981; Williams, 1984; Noakes & Du Plessis, 1996). The most probable explanation is that players are not game fit at the beginning of the season and lose some of their fitness during the mid-season break (Noakes & Du Plessis, 1996). There is also a tendency for senior players to be at increased risk of injury during the second half of play (Roy, 1974; Davies & Gibson, 1978). According to Noakes and Du Plessis (1996:111) this can also be attributed to inadequate fitness. Yet most South African schools, even those with a proud rugby tradition, do not maintain adequate pre-season fitness programmes (Upton *et al.*, 1996). Consequently, the injury epidemiology at senior-school level may continue to rise unless preventative measures – sufficient for the modern game – are employed.

The question has already been asked if the elite senior school player has the anthropometric composition, physical and motor abilities, as well as sport-specific skills demanded by the modern game (Hare, 1997; Hanekom, 2000; Plotz, 2004). Most school coaches, advocates of talent development and selectors put a high priority on the above abilities and implement programmes to develop bigger, stronger, faster and more skillful players who can excel at their sport (Quarrie *et al.*, 1996; Hare, 1999; Hanekom, 2000). However, these programmes do not place enough emphasis on the prevention of injuries (Nathan *et al.*, 1983; Lee & Garraway, 1996; Quarrie *et al.*, 1996; Upton *et al.*, 1996). Therefore the question that arises is how to prevent injuries among schoolboys at high risk.

Previous injury prevention studies have shown that athletes often become injured as they become stronger, but develop poor biomechanics (joint symmetry, dynamic muscle mobility and core stability) and posture in the process. These phenomena render the athlete prone to the overuse type of injury (Brukner & Khan, 2001; Sahrmann, 2002; Bell-Jenje & Bourne, 2003; Hattingh, 2003). Alarming, recent research by Hattingh (2003:185) revealed major shortcomings in elite senior school rugby players in certain of these biomechanical and postural areas. Recent research clearly confirms that injury prevention strategies should include the detection and correction of these biomechanical and postural deficiencies in order to eliminate postural defects, instability of joints and altered patterns of movement (Schwellnus & Derman, 2001a; Schwellnus & Derman, 2001b; Watson, 2001).

A further requirement of any prophylactic injury strategy is the screening of athletes for an existing injury (secondary prevention) and for underlying injury risk factors in order to prevent new injuries (primary prevention) (Schwellnus & Derman, 2001a). Also, to reduce rugby injuries, particularly those that are sustained early on in a season, or after a mid-season break, players need to undergo adequate physical conditioning (Derman & Schwellnus, 1996).

It is clear that a total injury prevention programme needs to address several risk factors such as incorrect training, faulty biomechanics, rehabilitation after a previous injury, and fatigue. The New Zealand Rugby Union has managed to reduce their injury rate by approximately 47% through the implementation of a similar total prevention programme, the so-called ACC (Accident Compensation Cooperation) Sport Smart 2000 programme. This programme paid attention to some of the above risk factors for injury. In their longitudinal study, 10 pointers were addressed and researched (Quarrie *et al.*, 2001):

- (i) Screening
- (ii) Warm-up/cool-down
- (iii) Physical condition
- (iv) Technique
- (v) Fair play
- (vi) Protective equipment
- (vii) Hydration and nutrition

- (viii) Injury surveillance
- (ix) Environmental factors
- (x) Injury management

This New Zealand example shows that the possibility of injury can be reduced. Most professional rugby union sides have already implemented prophylactic sports medicine programmes to curb injuries.

In contrast to senior players, prevention of injury is not a high priority among high school players and coaches (Upton *et al.*, 1996). To date, the author is unaware of other studies that have evaluated the effectiveness of an injury prevention programme in decreasing the number of high school rugby injuries.

Consequently, the questions of interest are, firstly, whether an approved injury prevention programme has an effect on the rugby injuries (overall, intrinsic and extrinsic injuries) of 15- and 16-year old schoolboys. The second question is what the effect of an approved injury prevention programme is on selected anthropometric, physical and motor, and biomechanical and postural (symmetry, dynamic mobility and positional core stability) variables. Answers to these questions will provide guidance to players, teachers/coaches, medical teams and management on how to prevent, reduce and manage injuries. Once the effect of this programme has been analysed, other programmes addressing injuries can be modified, if necessary. Furthermore, data will be added to the collective data bank of schoolboy rugby injuries, specific norms and characteristics of various schoolboy player groups, and their risk of injury.

1.3 RESEARCH AIMS

1. The primary aim of this research is to determine the effect of an approved injury prevention programme on the incidence of rugby injuries (overall (a), intrinsic (b) and extrinsic injuries (c)) of 15- and 16-year old schoolboys over a two-year period.
2. A secondary aim is to measure the effect an approved injury prevention programme has on the selected anthropometric (a), physical and motor (b), and biomechanical and postural variables (c) of all the groups involved in this study over a period of two years.

Originating from these aims, a sub-aim of this study is to use information from this study to provide modifications, if necessary, to the current prevention programme in order for it to be effectively applied at high school rugby level.

1.4 HYPOTHESES

1. An approved injury prevention programme has a significant effect on the incidence of rugby injuries (overall (a), intrinsic (b) and extrinsic injuries (c)) of 15- and 16-year old schoolboys, over a two-year period.
2. An approved rugby injury prevention programme has a significant effect on the selected anthropometric (a), physical and motor (b), and biomechanical and postural variables (c) of all the groups involved in this study, over a period of two years.

1.5 RESEARCH METHOD

1.5.1 LITERATURE REVIEW

In order to find relevant literature, the following electronic media, as well as sports and sports medicine journals, were searched:

- Eric (Psychological database)
- EBSCOHost (Academic Search Elite)
- Medline
- Nexus database
- Pubmed
- ScienceDirect
- Sport discus
- SA Journals
- Thesis and dissertations
- Web of Science

The chief medical officers of Wales, England, Scotland, Ireland, France, New Zealand, Australia and South Africa, the eight major rugby-playing nations, were also contacted via e-mail for their input and assistance on the research topics.

1.5.2 EMPIRICAL INVESTIGATION

1.5.2.1 Research design

A non-equivalent experimental-control group design with multiple post-tests was used in this study. Injury information was gathered through the use of sports-medical clinics and questionnaires.

1.5.2.2 Choice of subjects

The subjects included in the study numbered 120, all schoolboy rugby players. To ensure that the teams selected were coached more or less uniformly, only schools that were involved with the Rugby Institute of the North-West University (NWU Rugby Institute, formerly known as PUK Rugby Institute) were eligible for inclusion in the study. This ensured that the teams involved in the study were coached according to the technical and fitness guidelines supplied by the NWU Rugby Institute. The subjects came from two secondary schools in the North West Province. Both schools were schools with a tradition of excellence in rugby. Players who participated in the experimental injury prevention programme were the year-2004, 15- and 16-year old elite A teams. The B teams acted as controls.

1.5.2.3 Procedures and methods of data collection

Once the various schools and parents had given their approval, the testing commenced. Players were evaluated over a two-year period. During each of the two years there were

three testing occasions where all players were tested: pre-season, during the mid-season break and at the end of the season.

On the day of testing, the players rotated between different testing stations. The testing sequence and rest periods between tests were developed in such a way that no previous test might influence subsequent tests.

Players were given general prevention programmes to address the specific deficits identified at each testing occasion. All players in the experimental group received prevention programmes in accordance with the periodisation guidelines described by Hattingh (2003:182-184). However, a *post-season transition phase* (Twist, 1997) (see Figure 4.2) was added to the periods described by Hattingh (2003:182-184).

For the prescription of specific exercises, this study chiefly used the exercises suggested by Hattingh (2003:210-276). However, in order to improve the effect of this programme, exercises were combined with a few protocols recommended in various other publications (Turnbull *et al.*, 1995; Noakes & Du Plessis, 1996; Twist, 1997; Hazeldine & McNab, 1999; Prentice, 1999; Arnheim & Prentice, 2000; Brown *et al.*, 2000; O'Sullivan, 2000; Brukner & Khan, 2001; Mottram & Comerford, 2001; Schweltnus & Derman, 2001b; Sahrman, 2002; Luger & Pook, 2004).

(a) *Sports-medical clinics*

Injuries were screened and injury data collected through the use of *free* sports-medical clinics. Clinics were held once a week, either on the Monday after a rugby match or during the rest of the week (usually Wednesdays). Each clinic was manned by a qualified sports physician (medical practitioner specialising in sports injuries) or physiotherapist, biokineticist (specialist in preventative and rehabilitative exercise) and sport scientist (fitness and conditioning specialist, if available). The functions of the clinics were to diagnose, refer (to player's doctor, physiotherapist, biokineticist or sport scientist) and manage all players who reported injured.

(b) *Questionnaires*

Before injured players were allowed to be screened, they had to complete a current and previous injury and rehabilitation information questionnaire (Annexure A.2) (Hattingh, 2003). During the sports-medical clinic, the injured player and medical staff completed a relevant injury report form for each injury (Annexure A.3). These forms were used to register all rugby injuries. All data were then analysed to determine (i) injury incidence, (ii) severity of injuries, (iii) type of injury, (iv) anatomical region affected, (v) sustained during match or training, and (vi) intrinsic or extrinsic injury.

1.5.2.4 Battery of tests

The tests and protocols that were used were chosen from the literature, and their usefulness had been proven in previous studies. Only tests that were suited to the specific age, gender and sport were used. These tests can be divided into three main groups: an anthropometric, a physical and motor, and a biomechanical and postural group.

(a) *Anthropometric components*

To calculate anthropometric body composition, the protocol prescribed by the International Society for the Advancement of Kinanthropometry (ISAK), was used in this study (Norton *et al.*, 1996). For the anthropometric measurements, four standardized variables were used: body fat percentage (Forsyth & Sinning, 1973) by using the 4 skinfolds recommended for 14-19 year old male athletes (subscapular skinfold, abdominal skinfold, triceps skinfold, midaxillary skinfold), stature (Norton *et al.*, 1996) by using a stadiometer, body mass (Norton *et al.*, 1996) by using a calibrated electronic mass meter and somatotype (endomorph, mesomorph, ectomorph) by using the Heath-Carter anthropometric method for adolescents (Carter & Heath, 1990).

(b) *Physical and motor components*

For physical and motor evaluation, ten tests were used. The ten tests were: the 10 and 30 metres dash for *speed* (Hazeldine & McNab, 1998), the Illinois *agility* run (Kirby, 1991), vertical jump (Kirby, 1991) for *explosive power*, the bleep test (Brewer *et al.*, 1988) for *cardiovascular fitness*, a standardised test for *speed endurance* (Hazeldine & McNab, 1999), maximum push-ups in 1 minute (Turnbull, *et al.*, 1995), as well as the maximum pull-ups

(Turnbull, *et al.*, 1995) for local *muscle endurance*, and for *strength*, seven-stage abdominal strength (Ellis *et al.*, 1998) and grip strength (Kirby, 1991).

(c) *Biomechanical and postural components*

The third protocol can be classified under the biomechanical and postural make-up of the players (Kapandji, 1974; Watson, 2001). For the biomechanical and postural test battery a recent approach that measures a combination of symmetry, dynamic mobility and local stability was used (Hatingh, 2003). This biomechanical and postural assessment protocol evaluated different zones, namely lower limb, pelvic girdle, spinal column, upper limb and neurodynamics.

1.5.2.5 Statistical methods of data processing

Statistical software was used for the data analysis. Data was processed with the Statistica-7 program (StatSoft Inc., 2005). Descriptive statistics, repeated measures ANOVA and effect sizes (practical significance) were used (Thomas & Nelson, 2001; Ellis & Steyn, 2003).

1.6 STRUCTURE OF THESIS

This thesis consists of six chapters. **Chapter 1** contains the research problem and aims of this study. **Chapter 2** reviews modern developments in the game of rugby, with specific reference to talent identification, anthropometric characteristics, physical and motor abilities, and biomechanics. **Chapter 3** describes the extent of the rugby injury problem, the factors and mechanisms that cause sport injuries and how (possibly) to reduce their future risk and/or severity. In **chapter 4** the method of investigation is presented. **Chapter 5** deals with the results and their discussion. Finally, in **chapter 6** the summary, conclusions and recommendations on how to investigate and prevent future rugby injuries are given.

2

REVIEW OF LITERATURE

HISTORICAL ROOTS AND MODERN DEVELOPMENTS IN RUGBY

- 2.1 Introduction
 - 2.2 The game of rugby
 - 2.3 Modern developments in rugby with reference to talent identification, anthropometric characteristics, physical and motor abilities and biomechanics
 - 2.4 Conclusion
-

2.1 INTRODUCTION

The aim of this study is to investigate the effectiveness of an injury prevention programme. Before injury prevention can be discussed, it is important to address certain aspects regarding the evolution of rugby, with the emphasis on changes in the game that are important to the modern player. Consequently, the *main objective of this chapter* is to show that the game as we know it today differs from the first rugby games; and that these differences impact on the modern player, his performance requirements and often his injury incidence.

The *first* part of this chapter gives an overview of how the game of rugby has progressed historically. The *second* part of this chapter investigates the modern requirements of the game, with specific reference to talent identification, anthropometric characteristics, physical and motor abilities, and biomechanical and postural make up. Only after this has been

concluded can previous research on rugby injuries and their prevention be reviewed and shortcomings pointed out (discussed in Chapter 3).

2.2 THE GAME OF RUGBY

Over the centuries, the ancient forms of rugby evolved into the modern game of today. As the nature of the ancient society changed, so did the sports which formed part of that society (Home *et al.*, 2000).

The history of rugby can be divided into distinct phases: the folk game (Van der Merwe, 1999a); the formalisation of the athleticist-amateurist football codes in the English public schools (Noakes & Du Plessis, 1996; Home *et al.*, 2000); the split between association football and rugby football (Baker, 1988). the inter-war and post-war years of the 20th century (Baker, 1988; Van der Merwe, 1995); and then later within rugby itself – the years of further commercialisation of the game in the late 1900s (Home *et al.*, 2000); the emergence of the professional game in 1995 (Hattingh, 2003); and the more recent phases of further specialisation, sponsorship and media influences upon the game (Noakes & Du Plessis, 1996; Home *et al.*, 2000).

Many people believe that rugby originated from soccer. According to them it was William Web Ellis who in 1823 picked up the ball during a soccer game and started running with it (Van der Merwe, 1999a). In truth, this is a supposition that can be rejected (Van der Merwe, 1999a). Other games – more closely related to rugby – where the ball was also picked up, kicked and carried, were played long before soccer (Armitage, 1977). For example, long before the time of Web Ellis, the ancient Greeks and Romans played a variety of ball games involving tackling, throwing and catching. Nowhere has proof been found of a purely kicking game among the Greeks and Romans (Van der Merwe, 1999a).

Rather, it is believed that rugby originated from the ancient games of *folk football*, which were already played as early as the late 13th and early 14th century (Baker, 1988; Van der Merwe, 1999a). In some of these games it appeared that the ball was carried and passed

from one player to another before being carried between the goal-posts, again suggesting that the origins of rugby should be sought much further than is commonly assumed (Armitage, 1977). Examples of these were knappan in Wales, hurling in Cornwall and camp-ball in East Anglia (Van der Merwe, 1999a). This game of folk football served as the common ancestor from which rugby, soccer and even hockey developed (Van der Merwe, 1999a).

The earliest forms of these games were rough forms of football, played between the residents of neighbouring villages (Armitage, 1977). The players (villagers) met each other about halfway between villages. The aim of the “game” was to feed the ball – or a similar object – through the opposing town chief’s door frame (goal posts) (Noakes & Du Plessis, 1996). The character of this game was linked to tradition, and varied from region to region, with minor differences between them. One variety of folk football (camp-ball), dating as far back as the 15th century, featured elements that still make modern rugby attractive, such as chasing, battling against each other, line-outs, scrums, mauls, tackles and passes (Van der Merwe, 1999a; Armitage, 1977). The general properties of these early folk games were informal organisation, low role differentiation (division of labour) among players, unwritten rules, fluctuating game patterns, no fixed limits on territory, duration or number of participants, with the emphasis on physical force as opposed to skill (Horne *et al.*, 2000).

During these games there were little if any rules regulating equipment, number of players and even way of transport (Noakes & Du Plessis, 1996). Some players “played” on horseback, while others carried swords, clubs and sticks. Violence and murder were the order of the day during these games. Ambushes and drowning were common, because players used these to settle mutual hostilities and feuds (see chapter 3, paragraph 3.2 for more on injuries).

It is clear that the games during ancient times were played with the emphasis on physical force. Although physical force was emphasised, games like camping still required a combined athletic excellence, as a successful combatant was required to be a good runner, wrestler and boxer (Armitage, 1977). Folk football was not conducive to the mores, values or aspirations of an expanding commercial and industrial culture, as it was usually

accompanied with rowdiness, tumult or worse (Horne *et al.*, 2000). Because of this, the game was banned more than 30 times in the space of three centuries.

A combined effort of monarchs, church officials and city administrators, for various practical reasons, sought to stamp out folk football and other peasant games (Baker, 1988). In the face of moral preachings and official decrees, English common folk refused to relinquish their games (Baker, 1988). The peasants at that time had few rights, but considered their right to play an integral part of their birthright (Baker, 1988). In the course of time, the human body started to become the object of scientific interest (Baker, 1988), while urbanisation led to a greater interest in organised sport (Armitage, 1977). As the medieval world gave way to the early modern age, the nature of the ancient games also changed.

With the growth of cities, the Industrial Revolution gave birth to mass leisure (Baker, 1988). For a time, gentlemen of leisure dominated football. This soon changed when increased leisure time, extra spending money and new public facilities made football accessible to thousands of common people. Soon team sports, like football, appealed to city spectators, repelled by the brutalities of the prize ring, and bored by the lack of variety offered by footraces, boat races, and horse races (Baker, 1988). The growth of the middle classes also meant an increased demand for public school education (Armitage, 1977). The demand meant that new schools were founded and old ones enlarged. Opposition to the sport was not new with the onset of the nineteenth century, so it was unsurprising that at exactly the same time that popular recreational football was opposed, different football codes were emerging in the public schools (Horne *et al.*, 2000).

These different public school football codes laid the foundation for a later struggle between public schools to standardise the game (football descended from folk football). This happened in the 19th century in English public schools like Rugby, Westminster, Eton, Marlborough, Winchester, Charterhouse and Cheltenham (Noakes & Du Plessis, 1996). Nourished in the prestigious English “public” (private) schools, the old game would eventually split into two distinct styles of play (Baker, 1988): *association football* (soccer) which featured kicking and controlling the ball with the feet, without the use of hands; and

rugby football (rugby) which entailed handling, kicking, tackling as well as running with the ball. This was a gradual process of codification which took place over many years and amidst many disagreements. This split into two distinct styles of play happened later on, when the game became “socialised” and restricted to the borders of a playing field (Noakes & Du Plessis, 1996; Van Der Merwe, 1999a).

Among the different schools, Rugby School was the first to allow “handling” of the ball (Noakes & Du Plessis, 1996; Van Der Merwe, 1999a). The original rule stated that a player who caught a ball cleanly from the air had to retreat a few metres before he was allowed to kick the ball. William Web Ellis (1823) was the first player – instead of retreating and kicking – to run forward after such a catch. Consequently, the ruling at Rugby School was changed to allow the player who caught the ball to run with it, as long as he did not pass it. Each school, physically isolated from the others, developed its own style and rules of play, usually in accordance with the grounds available (Noakes & Du Plessis, 1996; Van der Merwe, 1999a). In schools like Rugby – where the playing fields were bigger – the “*handling*” game (where the ball could be carried) was favoured, while Eton – because of smaller playing fields – favoured the “*dribbling*” game. In the beginning (before the codification), schools used the games to develop the physical side and masculinity of pupils and to control disagreement and aggression (Noakes & Du Plessis, 1996). Compared to folk football, the nature of the game still required players to be physically strong, as they mainly counted on brute strength for performance.

By 1840, Eton, Harrow and all the other public schools except Rugby played a football game roughly equivalent to the future soccer game (Baker, 1988). When the boys from different private schools met at university, the result was confusion, as every man played the rules he had been accustomed to at public school. A codification of the rules was necessary. In 1846 – at a meeting at Cambridge University – new rules were drawn up. These “Cambridge Rules” favoured the “kicking/dribbling” game played by the old Etonians (Baker, 1988; Noakes & Du Plessis, 1996). The Cambridge rules did not allow “tripping”, “hacking” (kicking an opponent on the lower leg when face-to-face) or running with the ball. According to the Cambridge rules, the hands could only be used for stopping the ball and

placing it in front of the feet, on the ground. However, while some clubs preferred this “kicking” game, “hacking” an opponent stayed so popular during this time that some of the clubs in London decided not to abandon with the “hacking” and running game (Baker, 1988). *Soccer* (association football) and *rugby* (resembling rugby union) would finally arise from these earlier patterns of play (Van der Merwe, 1999a).

Firstly, in 1863 the Football Association was born and the game was officially known as “association football.” The Football Association was later abbreviated to “*Assoc.*”, whence came the word “soccer” (Baker, 1988).

Although this game basically consisted of scrum play, it was more closely related to modern soccer (Van Der Merwe, 1999a). Running with the ball was only allowed if a player caught the ball in the air. If the player was caught, he was not allowed to pass, and another scrum was formed. Points were scored by dribbling the ball forward from the scrum, through the opponent’s goal posts. The cross bar would only come later; consequently the height of the kick at goal did not matter. These teams were very big, with as many as 300 players in a team (Noakes & Du Plessis, 1996). Many of these players were used to crowd the goals and therefore it was very difficult to score any points. During this time, at rugby’s expense, there was a growing disapproval of the “hacking” game, as well as a spurt of popular support for the “kicking” game (soccer). Without a central body for the making and monitoring of rules, rugby could be developed no further (Horne *et al.*, 2000). Finally, this led to the establishment of new rules as well as the rugby equivalent of the Football Association, called the Rugby Football Union (rugby union), on 26 January, 1871 (Horne *et al.*, 2000).

The constitution of the new Rugby Football Union allowed for scrumming and for running with and passing the ball (Noakes & Du Plessis, 1996). According to these rules, a player was allowed to pass the ball to one of his team mates, as long as it was open play, away from the scrum. The rules of 1871 also allowed for an extension of the goal area, to include the goal line as we know it today. The ball could be placed behind this line to score a *try at goal*, which meant an opportunity to kick at goal. In 1880, the backline consisted of a single player. By the year 1883, the backline expanded to seven players, and passing between the

backline players became common. Unlike the earlier *folk* variations of the game, high *role differentiation* (division of labour) among players and player roles were already visible in rugby union. During this time, team captains, not paid coaches, controlled the game (Baker, 1988; Lyle, 2003). Raw strength and determination, not tricky plays, distinguished heroes. Because Britain's naval and commercial interests dominated the world in those days, rugby made its way into the far reaches of the globe (Baker, 1988).

Over time, rugby survived several years of war and depression through upper class army officers and civil servants throughout the British Empire (Baker, 1988). Besides the officers, concentration camp inmates also played rugby to keep morale high and fight the effects of stress and exhaustion (Van der Merwe, 1995). Likewise, under conditions of war, troops as well as prisoners-of-war often experienced a need to participate in sport (Van der Merwe, 1999b). For example, during the Second World War rugby was the sport that attracted most attention among the South African military serving in North Africa (Van der Merwe, 1999b). These South African soldiers readily played rugby matches against their British peers as well as the local communities (Van der Merwe, 1999b).

In the early days of the 20th century, the game still differed much from today. During this time, it seems to have been a sport played by big, strong often fast and talented, but relatively unfit, players who saw little need to train specifically for the game (Noakes & Du Plessis, 1996). After the early 1980s this started to change when physical educators and coaches of New Zealand (Blair, 1990), England (Hazeldine & McNab, 1991; Noakes & Du Plessis, 1996) and Australia (Noakes & Du Plessis, 1996) popularised the idea that rugby players could benefit from increased levels of physical fitness. An important development was that training programmes were made specific to the requirements of the particular game, namely rugby, and scientifically designed for the exact requirements of each individual playing position (i.e., specialisation).

Another turning point regarding competitiveness and the need for further *specialisation* in the game came with the explosion of worldwide media sport and, in 1995, the change to full professionalism (Hattingh, 2003). The *first* likely consequence of this major turning point

was the development of the sporting press and advances in telecommunications, which enabled a global sports market and turned sport into a mass spectacle (Crawford, 1992; Horne *et al.*, 2000). *Secondly*, the emergence of elite players and teams, chances to establish national and international reputations and tendencies of “monetisation” put extra pressure on players (Horne *et al.*, 2000). The effect of this newfound media exposure combined with the change to professionalism probably promoted competitiveness, and inevitably also the need for continued specialisation in rugby.

The effect of increased competitiveness and specialisation is still visible in present-day games and training methods. One factor that changes rugby from the old to the new is the number of games per season (Quarrie *et al.*, 2001). Gareth Edwards, former Wales and Lions player, averaged 16.25 games over 12 months. In contrast, Dallaglio, a later Lions player and England captain, averaged 35 games (Wilson, 2000). Yet another consequence of increased competitiveness and the need for continued specialisation is the progress in the development of very specialised training methods. According to David Young, former captain of Wales, players today spend hours improving their fitness, strength and speed (Wilson, 2000). These players do not only spend more time in the gym than before, they also follow specific training programmes to develop very specialised speed, agility, strength, flexibility, endurance and anthropometric components (Quarrie *et al.*, 1995; Nicholas, 1997).

Although this specialisation process demanded heavier and stronger forwards than before, it also meant that players who were not involved in certain phases of the game were now exposed to these phases for the first time (Noakes & Du Plessis, 1996). Early in the 20th century, the loose forwards were primarily involved in the scrums, line-outs, and mainly the rucks and mauls. Due to the continued specialisation over the last few decades their tasks now also include cross-defending and applying pressure on the half-back pairing. Additionally, players today need to be faster in order to cross the advantage line and avoid defenders and cross-defenders (Noakes & Du Plessis, 1996). Because players are under more pressure, they too have to speed up their play. All these increases in speed mean that if current-day players collide, it will be with increased momentum (also see paragraph 3.2, historical overview of rugby injury epidemiology).

During the early years of the modern game, the game consisted of picking up the ball, passing and catching the ball, kicking the ball accurately, good running abilities, backing up during attacking movements, low and powerful tackles, strong defence and linking up with team mates (Craven, 1977; Joynson, 1978). The present-day rugby players still need the same basic skills that were required in the past (Van Gent, 2003; Luger & Pook, 2004), the only difference from the past being that some skills – like different tackle situations – are emphasised more. The majority of Level 2 Australian coaches for example believe that passing while running (93%), front-on tackling (91%), catching while running at speed (87%), self-discipline (86%) and side-on tackling (82%) are the most important skills required by a rugby player (Gibson *et al.*, 1999).

One of the most recent differences from the old to the new is the process of *de-differentiation* of playing positions which has been observed in the 2000s. For example, in the back line, the player closest to the tackled player is responsible for regaining possession of the ball, in the process taking on some of the same characteristics of loose forwards (Noakes & Du Plessis, 1996). In the same vein, the forwards are now expected to run like backs.

In the future, the size, speed and fitness of rugby players may increase even further, while exercise methods will probably become more position- and game-specific. If rugby union is to compete successfully with other rugby codes, it must continue to develop into a game in which the ball is in play for much longer periods (Noakes & Du Plessis, 1996). It will be interesting to observe the influence of all these factors on the game of the future.

2.3 MODERN DEVELOPMENTS IN RUGBY WITH REFERENCE TO TALENT IDENTIFICATION, ANTHROPOMETRIC CHARACTERISTICS, PHYSICAL AND MOTOR ABILITIES AND BIOMECHANICS

From paragraph 2.2 it is evident that the way in which the current game of rugby is played differs from earlier forms of play. The current way rugby is played calls for players who can cope with the specific requirements of the modern game. Therefore it is important to discuss what the modern game of rugby requires of its players.

Coaches have constantly been searching for players who can measure up to the requirements of the game (Hanekom, 2000). Therefore it is important to identify these game-specific requirements. Some previous researchers were of the opinion that despite time and motion analyses of the game of rugby, attempts to quantify the physiological demands of the game have been inconclusive (Docherty *et al.*, 1988; McLean, 1992; Quarrie *et al.*, 1995). However, more recent match analysis together with conclusive observations regarding metabolic requirements during the game do exist (Nicholas, 1997).

It is well known that rugby players need to master a wide range of activities such as running, tackling, kicking, passing, catching, sidestepping and jumping. Because of professionalism, the modern game also requires improved components of morphology, physical and motor abilities and skills to excel (Nicholas, 1997). Through research it has been confirmed that the following morphological, physical and motor components have an important influence on the modern game of rugby (Quarrie *et al.*, 1996; Nicholas, 1997; Hazeldine & McNab, 1998):

- Morphology (anthropometric components like stature, body mass, percentage body fat and somatotype)
- Physical and motor abilities
 - Flexibility (part of *biomechanics*)
 - Strength
 - Power
 - Aerobic capacity

- Anaerobic capacity (speed endurance and muscle endurance)
- Speed
- Agility

From this literature it is clear that, to achieve success in the today's game, players need to measure up to the different but specific requirements of the modern game (Quarrie *et al.*, 1996; Nicholas, 1997; Hazeldine & McNab, 1998). According to Hanekom (2003:31), the rugby player of the future will have to prepare in a scientific way or else will not be able to adapt to the requirements of the modern game. Scientifically evaluating players with regard to all the above-mentioned components play an integral role in monitoring and developing these components among modern rugby players (Hanekom, 2003).

All the above-mentioned morphological, physical and motor requirements will also be utilised in the design of this study and will therefore be explained further in the paragraphs that follow (paragraph 2.3.2 to paragraph 2.3.4). Where relevant, attention will be paid to the relationship of these developments to injury incidence. Because coaches can now identify talented players and develop the necessary requirements from early on, talent identification will also be discussed in paragraph 2.3.1. In light of some earlier uncertainty surrounding the metabolic requirements of the sport, it is not surprising that a broad range of tests has been used to measure the different requirements of rugby players (Quarrie *et al.*, 1995). Therefore, it must be noted that the variety of tests used in evaluating some of the above components makes it difficult to compare the norms for players among all of the studies. Therefore this chapter will concentrate on the tests most often used in the literature.

2.3.1 TALENT IDENTIFICATION AND THE MODERN GAME OF RUGBY

Talent identification, according to Salmela and Régnier (1983:1), is described as a long-term process in which potentially talented athletes are identified and developed in sports which they are best suited for, not only because the sport suits their personal abilities, but also for their own satisfaction. Studies by Hare (1997), Pienaar and Spamer (1998), and Van Gent

(2003) have all made a contribution to talent identification among rugby-playing youths and adolescents.

Coaches have always been searching for talented young players who possess the necessary characteristics to play good rugby (Hanekom, 2000). To succeed in modern high-performance sport, screening for potential champions at a young age is required (Pienaar *et al.*, 2000). It is also important to identify talent at an early age in order to prescribe correct training and coaching for top performance at a later age (Potgieter, 1993). The advantage of this is that young sports participants can be channelled into sports for which they are physically and emotionally best suited, resulting in greater gratification and enjoyment (Gibson *et al.*, 1999; Hare, 1999).

From the literature it is clear that inborn talent must be exposed to a development programme to achieve results (Pienaar & Spamer, 1997; Hare, 1999). The real success of talent identification is dependent on the development programme that is followed after initial identification of talent (Schneider, 1993). Other researchers also believe in the importance of development and exercise programmes for successful sports performance (Ericsson & Charness; 1995).

Many clinics are held to develop the skills of young children (Spamer *et al.*, 1994). These development programmes are mostly presented according to own methods (Hare, 1999). According to the American Sports Education Program (ASEP) (quoted by Van Gent, 2003:3) more than two thirds of high school coaches have received little or no formal coaching education, and this despite the fact that special concern exists about the effect of intensive exercise on young sports participants (Maffuli & Helms, 1988). The consequence may be that some teachers and coaches may not be able to develop the talent of young players or protect them against injuries effectively.

It is clear that large amounts of money, energy and time are spent to develop talented players (Du Randt & Headly, 1993; Adendorff, 2002). Therefore it should be ensured that these talented young players are not lost to the sport due to injury, as sometimes happens.

According to Hare (1999:14) specific programmes that pay attention to physical health and wellbeing can also be incorporated into talent development programmes. This is one way of protecting talented young players against injury.

In the field of rugby specifically, research now states that in order to account for the effect of growth and late maturation, the number of potentially talented athletes identified at an early age should be increased (Adendorff, 2002). This means that a larger number of young rugby players may be exposed to development programmes. Furthermore, research already asks for accelerating these programmes, in order to prepare players for elite rugby faster (Hanekom, 2003). It is thus up to modern-day talent identification specialists to ensure that these growing numbers of youths exposed to accelerated talent development programmes are adequately protected against the risk of injury.

2.3.2 ANTHROPOMETRIC COMPONENTS AND THE MODERN GAME OF RUGBY

Anthropometric components are categorised under morphological components. According to De Ridder (1993:10), a kinanthropometric investigation measures the morphological components of humans in motion. Analysis of the body's structural variability is the domain of anthropometry, the study of comparative measurements of the human body (Whiting & Zernicke, 1998). Anthropometric measurements include osteometry (measurement of the dimensions of the skeletal system), craniometry (measurement of the bones of the skull), skinfold measurements to determine body composition, and measurement of height and weight (Arnheim & Prentice, 2000). Limb girth measurements taken during a rehabilitation programme can also be considered a type of anthropometric measurement (Arnheim & Prentice, 2000).

Through anthropometry, the morphological components can be studied in context with performance and/or motor functioning. The contribution of body build, form and composition (morphology) to performance has been researched from as early as the 4th century BC (Maas, 1974; De Ridder, 1993). Regarding rugby, it can be said that the players

who perform best in rugby should also have the most suitable body build for their positions in rugby (Swart, 2002).

Both coaches and selectors today place importance on a player's size and build when selecting players for different positions. This is becoming more important in the modern era. Stewart quoted by Noakes and Du Plessis (1996:14) said the following: "... many an international lock or prop represented his country at 13 or 14 stone up to the early 1950s. There were plenty who couldn't even make 13 stone. But from then on, it was 15 stone men who gained selection as locks or props." This has continued up to today, with modern locks weighing up to 120 kg and reaching body lengths of 2.05 m (Noakes & Du Plessis, 1996). Olds (2001:253) agrees that players on the whole have become taller, heavier and more mesomorphic (muscular). However, while the physiques of players have developed over time, the ligaments surrounding the major joints cannot be strengthened proportionally, making them vulnerable to injury (Wilson, 2000). Because of high global competition and growing financial support from television rights, the trend towards recruiting players with greater body size is likely to continue (Olds, 2001). Consequently, anthropometry will play an increasingly important role in the future of rugby.

Rugby players come in many shapes and sizes. Research confirms that different positions in rugby also differ morphologically (Coetzee, 1999). De Ridder (1993:287) found differences in body fat between different playing positions among primary school and high school Craven week players, with the forwards presenting a higher fat percentage than back-line players. The findings of Quarrie *et al.* (1995:263), namely that a national team's forwards were more endo-mesomorphic (relatively more fat and muscular) than its back-line players, support the above. Some believe that the reason for these differences is the diverse requirements of each playing position (Bell, 1980; Coetzee, 1999; Hanekom, 2000; Van Gent, 2003).

With regard to the requirements of forward play, Carlson *et al.* (1994:410) stressed that a heavier pack of forwards can provide better momentum and stability in the scrum, mauls or rucks, provided that their speed is not negatively affected. Other researchers have suggested

that this increased mass in forwards allows them to obtain greater momentum than the backs when sprinting, increasing their impact mass (Carlson *et al.*, 1994; Quarrie *et al.*, 1995). Thus the greater momentum that players with higher body mass can obtain is a definite advantage in body-contact situations, as players who collide will tend to move in the direction in which the player with the greatest momentum was travelling before the impact (Quarrie *et al.*, 1995). This increase in body mass may also be accompanied by greater total body fat, which could act as a buffer against contact forces and consequently protect against impact injuries (Carlson *et al.*, 1994). This is in contrast to research which suggests that excess body fat is detrimental to performance (Nicholas, 1997). Predominantly, the literature suggests that it is better for players to concentrate on increasing their lean body mass at the expense of their total body fat, with the aim of attaining an improved ratio of lean body mass to total body fat (Bell, 1979; Tumbull *et al.*, 1995; Nicholas, 1997).

It is known that male athletes often have a body fat percentage of between 8 percent and 12 percent (Arnheim & Prentice, 2000). However, players need a certain amount of body fat for normal physiological functioning of the central nervous system (Vander *et al.*, 1998). This stored fat also serves as energy reserves and protection for internal organs against injury (De Ridder, 1993). Wilmore (as quoted by De Ridder, 1993:22) states that if the fat mass of athletes is below optimum, secondary amenorrhoea (in females), kidney dysfunction and a drop in performance may occur. The amount of body fat content also gives an indication of the state of a player's fitness, since fat content falls with increasing levels of fitness and increases during the off-season (Noakes & Du Plessis, 1996). Thus, determining the fat content at which players are most healthy and effective on the rugby field will provide a useful reference for future playing seasons.

It is possible for the anthropometric composition of an athlete to be "shaped" through scientific training programmes (De Ridder, 1993). With this in mind, exercise specialists should ensure that body fat percentage does not go below 3 percent in males, because below this percentage the internal organs tend to lose their protective padding of essential fat, potentially subjecting them to injury (Arnheim & Prentice, 2000).

Other body dimensions can also play critical roles in injury (Whiting & Zernicke, 1998). According to research reports, anthropometric measures such as height, weight, body composition, muscle mass, and shape (somatotype) can all play a central role in assessing injury (Lysens *et al.*, 1991; Whiting & Zernicke, 1998). These anthropometric measures are also involved in determining body posture, biomechanics and flexibility (joint range of motion), which – either alone or in combination – can affect the risk of injury (Whiting & Zernicke, 1998). US Army studies have also found some associations between percentages of body fat (estimated from skinfold thickness and circumference measurement) and risk of injury (Jones *et al.*, 1992). These findings have not been consistent enough and more research is needed. In American football, lightweight players with thin necks are the most vulnerable to injury (Maroon, 1981). In rugby, players with long necks may also be more susceptible to spinal injury, should they be allowed to play in the front row of a scrum (Haylen, 2004).

Regarding more research on rugby, Babic *et al.* (2001:392) studied the influence of some anthropometric characteristics, body composition and constitution on the epidemiology of rugby injuries in the Croatian-Slovenian rugby league, where rugby is less popular and less often played. The authors found no statistically significant differences in anthropometric characteristics, body composition or constitution of injured and uninjured players. However, the authors found the injured backs and forwards to be on average heavier and taller compared to the uninjured backs and forwards. This compares well with two earlier studies, which found that heavier players tend to be injured more frequently (Van Heerden, 1976; Davies & Gibson, 1978).

Table 2.1 shows values for some of the anthropometric components found in the literature. In the literature, data obtained on certain player positions and levels of play were not always uniform for the same anthropometric components. This is probably because different test protocols, such as sum of six skinfolds, sum of four skinfolds and underwater weighing are used by different researchers (De Ridder, 1993; Heyward & Stolarczyk, 1996; Pienaar & Spamer, 1997). For future gathering of comparable anthropometric data, it is important that researchers use uniform scientific methods and protocols to evaluate players.

Table 2.1: Average values for body mass, body length, fat percentage and somatotype of rugby players

Author	Subjects	Age (years)	Body mass (kg)	Body length (cm)	Fat percentage	Somatotype		
						En	M	Ec
De Ridder (1993)	<i>Craven Week players</i>							
	<i>Juniors</i>							
	▶ forwards	13.1	60.2	167.3	16.7	3.0	4.4	2.8
	▶ backs	13.1	49.0	160.3	12.9	2.2	4.0	3.5
	<i>Seniors</i>							
	▶ forwards	18.1	87.3	183.3	18.4	3.3	5.0	1.9
	▶ backs	18.1	72.9	176.2	14.1	2.4	4.5	2.3
Carlson <i>et al.</i> (1994)	<i>USA National team</i>							
	▶ forwards	26.8	99.1	186.8	10.9	-	-	-
	▶ backs	25.8	80.8	178.9	8.4	-	-	-
	▶ all players	26.3	90.6	183.2	9.7	-	-	-
Quarrie <i>et al.</i> (1995)	<i>High school</i>							
	▶ forwards	16.7	82.6	180.2	-	3.4	5.6	2.0
	▶ backs	17.1	72.0	175.4	-	2.2	5.5	2.3
Nicholas (1997)	<i>First class players</i>							
	▶ forwards	23.1	92.2	186.1	13.1	-	-	-
	▶ backs	23.1	78.6	176.6	11.3	-	-	-
	<i>Second class players</i>							
	▶ forwards	22.4	82.2	177.2	12.7	-	-	-
	▶ backs	22.4	74.7	175.8	11.4	-	-	-
Pienaar & Spamer (1997)	<i>Junior Craven Week players</i>	10	44.2	152.2	-	-	-	-
Hanekom (2000)	<i>High school</i>							
	▶ 17-year olds	-	74.33	175.17	9.44	-	-	-
	▶ 19-year olds	-	77.36	175.61	9.86	-	-	-
Adendorff (2002)	<i>Successful</i>							
	▶ 18-year olds	-	83.06	181.85	9.89	4.4	4.2	2.0
Hattingh (2003)	<i>Elite school</i>							
	▶ 15-year olds	-	71.31	173.69	17.22	-	-	-
	▶ 18-year olds	-	87.13	180.68	12.98	-	-	-
	<i>Elite club</i>							
	▶ 19-year olds	-	87.29	181.45	11.79	-	-	-
	▶ 20-year olds	-	90.93	181.30	13.02	-	-	-
Spamer & Winsley (2003)	<i>Elite</i>							
	English	18	87.8	181.9	22.1	-	-	-
	South African	18	87.4	185.6	15.8	-	-	-

Table 2.1 continues

Author	Subjects	Age (years)	Body mass (kg)	Body length (cm)	Fat percentage	Somatotype		
						En	M	Ec
De la Port (2004)	<i>Elite National</i>							
	▶ 16-year olds	-	76.17	175.41	14.33	2.91	5.48	2.11
	▶ 18-year olds	-	85.07	180.27	15.14	3.23	5.82	1.86
Spamer & Hattingh (2004)	<i>Elite 15 year olds</i>							
	▶ forwards	-	83.8	176.60	21.52	-	-	-
	▶ backs	-	63.5	171.88	14.53	-	-	-

En = Endomorphy; M = Mesomorphy; Ec = Ectomorphy

The most accurate method of determining body composition is hydrostatic weighing (Prentice, 1999). When many athletes have to be assessed, skinfold measurement of subcutaneous fat provides a rapid, cost-effective and reliable predictor of body composition (Lohman, 1981; Jackson & Pollock, 1985; De Ridder, 1993).

In general, Table 2.1 indicates that anthropometric differences are apparent between different playing positions and age groups as well as between different levels of play. Most somatotype descriptions of rugby players have identified forwards as being generally more endo-mesomorphic (relatively more fat and muscular) than backs. As endo-mesomorphs have been shown to possess greater strength than either mesomorphs (muscular) or ecto-mesomorphs (relatively slender and muscular) (Bale *et al.*, 1984), this may reflect the greater demands for strength placed on forwards during scrummaging, rucking and mauling (Quarrie *et al.*, 1995). However, the most consistent anthropometric difference between forwards and backs, particularly among junior players, are in terms of body size (height and body mass). In order to make future anthropometric comparisons possible, the same models must be used when determining anthropometric components.

2.3.3 PHYSICAL AND MOTOR PERFORMANCE IN THE MODERN GAME OF RUGBY

Physical and motor conditioning is seen by some researchers as the most important base on which tactical and technical components are based (Hazeldine & McNab, 1998). As stated earlier in this chapter (introduction of paragraph 2.3) the following *physical and motor components* are important in modern rugby: flexibility, strength, power, aerobic capacity, anaerobic capacity, speed and agility. Consequently, these different physical and motor components are discussed in more detail.

2.3.3.1 Flexibility

Flexibility can be seen as the ability of a muscle or joint to move smoothly and easily through its maximum allowed range of movement (Nicholas, 1997; Arnheim & Prentice, 2000). More flexibility means more strength and power to the athlete, because flexible muscles can move through a greater range of motion and thus produce more power for longer periods of time (Nicholas, 1997). Others claim that flexibility is an important, though frequently neglected, aspect of performance (Armstrong & McManus; 1996). However, a lack of flexibility not only affects performance and technique, it results in uncoordinated movements and predisposes the athlete to muscle strain and tear-type injuries (Nicholas, 1997; Arnheim & Prentice, 2000). While there is an important hereditary component to general flexibility, specific joints or muscles may still become stiff as a result of over-activity, inactivity or injury (Brukner & Khan, 2001).

Flexibility is also one of the physical fitness components associated with injury (Jones & Knapik, 1999). For example, sprains, strains and dislocations may be more likely among highly flexible athletes (Knapik *et al.*, 1992). Furthermore, there is some evidence that less flexible rugby players are at increased risk of injury (Watson, 1981). Most sports therapists believe that maintaining good flexibility is important in prevention of injury to the musculotendinous unit, and consequently include stretching exercises as part of the warm-up before engaging in strenuous activity, although little research evidence is available to support this practice (Prentice, 1999). Nicholas (1997:391) agrees that flexibility does not receive

enough attention during the preparation of rugby players, even though it can contribute to increased strength and decreased injuries among players.

Like any other physical or motor ability, flexibility has to be maintained through training (Karstens, 2002). During rapid growth periods of children, a loss of flexibility may occur when joints become progressively taut. As a result, the risk of injury is increased (Micheli, 1983; Armstrong & McManus, 1996). Recent evidence from children engaged in formal sports training suggests that flexibility of older children can be increased with training (Armstrong & McManus, 1996). Still, it must be remembered that some research indicates that individuals with both high and low extremes of flexibility experience more injuries (Jones & Knapik, 1999; Knapik *et al.*, 1992). This suggests that it may be necessary for research to re-examine the common belief that greater flexibility protects against injury.

The sit-and-reach and Thomas tests are the most common methods used to evaluate the flexibility of rugby players (Nicholas, 1997). With the sit-and-reach test, good results can be obtained if the lower back, hamstrings or upper back is overly flexible, even if one of the other regions is tight. Also, disproportionate length between arms, trunk and legs can make the activity easier for some and more difficult for others. Furthermore, these tests only evaluate the flexibility of the lower back, hamstring, quadriceps, and iliopsoas muscle groups. When rugby is played, these are not the only muscle groups used, nor should they be the only muscles subjected to flexibility testing and flexibility exercises. Another method of evaluation not ordinarily seen in rugby research, but one which also allows for a more muscle and joint specific flexibility/mobility measurement – among other components – is the more complete *biomechanical and postural evaluation* used by Hattingh (2003:73) (also see paragraph 2.3.4).

Nicholas (1997:391) and Williford *et al.* (1994:860) report that flexibility differed among different playing positions and levels of play. In general, differences are related to differences in body composition (Williford *et al.*, 1994). There is currently a need in rugby research to evaluate more joint-specific flexibility, as well as to analyse specific flexibility required by different playing positions. Furthermore, there is a need in rugby research to find

the most correct evaluation methods of components to ensure accurate gathering of data (Hanekom, 2003).

2.3.3.2 Speed

According to Ohanian (1994:8) *speed* is defined as the distance travelled per unit of time. Noakes and Du Plessis (1996:9) pointed out that there has been an increase in the tempo of play in rugby. Others agree that this phenomenon is likely to continue (Hattingh, 2003; Luger & Pook, 2004). This means that players not only rely on speed to reach the points of breakdown faster, but they also need a more long-lasting maximal speed (speed endurance) to keep up with the pace of the modern game.

The ability to accelerate quickly from a standing or moving position is important for all fifteen players in the team (Hazeldine & McNab, 1991; Nicholas, 1997). Speed is vital during attack to get past the defence (and over the advantage line) and during defence to stop the opposition before they cross the advantage line (Meir, 1993). Speed is also important to accelerate away from the scrum, line-out, ruck and maul (Hazeldine & McNab, 1991). While running at or near maximal speeds, players will cover distances ranging from 3 to 34 meters (Luger & Pook, 2004). Today, acceleration of a player over the first 10 metres is emphasised and evaluated (Hanekom, 2000). Another commonly used speed test is the 30 m test for speed (Van Gent, 2003).

Although a high level of speed should be encouraged, the acceleration over 10 m from a standing start has been associated with injury in high level players of body contact sports (Watson, 2001). This is probably because acceleration is directly proportional to the force developed by the athlete, which presumably equates with greater stress on the athlete's tissues and thus increases risk of injury (Watson, 2001). Athletes who possess high levels of speed need to ensure that all other injury risk factors are minimised. One way of ensuring this is through thorough posture and clinical assessments (Watson, 2001).

Table 2.2: Average values for 10 and 30 m speed of rugby players

Author	Subjects	Age (years)	Distance (m)	Time (sec)
Quarrie <i>et al.</i> (1995)	<i>High school</i> ▶ forwards ▶ backs	18/19-year olds	30	4.60
				4.40
Hanekom (2000)	<i>High school</i>	17-year olds	10	2.21
		19-year olds		2.31
Adendorff (2002)	<i>Successful players</i>	18-year olds	10	1.80
			30	4.30
Swart (2002)	<i>Elite club</i> ▶ tight forwards ▶ loose forwards ▶ backs	19-year olds	10	2.01
			30	4.67
			10	1.88
			30	4.41
			10	1.85
			30	4.21
Hattingh (2003)	<i>Elite school</i>	15-year olds 18-year olds	30	4.42
			30	4.32
	<i>Elite club</i>	19-year olds 20-year olds	30	4.30
			30	4.24
Van Gent (2003)	<i>Provincial</i>	13-year olds	10	2.17
			30	5.08
		16-year olds	10	1.89
			30	4.56
		18-year olds	10	2.02
			30	4.53
		19-year olds	10	2.04
			30	4.49
Hanekom (2003)	<i>Elite</i> ▶ forwards ▶ backs ▶ total group ▶ forwards ▶ backs ▶ total group	19-year olds	30	5.00
			30	3.90
			30	4.40
		21-year olds	30	4.93
			30	3.80
			30	4.80
De la Port (2004)	<i>National squad</i>	16-year olds	10	1.90

Table 2.2 continues

Author	Subjects	Age (years)	Distance (m)	Time (sec)
Spamer & Hattingh (2004)	<i>Elite</i>			
	▶ forwards	15-year olds	30	4.45
	▶ backs	15-year olds	30	4.39

The running speed of males improves more or less linearly from 5 to 17 years (Malina & Bouchard, 1991). Research by Nicholas (1997:388), Hanekom (2000:56) and Hattingh (2003:96, 106) on players 17 years and older also indicates that speed can still increase after 17 years of age (see Table 2.2). Table 2.2 highlights differences in speed between different playing positions and levels of play. Most of this research found back-line-players of the highest level to be the fastest.

2.3.3.3 Agility

According to Meir (1993:14) *agility* is the ability to make sudden, effective changes in direction without losing much speed (Van Gent, 2003). For good agility one needs different qualities such as speed, power, rhythm, timing, body control and balance (Malina & Bouchard, 1991). There is insufficient evidence to determine the exact importance of agility in rugby, due to the difficulty in differentiating between positions and levels of performance (Nicholas, 1997). What is known is that rugby players need agility in both attack and defence situations (Meir, 1993).

Over the years a variety of tests, such as the Illinois-agility-test, T-test for agility, 505-agility-test and Herzberg agility test, have been used to evaluate a player's agility (Bloomfield *et al.*, 1994; Nicholas, 1997; Hattingh, 2003). Whichever agility test is decided on, it should incorporate changes of direction, acceleration/deceleration, and quick starts and stops (Prentice, 1999). The lack of a universal agility test and the fact that agility is sport-specific mean that results from different studies are not always comparable. One of the tests often used is the Illinois agility test.

Results for the Illinois agility test indicate that agility improves with age as well as level of play (Table 2.3). Other research results for younger age groups show that agility also

improves with age among boys from 5 to 8 years, and then at a lesser rate up to 18 years (Malina & Bouchard, 1991; Armstrong & McManus, 1996). Players with good speed, strength and power are usually the ones who perform well in agility tests (Quarrie *et al.*, 1996).

Table 2.3: Average performance of rugby players for the Illinois agility test

Author	Subjects	Age (years)	Illinois agility (sec)
Swart (2002)	<i>Elite club</i> ▶ tight forwards ▶ loose forwards ▶ backs	19-year olds	17.98
			17.10
			17.00
Hattings (2003)	<i>Elite school</i>	15-year old	18.98
		18-year old	17.74
	<i>Elite club</i>	19-year old	17.72
		20-year old	17.58
Van Gent (2003)	<i>Provincial</i>	13-year olds	19.50
		16-year olds	18.01
		18-year olds	17.15
		19-year olds	16.41
Hanekom (2003)	<i>Elite</i>	19-year olds	17.20
		21-year olds	17.20
		seniors	17.40
De la Port (2004)	<i>Elite</i> <i>National squad</i>	16-year olds	15.07
		18-year olds	14.97

2.3.3.4 Strength and Power

Muscle *strength* is the ability of a muscle group to exert force against a resistance in one maximal effort (Armstrong & McManus, 1996) while *power* (dynamic strength) is the ability to apply the maximum force as fast as possible (speed of contraction) (Malina & Bouchard, 1991). According to Nicholas (1997:390) basic strength, dynamic strength (*power/explosiveness*) and static strength (isometric strength) are the strength components important to rugby players. These different kinds of strength are important in different rugby situations.

Because of their high work rate and play in the tight phases of the game, the tight five need more basic strength, static strength and power than their team mates (Noakes & Du Plessis, 1996; Nicholas, 1997). Power is important in any situation where the player needs a combination of strength and speed (Prentice, 1999). Rugby is a sport for powerful rather than strong players (Turnbull *et al.*, 1995). Still, it is important to bear in mind that power is founded on having a strong base of strength (Turnbull *et al.*, 1995). In rugby, an example of this power is the explosive jump in line-outs. The vertical jump therefore has been described as important to forwards, who must compete for the ball in line-outs (Maud & Schultz, 1984).

The relationship between strength and risk of injury is not always clear (Knapik *et al.*, 1992). It is known that strength plays an important part in a player's ability to absorb the impact from a tackle while still keeping the ball in play (Walsh, 1990). A decrease in strength may be an indication of overtraining, as overtraining can have a negative effect on the development of muscle strength (Prentice, 1999). Muscle weaknesses can result in abnormal movement or gait and can impair normal functional movement, thereby increasing the risk of injury (Prentice, 1999).

A study on university rugby players in America confirmed that the stronger a player becomes, the better the quality of his play and the fewer the injuries he sustains (Hage; 1981). Of particular importance in the prevention of injuries is the eccentric (muscle lengthening while still applying force) muscle strength (Prentice, 1999). On the other hand, some studies have also found a tendency among stronger subjects to be injured more often (Knapik *et al.*, 1992). Although researchers were not able to fully explain this finding, they postulated that various structures within the joints or muscles could be damaged by high forces when muscles are very strong relative to body mass (Knapik *et al.*, 1992). However, it could also have been that the stronger athletes played the sport more often than weak ones and the additional exposure resulted in the higher injury incidence (Knapik *et al.*, 1992).

Muscle strength has been expressed in a variety of ways. Most studies have expressed strength in terms of an isolated muscle or a composite (totalled strength scores from several

different muscle groups) (Armstrong & McManus, 1996; Van Gent, 2003). Different tests used to evaluate strength components are the bench press test, leg press test, isokinetic tests, grip strength and abdominal strength test (Shields *et al.*, 1984; Hanekom, 2000; Hattingh, 2003). For injury prevention reasons, the use of certain 1-rm (one-repetition-maximum) tests is not advocated in adolescents below the age of 17-18 years of age. Some of these tests, such as the squat test, require specialised lifting technique training as well as experience to master, and may put unnecessary stress on the spines or epiphysial growth plates of children (Armstrong & Welsman, 1997; Bartlett, 1999; ACSM, 2000).

Regardless of the tests used, strength increases almost linearly with advancing age in boys until 13 or 14 years of age, when there is an adolescent strength spurt, followed by slower increases into the early or mid-twenties (Malina & Bouchard, 1991; Armstrong & McManus, 1996; Armstrong & Welsman, 1997). Senior players are stronger than their junior counterparts; therefore it can be assumed that strength will also improve from junior to senior level (Nicholas, 1997; Van Gent, 2003). Previous research on grip-strength and abdominal strength can be viewed in Table 2.4.

Power increases follow much the same route as strength, with linear improvements until 13 years of age, followed by more sharp increases, indicating a spurt (Malina & Bouchard, 1991). One test of explosive power that has frequently been used is the vertical jump (Nicholas, 1997), and the scores for rugby union players are presented in Table 2.4. In general, Table 2.4 indicates that both strength and power of rugby players improve with age as well as level of play.

Table 2.4: Average scores of rugby players for the vertical jump, pull-ups, abdominal strength, 1-minute push-ups and grip strength

Author	Subjects	Age (years)	Vertical jump (cm)	Pull-ups (n)	Abdominal strength (level)	1min Push-ups (n)	Grip-strength (kg)	
							L	R
Hare (1999)	<i>Talented players</i>	16	43.84	-	-	-	48.16	51.58

Table 2.4 continues

Author	Subjects	Age (years)	Vertical jump (cm)	Pull-ups (n)	Abdominal strength (level)	1min Push-ups (n)	Grip-strength (kg)	
							L	R
Hanekom (2000)	<i>High school</i>	17-year olds	40.29	-	-	32.67	50.37	51.96
		19-year olds	40.96	-	-	32.70	50.88	53.38
Adendorff (2002)	<i>Successful</i>	18-year olds	47.00	10.78	5.78	-	-	-
Hattingh (2003)	<i>Elite school</i>	15-year olds	46.46	10.48	4.72	-	-	-
		18-year olds	50.60	10.29	5.76	-	-	-
	<i>Elite club</i>	19-year olds	55.40	9.42	4.67	-	-	-
		20-year olds	54.30	10.15	5.59	-	-	-
Spamer & Winsley (2003)	<i>Elite</i> ▶ English ▶ South African	18-year olds	44.0	-	-	-	45.9	50.2
		18-year olds	52.4	-	-	-	50.2	59.6
Van Gent (2003)	<i>Provincial</i>	13-year olds	30.19	9.86	3.52	-	-	-
		16-year olds	40.55	6.68	4.10	-	-	-
		18-year olds	47.06	4.72	3.89	-	-	-
		19-year olds	51.84	8.47	5.00	-	-	-
Hanekom (2003)	<i>Elite</i>	19-year olds	52.40	9.70	5.4	57.0	-	-
		21-year olds	53.20	10.60	4.9	59.9	-	-
		seniors	54.40	9.50	4.4	68.5	-	-
Plotz (2004)	<i>Elite</i> ▶ Ivybridge ▶ Blue Bulls ▶ Leopards	18-year olds	44.00	-	-	-	45.86	50.15
		18-year olds	52.40	-	-	-	56.05	59.61
		18-year olds	50.54	-	-	-	52.55	55.00
Spamer & Hattingh (2004)	<i>Elite</i> ▶ forwards ▶ backs	15-year olds	45.92	9.54	4.42	-	-	-
		15-year olds	47.00	11.50	5.00	-	-	-

L = Left: R = Right

2.3.3.5 Endurance

All rugby players need good *aerobic* and *anaerobic endurance* (Hanekom, 2000). Aerobic endurance is a measure of the long-term energy system's efficiency and is most accurately determined through measurement of maximum oxygen consumption (maximum *aerobic capacity*) during exhaustive work (Prentice, 1999). As can be expected, there is an increase in oxygen consumption with an increase in exercise intensity (Noakes, 1986). The aerobic capacity of athletes depends on the ability of the body to increase whole-body oxygen uptake during exercise.

Improved aerobic endurance may possibly contribute to faster recovery from fast, high-intensity activities (Williford *et al.*, 1994). Individuals with low aerobic fitness will

experience more physiological stress relative to their maximum at any performance level (Jones & Knapik, 1999). This fitness will allow players to produce a high work rate throughout 80 minutes (Turnbull *et al.*, 1995).

The best method of measuring aerobic endurance is through VO₂ maximum (VO_{2max}) tests (Nicholas, 1997). However, this measurement requires expensive laboratory equipment and is impractical for determining fitness of many athletes during pre-participation screening (Prentice, 1999). There are other methods of measuring VO_{2max} (ACSM, 2000). An athlete's VO_{2max} can be assessed through direct measurement tests or through indirect field tests – from which VO_{2max} can be predicted. The advantages of field tests are that large numbers of individuals can be tested at one time and little equipment is needed (ACSM, 2000). The disadvantages are that they are presumably maximal tests and VO_{2max} has to be estimated from results. A common field test for the measurement of a rugby player's cardiovascular fitness (aerobic) is the progressive shuttle-run test (bleep test) (Brewer, 1988; Hazeldine & McNab, 1991). Results for the bleep test are presented in Table 2.5.

Table 2.5: Average performance of rugby players during the bleep test

Author	Subjects	Age (years)	Bleep (level)
Hanekom (2000)	<i>High school</i>	17-year olds	8.7
		19-year olds	8.8
Adendorff (2002)	<i>Successful</i>	18-year olds	9.47
Hattingh (2003)	<i>Elite school</i>	15-year old	9.23
		18-year old	9.61
	<i>Elite club</i>	20-year old	11.55

The aerobic system cannot supply all the energy and so energy is also supplied from the anaerobic (without oxygen) system. As well as possessing a good aerobic capacity, rugby players therefore need a well developed *anaerobic endurance* base (Hanekom, 2000). The anaerobic endurance of players can be gauged through the measurement of their *anaerobic*

capacity. The anaerobic capacity assesses the immediate and short-term energy system's efficiency (Prentice, 1999).

Rugby is classified as an interval type activity, which means players must perform several high-intensity efforts during a game such as sprinting, pushing in the scrum and explosive jumping in the line-outs (Hazeldine & McNab, 1991; Morton, 1992; Turnbull *et al.*, 1995). To achieve this, players need sound anaerobic endurance, which includes *muscle endurance* and *speed endurance* (Van Gent, 2003).

Muscle endurance is related to aerobic fitness (Hazeldine & McNab, 1991). Muscle endurance is the ability to apply force repeatedly over a period of time (Malina & Bouchard, 1991). Local *muscle endurance* is of particular importance to rugby players when wrestling for the ball during a maul, when making a series of sprints or when driving forward in a scrum (Hazeldine & McNab, 1991). Muscle strength and muscle endurance are closely related (Prentice, 1999). As one improves, the other tends to improve too (Arnheim & Prentice, 2000).

The most common methods used in the assessment of local muscle endurance are the maximum number of a specific exercise performed in a set time or to a set rhythm (Nicholas, 1997). The maximum number of push-ups, sit-ups or pull-ups a player can perform in 60 seconds generally gives a good indication of his muscle endurance (Meir, 1993; Nicholas, 1997). This number is a good estimate of the player's ability to apply force repeatedly over a certain time span (Hanekom, 2000).

From the studies in the literature, it has been found that forwards showed better muscle endurance in the sit-up test (maximum number of sit-ups in 60 seconds) while the backs performed better in the pull-up and push-up departments (maximum number in 60 seconds) (Nicholas, 1997; Hattingh, 2003; Van Gent, 2003). Nicholas (1997:392) also found the muscle endurance of first-league rugby players to be superior to those of second league players. According to the author, the back-line players performed best in the muscle endurance tests. Regarding the relationship between muscle endurance and injuries, the US

Army has found less significant associations between low numbers of sit-ups and push-ups and risk of injury. This data warrants further systematic investigation to prove associations (Jones *et al.*, 1993; Jones & Knapik, 1999).

Also important is a player's ability to keep reproducing fast sprints with minimum loss of power. This ability is an indication of his speed endurance (running) (Hazeldine & McNab, 1991). Repeated high-intensity shuttle tests that measure the decrease in performance by means of a fatigue index have commonly been used to assess the speed endurance component of rugby fitness (Nicholas, 1997). In terms of individual positions, it has been observed that half-backs have the lowest fatigue index among the backs and the hookers the lowest among the forwards (Quarrie *et al.*, 1996). Average values for one of these tests are presented in Table 2.6. These values indicate that fatigue index decreased with increased level of play. A range of other tests for evaluating speed endurance is available from the literature. These different ways of evaluating speed endurance make it hard to compare results from different studies.

Table 2.6: Average values for speed endurance of rugby players

Author	Subjects	Age (years)	Speed endurance (%)
Hare (1999)	<i>Talented players</i>	16-year olds	5.43
Hanekom (2000)	<i>High school</i>	17-year olds	6.90
		19-year olds	6.65
Adendorff (2002)	<i>Successful</i>	18-year olds	6.13
Hattingh (2003)	<i>Elite school</i>	15-year olds	12.46
		18-year olds	12.82
	<i>Elite club</i>	19-year olds	13.01
		20-year olds	14.13

Table 2.6 continues

Author	Subjects	Age (years)	Speed endurance (%)
Van Gent (2003)	<i>Provincial</i>	13-year olds	5.11
		16-year olds	6.58
		18-year olds	5.81
		19-year olds	5.00
Spamer & Hattingh (2004)	<i>Elite</i> ▶ forwards ▶ backs	15-year olds	12.13
		15-year olds	12.75

2.3.4 BIOMECHANICS AND THE MODERN GAME

Biomechanics can be defined as the area of science that is interested in the application of mechanical principles (forces) to biological problems (Whiting & Zernicke, 1998). The term biomechanics is used in multiple ways. Topics as diverse as forces in biological structures, blood-flow dynamics, human gait, prosthetic design and biomaterials fall under the broad area of biomechanics (Bloomfield *et al.*, 1994; Whiting & Zernicke, 1998; Bartlett, 1999). Human biomechanics includes only humans, while exercise and sport biomechanics can be defined as the study of forces and their effects on humans in exercise, sport and sports injuries (Derman & Schweltnus, 2001a; McGinnis, 2005). The impact of exercise and sports biomechanics may be greater in the future due to rapid improvements in technology (McGinnis, 2005). With *good biomechanics* (near symmetry, good dynamic mobility and core stability), researchers believe that humans experience decreased energy expenditure along with increased muscle efficiency, resulting in decreased stress and fatigue (increased performance, decreased injuries) (Blustein & D'Amico, 1985; Neely, 1998). These biomechanical principles can be used to provide the basis for alterations in technique, equipment, posture or training to prevent or rehabilitate injuries (McGinnis, 2005). Some believe that the primary aim of exercise and sports biomechanics should be "injury prevention and rehabilitation" (McGinnis, 2005).

The understanding of biomechanics is the foundation for the assessment of musculoskeletal sports injuries (Arnheim & Prentice, 2000). The primary focal point of this study will be the mechanical causes and effects of force (principles of physics) applied to the human

musculoskeletal system. Of major concern is *pathomechanics*, which may precede an injury (Arnheim & Prentice, 2000). Pathomechanics refers to mechanical forces that affect the body because of a structural body deviation, leading to faulty alignment (Arnheim & Prentice, 2000). These pathomechanics often cause overuse injuries (also see Figure 3.6) (Arnheim & Prentice, 2000).

From the pathomechanical point of view a good biomechanical position will be defined as a combination of *near symmetry*, *good dynamic mobility* (also see flexibility, paragraph 2.3.3.1) and *core stability*. The muscles of this system can be classified as local stabilisers, global stabilizers or global mobilisers (Mottram & Comerford, 2001). Muscle imbalances in this biomechanical system can lead to joint dysfunction, postural imbalances and ultimately injury (Bell-Jenje & Bourne, 2003). For a more in-depth review of the relationship between biomechanics and injury, see Chapter 3 (paragraph 3.8.1.4). For reasons of clarity, symmetry, dynamic mobility and core stability will be explained in more detail.

With *symmetry*, a neutral postural position is implied. In this neutral position ligaments or the capsule gives minimal resistance. At the spinal level, for example, this position is dependent on three interactive systems of movement: passive osteoligamentous, active muscle and fascia, and neural control (Panjabi, 1992). These systems are interdependent and loss of cartilage, rupture of ligaments or weakness of stabilising muscles may affect this postural position. The result of this will be an abnormal increase in the size of the neutral postural position or lack of control of the neutral position (Panjabi, 1992). Instability normally presents and consequently compensatory strategies are adopted. If the individual is exposed to repetitive stress, he/she will eventually present with strain. Therefore, rugby players with a symmetry dysfunction must learn automatically to assume the neutral/symmetrical position.

Good *dynamic mobility* is synonymous with good flexibility of the global mobilising muscles. The global mobilisers are the large outer units/slings of the body. They are the torque generating muscles which primarily produce movement and spinal orientation, and balance external loads (Jull & Richardson, 2000; Mottram & Comerford, 2001). These

muscles have a load transfer function. They tend to tighten and shorten if overused and must be assessed and mobilised (stretched) if needed.

The muscles responsible for *core stability* are the small, intrinsic muscles of the body, known as the local stabilisers/inner units/core muscles (O'Sullivan, 2000; Mottram & Comerford, 2001). These muscles pre-anticipate movement and give stability around the neutral zone (Bell-Jenje & Bourne, 2003). When the body is subjected to a load – for example the scrum in rugby – these muscles control segmental motion and a neutral spine by increasing muscle stiffness (Mottram & Comerford, 2001). Another group of stabilisers, the global stabilisers, controls eccentric contraction through a specific range of movement (Mottram & Comerford, 2001). Through motor learning exercise protocols which focus on stability training and practising of correct recruitment sequencing, players can be taught to isolate and condition the different stabilising muscles (Jull & Richardson, 2000). In terms of rugby, this means that players will become more stable in contact, better able to withstand tackling and less likely to experience injuries involving the lower back (Luger & Pook, 2004).

2.4 CONCLUSION

Early games of folk football survived not only practical and moral assaults but also legal prohibitions, thus to develop into modern rugby. It is especially clear that the game of the future will demand athletically trained players who can play a more fluent running and handling game.

The body contact nature of modern rugby appears to demand specific anthropometric, physical and motor and biomechanical performance characteristics from players. The results of studies which investigated the above-mentioned characteristics of rugby players indicated that different levels of these characteristics were required in the game of rugby, depending on the position and level of performance. Scientific training is needed if modern rugby players are to measure up to the requirements of the future game.

Although young players should be exposed to talent development programmes which

improve these athletic abilities, the programmes should also include modern injury prevention strategies. With the increased demands placed on players with the introduction of professionalism, major championships and commercialism, information about the demands of the game, as well as methods of assessing and improving rugby-specific performance characteristics of rugby players, are of particular importance. There is a need for future research to study the effect of specific, longitudinally designed training programmes on the overall performance parameters as well as injury incidence of rugby players.

3

REVIEW OF LITERATURE

INCIDENCE, ETIOLOGY AND PREVENTION OF RUGBY INJURIES

"Those who fail to prepare must prepare to fail"
(Abraham Lincoln)

- 3.1 Introduction
 - 3.2 Historical overview of rugby injury epidemiology
 - 3.3 Modern injury definition
 - 3.4 Consequences of rugby injuries
 - 3.5 Rugby injury incidence
 - 3.6 Injury frequency by type of injury sustained and anatomical site injured
 - 3.7 Etiology of rugby injuries
 - 3.8 Prevention of rugby injuries
 - 3.9 Conclusion
-

3.1 INTRODUCTION

In the previous chapter (Chapter 2) the evolution of rugby, with the emphasis on changes in the game and their impact on the modern player, have been discussed. From Chapter 2 it is evident that these changes impact on the modern player, his performance requirements and sometimes his injury incidence.

In this chapter rugby injuries and their prevention will be discussed in more detail. The object of this chapter is to review existing literature on the epidemiology of rugby injuries.

With epidemiology, the study of the incidence, distribution and control of disease and injury in a given population is implied (Whiting & Zernike, 1998). It will become clear which rugby players are at greatest risk of injury, and under what circumstances. *Firstly*, the relationships of injuries to changes in the game will be highlighted. *Secondly*, the rugby injury will be defined and its consequences, incidence, etiology and prevention will be discussed from the literature. Prevention of injury should start at a young age, as young rugby players form the cornerstone on which adult rugby is built. This is one of the reasons why the empirical investigation of this study focuses on schoolboys. Therefore this chapter will also refer to schoolboys where possible.

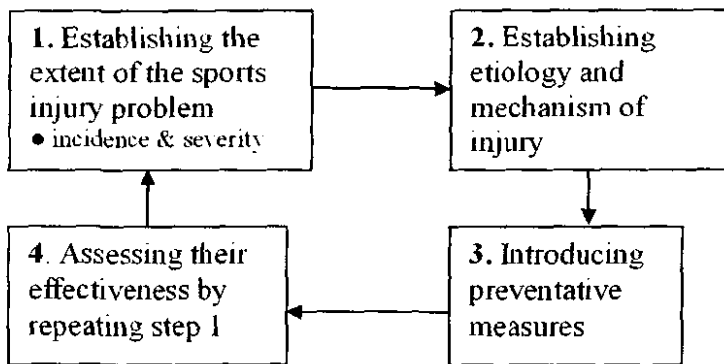


Figure 3.1: The “sequence of prevention” of sports injuries (Van Mechelen *et al.*, 1987)

To reduce injuries effectively it is firstly necessary to know that injury prevention requires different steps. The different steps of an injury control programme are known as the “sequence of prevention” (see Figure 3.1) (Van Mechelen *et al.*, 1992). The *first step* required in injury prevention is to describe the extent of the sports injury problem. *Secondly*, risk factors, mechanisms and causes for these injuries must be established. The *third step* is to propose measures to reduce the future risk and/or severity of sports injuries and to ascertain whether proposed interventions actually reduce injuries. These preventative measures should be based on the etiological factors and mechanisms of the second step. Only after these steps can effective interventions be implemented (Jones & Knapik, 1999). *Finally*, the effectiveness of the preventative measures must be evaluated by repeating the

first step. Furthermore, continuous monitoring is needed to see whether programmes retain their effectiveness (Jones & Knapik, 1999). By comparing Figure 3.1 with the literature available in this chapter, it will become clear that the prevention of rugby injuries is also subject to this distinct “sequence of prevention”.

3.2 HISTORICAL OVERVIEW OF RUGBY INJURY EPIDEMIOLOGY

As mentioned before, *epidemiology* is the study of the incidence, distribution and control of disease and injury in a given population (Whiting & Zernicke, 1998). In the previous chapter (paragraph 2.2) the evolution of the game of rugby was reviewed. Now, in this chapter, it will be explained how the historical changes in the game also influenced injury epidemiology in rugby.

From chapter 2, it is clear that rugby has undergone a metamorphosis from the old game to the current game. It will now become evident that, that these evolutionary developments in the game not only changed the anthropometric, physical and motor, and biomechanical and postural components demanded from the player, but it also influenced rugby injuries in a major way.

Regarding the nature of the game in its earlier form it is clear that games were very rough and aggressive, characterised by “battle excitement” (Van Der Merwe, 1999a; Horne *et al.*, 2000). These medieval games were characterised by a minimum number of rules and a large number of injuries due to violence. In one of these games, in 1280, two players died as a result of knife wounds sustained accidentally during the game (Young, 1968). In a later instance during the 18th century, a game of camp-ball claimed nine lives (Armitage, 1977). The game was also alleged to cause, “the assembling of a lawless rabble, suspending business to the loss of the industrious, creating terror and alarm to the timid and the peaceable, committing violence on the persons and damage to the properties of the defenceless and poor, and producing in those who play moral degradation and in many extreme poverty, injury to health, fractured limbs and (not infrequently) loss of life;

rendering their homes desolate, their wives widows and their children fatherless." (*Derby Mercury*, 29 January 1845, quoted by Horne *et al.*, 2000:78).

In light of the above, it is no wonder that many were opposed to the sport. In the early 16th century, Sir Thomas Elyot (a humanist author) denounced the game as "beastly fury and extreme violence" (Baker, 1988). In 1583 Stubbes (quoted by Van Der Merwe, 1999a:9), a "reformed football player" branded the game as devilish and said: "... so that this means sometimes their necks are broken, sometimes their eyes start out, and sometimes hurte in one place, sometimes in another. But whoesoever scapeth away the best goes not scot-free, but is either sore wounded and bruised, so as he dieth of it, or else scapeth very hardly..."

Later on, with the advent of the Industrial Revolution in the 19th century, medical progress accelerated (Whiting & Zernicke, 1998). During the early stages of industrialisation, people underwent a civilising change and rapid transition away from violent acts (Horne *et al.*, 2000). Consequently the injury scenario also improved as the games during these times were characterised by lower levels of socially tolerated violence, more emotional control and more restraint. Still, life in the public schools was coarse and brutal, while discipline was lacking (Baker, 1988). Boys mostly governed themselves by means of their own pecking order. This was reflected on the playing fields as well, where older boys bullied newcomers mercilessly (Baker, 1988). Consequently those who suffered most from violence and injuries were the younger, weaker and more timid ones.

From Chapter 2 it is clear that even when the world wars occurred, many soldiers participated in rugby to combat boredom and a low morale. Even this was not without injury incidence. In this regard it has been commented that the large number of injuries sustained from participation in rugby could have impacted negatively on the war endeavours of many South African soldiers during the Second World War (Van der Merwe, 1999b).

In total, the game of rugby was played for almost a century before the first study on injury epidemiology was reported by O'Connell in 1954 (Hattingh, 2003). The American football

world, on the other hand, did not take this long before the importance of injury epidemiology was recognised.

American football can be considered the prototype regarding the recording of adequate injury statistics as well as the implementation and legislation of several major injury prevention steps at national level (Albright *et al.*, 1985). American football (*gridiron football*) – which developed from rugby - was one of the first sports to import techniques for the observation and reduction of injuries. This sport set a good example of how to approach the injury problem in contact sport (Noakes & Du Plessis, 1996). Just like rugby, from early times, American football was also plagued by injuries. For example, during 1884 the 11 best players of the Yale team sustained eight serious injuries (Noakes & Du Plessis, 1996). During these times, the injury issue became so serious that the sport was banned from several universities.

In 1905, a series of media articles on the violent and villainous character of the sport reached the public. This was so serious that it forced the Americans to implement rule changes. Thirty years later the injury issue became evident again. The Americans were forced to act preventatively. The governing bodies of American football then decided to develop injury surveillance techniques to monitor the injury incidence on all levels of play. Since 1931, American football has been monitoring catastrophic injuries through their so-called “Injury Register” (Cantu, 1990). An important outcome of this was that they were able to detect the increases in serious spinal cord injuries during the mid 1970s. Because of this early warning, effective preventative measures could be implemented.

In contrast to American football, none of the rugby-playing nations in the northern and southern hemispheres revealed the same concerns regarding rugby injuries. During the same time, no similar tracking system existed in rugby. Because of this, rugby was unable to predict the unfavourable publicity that arose from the sudden increase in spinal cord injuries during the late 1970s and early 1980s (Noakes & Du Plessis, 1996).

As previously noted in paragraph 3.2, a study by the Irish orthopaedic surgeon O'Connell was the earliest study on injury epidemiology and the reduction of injury risk in rugby. In this study, he already proposed certain injury prevention strategies. What he suggested still applies today (Hattingh, 2003). O'Connell (1954:23-26) suggested the following to reduce injury risk):

- Proper pre-season preparation and training;
- protective devices for the head and face, padding for the shoulders and strapping or bracing of the ankles;
- on the field, the use of flexible corner flags, padding of the goalposts and clearing the field of stones, animals and animal faeces; and
- lastly, the adequate rehabilitation of injured players before returning them to the game.

These strategies were only concerned with causative factors from outside the game itself. It is remarkable that it took another twenty years before the next series of articles on rugby injuries was published (Noakes & Du Plessis, 1996). This confirms that not many in the sports medicine fraternity foresaw the injury crisis that followed a few years later. This crisis happened during the middle to late 1970s, when all the big rugby-playing nations experienced an increase in spinal cord injuries, specifically at school level.

In the 1970s many questions regarding rugby injuries arose from all rugby nations. Most of these questions which arose had already been raised in American football studies dating as far back as 1905 (Noakes & Du Plessis, 1996). Just before the injury crisis, some researchers concluded that the high injury trend visible in rugby was unnecessary and could be reduced if the game was more properly regulated (Micheli & Riseborough, 1974; Roy, 1974; Walkden, 1975). These authors foresaw the epidemic of spinal cord injuries which followed only a few years later. Unfortunately it took more than a decade before rule changes were introduced to protect players against dangerous phases of play (Hattingh, 2003). Apart from the facts already discussed, other factors also played a part in the incidence of rugby injuries.

With the advent of television, everyone could share in the excitement and consequently there were new competitions (Armitage, 1977). The first Rugby Union World Cup was introduced in 1987. This event showcased rugby of the highest quality and standard available (Jakoet & Noakes, 1998). Unfortunately, this event also had an impact on injury epidemiology. With the introduction of this high standard of competition, a higher than normal injury rate was observed (Jakoet & Noakes, 1998; Hattingh, 2003). This was not the last time that increases in injury rates were observed.

Since 1995 when rugby became a professional sport, the game has undergone a virtual metamorphosis (see paragraph 2.2). The introduction of professionalism can be seen as a turning point in injury incidence (Hattingh, 2003). In the year 1996, the first fully professional rugby competition was held between South Africa, New Zealand and Australia. Statistics recorded at this competition revealed the highest ever injury incidence up to that date (Targett, 1998). Confirming this, Bathgate *et al.* (2002:266) reported a significant increase in rugby injury rates post-1995, which was the year in which professionalism was introduced. Likewise, Garraway *et al.* (2000:348) reported that, since professionalism has been introduced, professional era players sustained twice the number of injuries any amateur group did. The question can be asked, “why this turning point in injury incidence?”

Garraway *et al.* (2000:350) ascribed this turning point in injury incidence to over-training and an inadequate pre-season rest period. This is in agreement with the conclusions of Targett (1998:280). According to Targett (1998:280) rugby activities of professional players are spread over a 12-month period. According to the author, top New Zealand players essentially had no break from regular rugby games in 1997. Not only was the season longer, but the players also had to play at a higher intensity for a greater period of time than usual. Travel across time zones and altitude differences were additional stressors to these modern-day players.

The fact that players today have to stay competitive during an extended season also means they have to maintain intensive training schedules for a longer period of the year. To obtain the morphology, physical and motor abilities, biomechanics and skills required by the

modern game requires a lot of time and hard work. Players who turn professional suddenly have more time in which to train. All the hours spent on improving the qualities required by the modern game may put a lot of strain on the musculoskeletal structures of players and make it easier for them to train too much (overtrain).

The risk of “overtraining” is not unique to modern rugby and has also been reported in other activities. For example, among US Army trainees of similar cardio-respiratory fitness levels, risk of injury is heightened for those who run a greater total distance (Jones & Knapik, 1999). This finding is consistent with literature on civilian runners (Macera, 1992; Jones & Knapik, 1999), suggesting that there may be a risk of injury per kilometre run/per running stride in sports where running constitutes one of the main activities. The probable risk of overtraining is not the only trend associated with modern rugby training.

Other training factors, such as new methods of improving strength, combined with the use of the scrum machine, meant that the pushing force of the scrum has increased, thus increasing the risk of injury among forwards (Noakes & Du Plessis, 1996). Additionally, because of more specialised training, players are more skilled and physically better prepared for the requirements of their positions (Roux, 1992). The improved skill and physical preparation are supposed to decrease players' risk of injury. This is not always the case. Instead, other consequences brought on by specialisation (competitiveness, increased speed of play, see chapter 2, paragraph 2.2), have adversely affected the risk of injury.

Concerning the way the game itself has changed O'Brien (1992:243) did a retrospective study of rugby injuries of 50 senior rugby players in Leinster province, Ireland. A total of 120 injuries were reported, which relates to an injury incidence of 1 in 31 appearances. This was more than double the figure quoted by O'Connell (1954:26) in the first study on the epidemiology of rugby injuries in Ireland. O'Brien (1992:244) concluded that the increase was partly because the modern game required faster, stronger and fitter players who play a high-speed contact sport. Furthermore, the ball is in play for longer periods, increasing the risk of injury (Bathgate *et al.*, 2002). Research also found speed, tackling and counterattack to be some of the key tactical features in modern rugby (Bottini *et al.*, 2000). No wonder the

most common mechanism of injury in recent years is loose play (Hattingh, 2003). Evidence indicated four times more tackles and rucks per player in the modern-day game, making it far more dangerous and the players more susceptible to injury (Hattingh, 2003).

In conclusion, rugby injuries were part of the game from the earliest times. However, the nature of the game as well as the injuries changed over time. From the first scientific studies, an increase in rugby injuries was reported. Since the coming of professionalism this injury trend has accelerated even further. Today, the rugby world has to face unique challenges regarding the type of rugby injuries and their prevention.

3.3 MODERN INJURY DEFINITION

An important consideration when studying injury is to define the terms and population concerned (Neely, 1998). Inconsistencies still arise among injury definitions, severity of injury and when an injury is regarded to be 'significant'.

"Sports injury" is a collective name for all types of injuries obtained in the course of sports activities (Lysens *et al.*, 1991), while "injury" is the damage caused by physical trauma, sustained by tissue of the body (Whiting & Zernicke, 1998). Various studies on strength, flexibility and injury have used many different definitions of injury (Knapik *et al.*, 1992). Even within the field of an individual sport, different operational definitions of injury may be found.

The current definition of a 'reportable injury' is still under question (Armsey & Hosey, 2004). Within rugby research, injuries have been considered reportable under varied circumstances; for example, when a player perceives that bodily harm has been sustained necessitating stoppage of play, when a player has to be substituted, when a player displays obvious disability, when the injury requires medical attention, or when a player has to take time off from rugby related activities. Some researchers considered a significant injury as an event that resulted in a player requiring medical attention or causing the player to miss at least one scheduled game or team practice (Waller *et al.*, 1994). Others like Nathan *et al.*

(1983:132) and Roux *et al.* (1987:307) defined “injury” as one which was severe enough to prevent the player from returning to rugby for at least seven days after sustaining the injury. By choosing this definition, the authors felt that minor injuries which were of short-term consequence could be ignored, as their inclusion would overestimate the true risk of playing rugby.

For the purpose of Jakoet and Noakes’s study (1998:45), a rugby injury was defined as a new injury that necessitated the player’s leaving the field of play for the remainder of the game. On the other hand, Targett (1998:281) in a study on professional rugby players competing in the Super 12 competition defined a rugby injury as something that prevents a player from taking part in two training sessions, from playing the following week, or something requiring special medical treatment (suturing or special investigation).

During the last ten years the sensitivity of injury recording has generally improved. The injury definitions of Garraway and Macleod (1995:1485), Lee and Garraway (1996:214) and Lee *et al.* (2001:412) are more specific than those in the above paragraph and are commonly used in current rugby studies. In one of these three studies Lee *et al.* (2001:412) defined a rugby injury as “an injury sustained on the field during a competitive match or during training, which prevented the player from playing or training from the time of injury or from the end of the match or training session in which the injury was sustained”. The studies of Garraway and Macleod (1995:1485) and Lee and Garraway (1996:214) are even more specific than the previous definition and defined a rugby injury as “an injury sustained on the field during a competitive match or during training, *or during other training actively directly associated with rugby*, which prevented the player from playing or training from the time of injury or from the end of the match or training session in which the injury was sustained” (Garraway & Macleod, 1995; Lee & Garraway; 1996). These authors added that injuries which allowed a player to return to rugby or rugby-related practice within seven days of its occurrence were graded as transient.

Linked with the definition of a “reportable rugby injury” is defining the severity of this injury. Regarding the severity of injury it can be said that there are different classification

systems to describe the severity of sports injuries. These schemes differ, mostly based on the tissue (e.g., bone vs. ligament) and body regions (e.g., head vs. leg) involved (Whiting & Zernicke, 1998). Although these systems differ, they all have one thing in common – injury severity is linked to the amount of tissue damage (Whiting & Zernicke, 1998). The more damage to the tissue structure, the more severe the injury. In most of these classification systems each grade of severity (e.g., mild, moderate, severe) can be linked to a corresponding performance deficit or functional limitation.

Generally, the severity of sports injuries can be described on the basis of different criteria: the nature of the sports injury; duration and nature of treatment; amount of sporting time lost/days needed to recover; working time lost; permanent damage; and cost (Van Mechelen *et al.*, 1992; Armsey & Hosey, 2004). However, in order to improve compatibility of research results, it is important that uniform definitions of injury severity be used. According to Van Mechelen *et al.* (1992:89) the length of sporting time lost gives the most precise indication of the consequences of an injury to an individual. One of the definitions utilising the length of sporting time lost is that used by the National Athletic Injury Registration System (NAIRS) in the US (Van Mechelen *et al.*, 1992). The NAIRS graded injuries according to the duration of the time that athletes are unable to participate in their sport: 1 to 7 days of incapacitation is graded as “minor”, 8 to 21 days as “moderately serious”, and over 21 days or permanent damage as “serious” (Van Mechelen *et al.*, 1992:85).

In rugby injury research, examples of different definitions using the length of sporting time lost are those of Myers (1980:17), Nathan *et al.* (1983:132), Garraway and Macleod (1995:1485), Lee and Garraway (1996:214) and McManus (2000:342). Table 3.1 shows how each of these researchers graded injury. The definition of McManus (2000:342) is significant in that the author devised the four definitions following a review of previous injury definitions and data collection instruments used in published literature. This grading system includes categories for all injuries and incorporate the most commonly used definition (player missed one week) to allow some comparison of results with previous and current sports injury studies. The definition of Garraway and Macleod (1995:1485) is also useful as it codes injuries according to the International Classification of Diseases (9th revision). Many

South African studies used this definition to code the severity of injury. Most of these definitions agree with the general view that injuries are graded as significant if the athlete is disabled for 7 days or more (Armsey & Hosey, 2004).

To summarise, there are still many inconsistencies in the definition of a significant rugby injury and the severity of the injury. In order to facilitate the comparability and validity of research, the researcher must ensure that he/she chooses the most up-to-date, topic-specific and generally acknowledged definitions for the purpose of his/her study. For the purpose of this study the rugby injury definition of Garraway and Macleod (1995:1485) will be used, while the severity of injury will also be defined according to the definition of Garraway and Macleod (1995:1485).

Table 3.1: The severity of rugby injuries graded according to the duration of sporting time lost

Author	Severity	Description
Myers (1980)	▶ Trivial	▶ Minimal interference with performance. No active treatment required.
	▶ Minor	▶ Interfering with performance or requiring active treatment, but injury is not expected to prevent the player from playing in one week.
	▶ Major	▶ Injury requires active treatment expected to prevent the player from playing for up to five weeks.
	▶ Serious	▶ Potentially life-threatening injury. Requires hospital admission or is expected to prevent the player from playing for more than five weeks.
Nathan <i>et al.</i> (1983)	▶ Grade I	▶ Injury prevented player from returning to rugby for at least one week.
	▶ Grade II	▶ For up to three weeks.
	▶ Grade III	▶ More than three weeks.

Table 3.1 continues

Author	Severity	Description
Garraway & Macleod (1995);	▶ Transient	▶ Missed fewer than 7 days from training or playing in matches.
	▶ Mild	▶ 7 to 28 days.
Lee & Garraway (1996)	▶ Moderate	▶ 29 to 84 days.
	▶ Severe	▶ More than 84 days.
	▶ Minor	▶ The player was able to return to the game or training in which the injury occurred.
McManus (2000)	▶ Mild	▶ The player missed one week.
	▶ Moderate	▶ The player missed two weeks.
	▶ Severe	▶ The player missed more than two weeks.

3.4 CONSEQUENCES OF RUGBY INJURIES

Unwanted socio-economic consequences of sports injuries are often the direct and indirect costs associated with injury. Direct costs are the costs of medical treatment (X-rays, doctors' fees, cost of medicines, admission costs, etc.), while indirect costs may be things such as absence from work, working time lost, lost study time and permanent damage (Van Mechelen *et al.*, 1992).

In recent years, the leading rugby nations have expressed increasing concern with regard to the long-term consequences of rugby injuries. One of these concerns is the financial implications of rugby injuries (Noakes & Du Plessis, 1996). For example, it has been thought that many of the 1998 Springboks were playing with injuries for fear of losing their match fees (Dobson, 1999). This is also true for Australia, where many players have incentive-based contracts and would therefore sacrifice income if they missed games (Bathgate *et al.*, 2002). Furthermore, the alarming increase in injury rates impacts negatively on playing life (Hattingh, 2003). This could adversely affect a player's income, as well as player availability. In New Zealand, the cost of rugby injuries during 1990 was judged to be NZ\$19.3 million (Dixon, 1993). In a country like South Africa – which has even more rugby players – the cost of rugby injuries could be more. Affordable and accessible accident

insurance and medical cover is necessary to ensure that players are protected against these financial implications of rugby injuries.

In what was possibly the first scientifically published study of rugby injuries among amateur players, O'Connell (1954:20) remarked that "employers are not so inclined to take a lenient view of absence from work which may be due to sports injuries, whilst the premium for accident insurance for sports (and especially rugby) has become almost prohibitive for younger players". By 1979, few of the English schoolboys who suffered cervical spine injuries were covered by accident insurance, which left them not only paralysed, but also with an enormous financial burden (Hoskins, 1979). In 1996, Noakes and Du Plessis (1996:226) expressed concern for the provision of adequate insurance cover for rugby players in South Africa. The authors emphasised the very high financial cost of catastrophic injuries, injuries requiring surgery and the cost of rugby injuries on a national scale. In South Africa, the problems were that it would be difficult to force all players to take out insurance and consequently, if only a small proportion of players took out insurance or full coverage for catastrophic injuries, the cost of these policies would be prohibitive. To date, there has been a change in the South African situation. Currently, there are some insurance companies who are willing to cover rugby players. However, an analysis of the costs of insurance could not be found in the literature.

Considering the consequences of rugby injuries to young players, Garraway and Macleod (1995:1487) have demonstrated that rugby injuries are an important source of morbidity in these players. Their research revealed a high level of incapacity due to injury. Apart from the fact that players lost time from games or training, this also had economic implications. The authors revealed that in almost a third (28%) of injury episodes players lost time from employment or education – a mean of 18 days.

When comparing rugby played at school level with that played at senior level, it was found that injuries at school level were not as serious and less time off was lost (Lee & Garraway, 1996). The authors found that 16% of all schoolboy match injury episodes resulted in missed school attendance compared with 27% at senior club level, which involved loss of

employment or education. For players missing work or education following a match injury, the mean duration of absence (from the date of injury to the date of return) was 3.6 days for schoolboys and 18 days for club players (Lee & Garraway, 1996).

To sum up, it is clear that there are several consequences of rugby injuries. A cost-benefit analysis of the positive and negative effects of rugby activities on a player's socio-economic position may be needed to calculate the exact consequences of rugby injuries. Data of this nature can be used by insurance companies to compare the cost of rugby injuries to other situations involving risks, such as work and traffic. An injury registration system is essential for the assessment of the total cost associated with sports injuries (Tolpin *et al.*, 1981). This system should be reliable, continuous and identify the expenses of rugby. Furthermore, players today should be fully aware of the level of insurance in their contracts and there should be more support structures in place to advise rugby players on their entitlements and to which direction their life could go after serious injury. Finally, a national insurance policy, which also accommodates accident insurance for South African schoolboys and amateurs, should be considered.

3.5 RUGBY INJURY INCIDENCE

Injury incidence is defined as the number of new injuries in a fixed time period divided by the number of people at risk (Steiner *et al.* as quoted in Whiting & Zernicke, 1998). Injury incidence is important because it determines patterns of injury and identifies dangers in the game. Incidence values are useful in estimating and evaluating the level of risk for participants in sport (Fuller & Drawer, 2004).

The injury incidence can also be expressed in terms of *injury rate*, which is the number of injuries in a population divided by a reference number (Whiting & Zernicke, 1998). A reference measure can be the number of hours of exposure, the number of kilometres run, games played, etc. Examples of injury rates would include the number of injuries per year, injuries per match, injuries per season, injuries per 1000 players or injuries per 1000 hours of rugby participation (Van Mechelen *et al.*, 1992; Whiting & Zernicke, 1998). Because

published studies have reported data with different denominators, it is not always possible to generalise results on a broad scale (Armsey & Hosey, 2004). Van Mechelen *et al.* (1992:83) propose that sports injury incidence should preferably be expressed as number of sports injuries per exposure time (e.g. per 1000 hours of participation). This facilitates the comparability of research results. One should also be aware of differences between training and competition, as well as differences between overall time spent on sports participation and actual exposure time at risk (Van Mechelen *et al.*, 1987; Van Mechelen *et al.*, 1992). Previous rugby studies have quoted these rates of injury incidence in a variety of ways.

As with the injury definition (paragraph 3.3), the definition of injury incidence in rugby has changed over time (Hattingh, 2003). The earliest literature on injury incidence dates back to medieval times. In this period, injury incidence was associated with the *total amount of gross disablement or unfortunate death* associated with a game (Noakes & Du Plessus, 1996; Hattingh, 2003). In 1954, O'Connell (1954:20-26) published the first study of injuries in rugby union (O'Connell, 1954). During this time, injury per player-hour rate was still unheard of (Hattingh, 2003). In 1973, Roy (1974:2322) reported the injury rate in different quarters of the game. In accordance to previous studies in American football, Roy (1974:2321-2322) defined injury rate as number of *injuries per month/year*. In subsequent years Meyers (1980:18) reported an injury rate of 0.032 *injuries per player-hour*, or 1.23 *injuries per game* or 0.041 *injuries per player appearance*.

During the same period (1980-1983), Sparks (1985:71) studied the injuries sustained by players at an English public school in the town Rugby. Sparks (1985:71) reported an injury incidence of 194 *injuries per 10 000 player hours*, or 0.019 *per hour*. A study by Nathan *et al.* (1983:132) on schoolboy rugby, again expressed injury incidence as *per player hour* (15 players playing for one hour equals 15 hours of rugby). He reported one injury for every 243 *boy-hours* played at secondary school level and 1/1044 *boy-hours* at primary school. Roux *et al.* (1987:308) used the same method as Sparks (1985:71) and Nathan *et al.* (1983:132) to describe injury incidence. Roux *et al.* (1987:308) found an overall injury incidence of 1/142 *boy-hours* in match play and 1/1 825 during practicc. Davidson (1987:119) in his study on

schoolboy rugby injuries reported an injury incidence of 176/10 000 *player-hours*, or 1.56/100 *player-games*.

In the early 1990s another researcher also used a similar definition than that used by Nathan *et al.* (1983:132) and Roux *et al.* (1987:308). This author found an overall injury incidence rate of 1/171-*player hours*, with 1/60 during matches and 1/780 during practice (Clark *et al.*, 1990). In the 1990s, Badley (1990:1) again expressed injury incidence in a different way. He described injury incidence as losing a player every *x* games, or alternatively an individual player presenting with an injury every *x* games.

During the mid 1990s, Garraway and Macleod (1995:1486) were among the first to describe injury period prevalence in rugby in terms of *injuries/1000 player hours*. They (Garraway & Macleod, 1995) reported 13.95 injuries per 1000 player hours, which equals an injury episode every 1.8 rugby matches. In the same period of time there were other researchers who differed from Garraway and Macleod (1995:1486) in their description of injury incidence. For example, Lee and Garraway (1996:214) expressed injury rate as *injuries/player-seasons*. They reported an injury incidence at senior club level of 160.4/1000 player-seasons. Bird *et al.* (1998:321) also differed from Garraway and Macleod (1995:1486) in their description of injury incidence. They described rate of injury incidence as *injuries per 100 player-games*. According to Bird *et al.* (1998:321) males, at 10.9 injuries per 100 player-games, had a higher injury incidence than females, at 6.1 injuries per 100 player-games. With the change to professionalism, it seems as if the injury incidence used by Garraway and Macleod (1995:1486) became the most popular.

With the third Rugby World Cup held in South Africa, Jakoet and Noakes (1998:46) used the same method of Garraway and Macleod (1995:1486) to calculate the frequency of injury for this competition. Jakoet and Noakes (1998:46) reported a frequency of 32 injuries *per 1000 player-hours* in the preliminary rounds and a frequency of 43 in the last seven final-round matches. Also using the same description of injury incidence, Targett (1998:280) documented injury rates of professional rugby players playing in the Rugby Super 12 competition. He found a high incidence rate of 120/1 000 *player-hours* and expressed the

need for ongoing research to use accurate, standardised methods of data collection and description.

In 2001, Babic *et al.* (2001:395) reported an injury incidence of 28.22 *per 1 000 player hours* during matches, and 1.24 during training for first-league rugby players in the Croatian-Slovenian league. These results correlated well with the earlier findings of Jakoet and Noakes (1998:46). In 2001 a South-African study on the professional teams participating in the 1999 Rugby Super 12 competition recorded an overall injury incidence of 55.4 *injuries/1 000 player game hours*, and 4.3 *injuries/1 000 player training hours* (Holtzhausen, 2001). More recent literature by Bathgat *et al.* (2002:265) still use *injuries/1 000 player-hours* to describe injury incidence. This study recorded an overall injury incidence rate of 69/1 000 player hours for elite Australian rugby players (Wallabies). Bathgat *et al.* (2002:265) emphasised that with the coming of professionalism, injuries increased from 47/1 000 player-hours during the pre-professional era, to 74/1 000 player-hours in the professional era.

From the information on injury incidence a few things are clear. Firstly, a change in the expression of injury incidence over time is observed. Secondly, because of these different definitions, rugby injury data are not always comparable. This is probably because the direct comparisons of incidence rates and frequencies across levels of injury severity are complicated by differences in categorisation of information and how injury itself, severity of injury and specific diagnoses are defined. However, all data available still provide a valuable perspective on the magnitude of the rugby injury problem. Thirdly, an increase in injury incidence with the introduction of professionalism is visible. Finally, the most recent descriptions of injury incidence suggest that the injury incidence is still climbing.

3.6 INJURY FREQUENCY BY TYPE OF INJURY SUSTAINED AND ANATOMICAL SITE INJURED

To understand how rugby injuries develop, it is important to have knowledge of which anatomical structures are mostly injured, which type of injuries are most common, which mechanisms cause most injuries and who are most at risk of these injuries. To realise a part

of this objective, the frequency with which each type of injury occurs, as well as the anatomical structures most frequently injured, is discussed next.

3.6.1 MOST FREQUENT TYPE OF RUGBY INJURY SUSTAINED

An early study on the medical hazards of rugby (Walkden, 1975) stated that:

- 30.8% of rugby injuries were of miscellaneous origin;
- 25% were musculo-tendinous lesions;
- 20% were joint related;
- 6.5% were head injuries;
- 5.7% of serious injuries were fractures;
- Cutaneous injuries were the main reason for the rise in injury epidemiology seen from 1970.

This study already indicated the high incidence of the musculo-tendinous type of injury.

In a study on the nature of rugby injuries experienced at one school, Nathan *et al.* (1983:134) reported that concussions and muscle injuries were most common (21.5 % each), followed by ligament injuries (17.7 %) and fractures (15.2 %). A later study by Roux *et al.* (1987:310) reported fractures (27%), ligament/tendon injuries (25%) and muscle injuries (17%) to be the most common types of injury among South African schoolboys. Except for a lower incidence of concussions, this agrees with the earlier study of Nathan *et al.* (1983:134). Roux *et al.* (1987:311) explained that because schools were monitored via correspondence, underreporting of injuries, in particular concussions occurred.

A recent study by Hattingh (2003:150) also reported that sprains were the most commonly recorded injury for both 15-year old (39.33%) and 18-year old (35.02%) elite schoolboys. This study differed from the studies of Nathan *et al.* (1983:134), who recorded concussions as the most common type of injury and Roux *et al.* (1987:310), who recorded fractures to be the most common. Although not confirmed by recent rugby studies, a high number of fractures is still visible in young rugby league players (Gabbett, 2004). Hattingh (2003:150)

attributed these phenomena to the changes and evolutions of the game seen in the last decade. This trend of a high occurrence of muscular and ligament strains and sprains at school level was also confirmed for club rugby. In studies on club rugby, Bird *et al.* (1998:319) reported the most common type of injury in both club matches (46.7%) and training (76.1%) to be strains/sprains, while Babic *et al.* (2001:397) also reported dislocations, sprains and strains to be the most frequent.

The following figure by Gerrard *et al.* (1994:230) represents rugby related-injuries sustained by a combination of male as well as female club and school rugby players. In figure 3.2 rugby injuries are presented according to the different types of injury. The majority of injuries sustained by this combined group of players were sprains, strains and other soft-tissue injuries. Again, this correlates well with other work (Nathan *et al.*, 1983; Bird *et al.*, 1998).

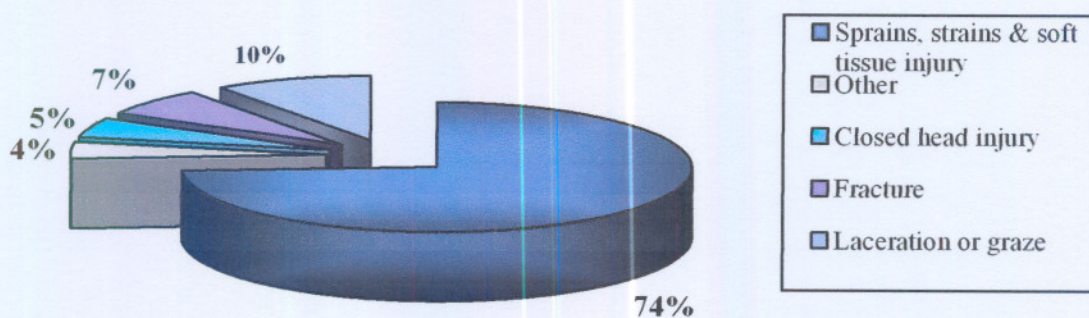


Figure 3.2: Distribution of type of injury (Gerrard *et al.*, 1994)

Considering rugby at professional level, Jakoet and Noakes (1998:45) found that 71% of injuries sustained during the 1995 Rugby World Cup were either ligamentous, muscular or lacerations. This was confirmed by Targett (1998:282), who reported that the majority of injuries during a professional rugby competition (Super 12) were musculo-tendinous strains and sprains (28.6%), contusions (22.4%), and ligament sprains (16.3%), regardless of grade.

Furthermore, more than half (56%) of days lost to the game during the professional era were caused by injuries sustained to the muscles, ligaments and joints of the lower limb regions (Garraway *et al.*, 2000). During 2001 it was confirmed that most (50%) of all injuries sustained at professional level in South Africa were either ligament sprains or musculo-tendinous strains (Holtzhausen, 2001).

The above-mentioned research indicates that muscle strains and ligament/tendon sprains are the most common injuries in both senior club and professional rugby players, but that the relative proportion of these injuries differs between the groups. The high incidence of fractures among schoolboys may reflect the relative immaturity of adolescent bones which only gain their full strength in adulthood (Noakes & Du Plessis, 1996). A possible reason for the higher incidence of muscle injuries among senior players is that they run faster and are therefore more likely to sustain these injuries (Noakes & Du Plessis, 1996).

3.6.2 ANATOMICAL SITE MOST FREQUENTLY INJURED

During earlier years the head and shoulder were the body parts most often injured (O'Connell, 1954). Later on, during the 1979 season in Brisbane, Australia, Myers (1980:17) documented injuries presenting from rugby union football. Myers (1980:18) still found the head and neck to be the most frequently injured anatomical region (52%), followed by the lower limb (21%), the upper limb (19%) and the trunk (8%). Although this partly supports the earlier research of O'Connell (1954:21), there exists additional literature which indicates that serious injuries to the head and neck were increasing.

In this regard, Hoskins (1979:365) gathered data from all spinal injury units in the United Kingdom, and requested information from medical officers and headmasters of rugby-playing schools. The incidence of these injuries and their seriousness can be seen in Table 3.2. From these results Hoskins (1979:366) concluded that there was an evident increase in *schoolboy* cervical spine injuries. During the same period, South Africa was also plagued by the rising incidence of catastrophic cervical spine injuries (Scher, 1977). Sadly, it took the tragic death of two players (Chris Burger in 1980 and Petro Jackson in 1989) to spark a series

of new research studies on rugby injuries in South Africa (Noakes & Du Plessis, 1996). Internationally, similar occurrences also initiated more research on the incidence and nature of rugby injuries post-1980.

Table 3.2: Occurrence of cervical spine injuries

Time span	Injury incidence	Consequences
1942 - 1968	5	fatal/tetraplegia
1973 - 1978	12	fatal/tetraplegia
1971 - 1978	16	No permanent neurological deficit, prolonged morbidity
36 years	33	

The results of some of this new research are reviewed in Table 3.3. Table 3.3 emphasizes the frequency with which injury occurred at the four major anatomical sites, as found in some of the international and local research articles. From Table 3.3 it is apparent that the majority of injuries occur to the lower limb. This shows that although the incidence of catastrophic spinal cord injury may have increased up to the mid 1980s, the percentage of injuries to the total head and neck area – not only the spinal area – actually decreased from the late 1980s onwards (Sparks, 1985; Clark *et al.*, 1990). This represents a change from the large percentage of injuries attributed to the total head and neck area during earlier years. The probable reasons for this are the implementation of rule changes aimed at reducing catastrophic spinal injuries during the early 1980s, as well as the evolutionary changes in the way the game is played.

Table 3.3: Incidence of injury by anatomical region according to different authors

	Region	Sparks (1985)	Clark <i>et al.</i> (1990)	Jakoet & Noakes (1998)	Bathgate <i>et al.</i> (2002)	Hattingh (2003)
Subjects		Schoolboy	Senior club	World cup	Senior elite	Elite 15-year old
	Lower limb	36%	44%	42%	52%	55%
	Head and neck	27%	23%	26%	29%	16%
	Upper limbs	27%	27%	29%	15%	14%
	Trunk	10%	7%	3%	4%	15%
	Not specified					

Other researchers (not shown in Table 3.3) also highlighted the anatomical regions most frequently injured (Nathan *et al.*, 1983; Roux *et al.*, 1987). In this regard, a study on the incidence and nature of rugby injuries experienced at one South African school during the 1982 rugby season found the anatomical regions most affected were (Nathan *et al.*, 1983):

- Upper limb (29%);
- Lower limb (25%);
- Head and face (25%);
- Neck, (13%); and
- Trunk (8%).

These findings correlated well with those of Meyers (1980:17), but differed slightly from the findings of Sparks (1985:72) (see Table 3.3). Another study at school level, this time by Roux *et al.* (1987:310) in South Africa, correlated with the study of Sparks (1985:72). This study found the lower limb (37%), followed by the head and neck (29%) and the upper limb (20%), to be highest at risk. The lower limb was also identified as the most commonly injured body part at senior club level (Addley & Farren, 1988; Babic *et al.*, 2001) in the RIPP II study (Gerrard *et al.*, 1994); at junior as well as senior level (Clark *et al.*, 1990; Garraway & Macleod, 1995; Bird *et al.*, 1998; Bottini *et al.*, 2000; Garraway *et al.*, 2000); at

professional level (Jakoet & Noakes; 1998) and among elite players in the amateur as well as professional era (Bathgate *et al.*, 2002). The findings of these studies differed from those of Targett (1998:282) on professional Super 12 rugby, who found the head and neck to be the most commonly injured areas. However, the injuries in the Targett (1998:282) study were mostly lacerations requiring suturing and not the serious neck injuries commonly seen in earlier studies.

In summary, the data in this discussion show that the lower limbs are most frequently injured and that there is no marked difference in the relative anatomical distribution of these injuries between seniors and schoolboys. The next important analysis is that the frequency of head and neck injuries still remains high. Although head and neck injuries are less frequent than in the past, concussions are still common among schoolboys (Noakes & Du Plessis, 1996). Since the start of the modern era (post 1996), a lack of documented research on schoolboy rugby injuries has been experienced (Hattingh, 2003).

In the year 2002, South African schools were again plagued by an increase in catastrophic cervical spine injuries. Consequently, a taskforce was charged by SARFU (the South African Rugby Football Union) to deal with this new trend (Hattingh, 2003). In a discussion between a team of experts and the South African Minister of Sport at the time (2002), the reduction of these injuries was discussed (Steyn, 2005). During this discussion the possibility of an intrinsic factor that predisposes a schoolboy rugby player to a cervical spinal cord injury was discussed. At the time no specific intrinsic factor could be identified. Since then, Steyn (2005) completed a thesis at the North-West University, concluding that a therapeutic exercise programme for the correction of such an intrinsic factor – namely *biomechanical dysfunction of the cervical spine* – “is effective in correcting biomechanical dysfunction found in schoolboy rugby players as well as safe for players without dysfunction. Thus this programme could be implemented for all schoolboy rugby players without physiotherapy evaluation or x-rays to test for possible dysfunction” (Steyn, 2005). This programme could prove valuable if implemented as part of a spinal cord injury prevention programme, owing to the fact that it significantly corrected cervical biomechanical dysfunction, as well as improved neck muscle strength (Steyn, 2005).

3.7 ETIOLOGY OF RUGBY INJURIES

While the surveys and surveillance on injury incidence mentioned in the beginning of this chapter do indicate that rugby injuries are an important problem, this alone does not provide the information necessary to prevent injuries (Jones & Knapik, 1999). The foundation of an effective injury prevention programme is detailed knowledge of the causes or risk factors of injury, which requires focused research (Jones & Knapik, 1999).

Since the first studies on injury epidemiology, researchers wanted to know the possible reasons why these injuries occurred (Hattingh, 2003). If injury incidence was dependent on exposure only, a constant injury rate would be seen (Alsop *et al.*, 2000). Modern researchers still emphasise the need to identify the different causes of an injury problem. Jones and Knapik (1999:116) state that, after a problem such as training injuries has been identified, the next step in the control process (see Figure 3.1) is to identify causes and risk/contributory factors of injury.

An injury *risk factor* is something that contributes to increasing the probability of an injury (Whiting & Zernicke, 1998). This hazard is any condition, object or situation that may be a potential source of harm to people (Fuller & Drawer, 2004). It should not be confused with *mechanisms*, which establish a cause-and-effect relation. A characteristic of risk factors is that if the risk factors remain unchanged, then the same injury incidence can be expected to recur (Meeuwisse, 1991). Simple survey and research methods can be used to identify these risk factors.

Modern studies which attempt to identify risk factors must control for the interrelationship that exists between single risk factors (Jones & Knapik, 1999). These studies should employ multivariate analysis of data in order to identify the most significant single risk factors or combinations of risk factors. Previous methods employed to study risk factors for exercise-related injuries include Mantel-Haenzel stratified χ^2 tests, logistic regression analysis, survival analysis and proportionate hazard models (Jones & Knapik, 1999). When studying

the risk factors of sports injuries, the choice of research design is also important (Van Mechelen *et al.*, 1992). Because case series usually give little information on the population at risk, research on risk factors should be undertaken on homogeneous groups (Van Mechelen *et al.*, 1992). Table 3.4 highlights some risk factors for training/sports injuries identified by military, civilian and different sports medicine studies (Van Mechelen *et al.*, 1992; Jones & Knapik, 1999). These factors can be categorised as either intrinsic or extrinsic in nature (Noakes & Du Plessis, 1996; Jones & Knapik, 1999; Rossouw & Rossouw, 2003). Both types of risk factors can modify the likelihood of a participant's sustaining an injury and/or the severity of the injury sustained (Fuller & Drawer, 2004).

Table 3.4: Intrinsic and extrinsic risk factors that may play a part in sports and training injuries (Van Mechelen *et al.*, 1992; Jones & Knapik, 1999)

INTRINSIC FACTORS	EXTRINSIC FACTORS
Postural/anatomical/biomechanical defect	Sports-related factors
Physical fitness	type of sport
muscle endurance	exposure
aerobic endurance	nature of event
strength	role of opponents and team mates
speed	Venue
sporting skill/coordination	state of floor or ground
flexibility of muscles	lighting
Previous injury	safety measures
Psychological factors	Equipment
self-concept	tools e.g. stick or racket
risk acceptance	risk acceptance
type A and type C personality	protective equipment
locus of control	other equipment (shoes, clothing etc.)

Table 3.4 continues

Physical build	Weather conditions
height	temperature
weight	relative humidity
joint stability	wind
body fat	Trainer
Age	conduct of match
Sex	rules
Gender	referee's application of rules
Sedentary (inactive) lifestyle	Type of training
Tobacco use	

When a given task is performed, the different intrinsic and extrinsic risk factors interact to set the level of risk for a particular individual during a specific performance (McGinnis, 2005). The intrinsic factors taken together *set the threshold value* for the stress that may cause an injury (McGinnis, 2005). The sum of the extrinsic factors reflects the *potential* of the relevant performance/task to *exceed this threshold value* (McGinnis, 2005). Therefore, risk of an injury during a task can be considered an interaction between the intrinsic risk factors characterising the individual and the extrinsic factors characterising the specific task and the environment in which it is performed (McGinnis, 2005). The total risk can therefore be considered as the probability or likelihood that a risk factor will have an impact on people (Fuller & Drawer, 2004). Up to now, multiple intrinsic and extrinsic risk factors have been identified for rugby injury. The main risk factors will be discussed in the following paragraphs.

3.7.1 INTRINSIC INJURY RISK FACTORS

Intrinsic risk factors are inherent characteristics of individuals, specific to the particular individual (Jones & Knapik, 1999; Quarrie *et al.*, 2001). Injuries which commonly result from these risk factors do not result from external trauma, but usually from repetitive overuse of the body (Noakes & Du Plessis, 1996). These risk factors will become more prominent in

the future, as rugby players are required to undertake pre- and in-season training programmes that include running and weight training (Noakes & Du Plessis, 1996). Intrinsic risk factors for rugby injuries can be divided into physical, psychological and demographic factors. These different categories of intrinsic risk factors will next be discussed in more detail.

3.7.1.1 Physical characteristics

Table 3.4 lists some intrinsic physical characteristics for training or sports injuries (Van Mechelen *et al.*, 1992; Jones & Knapik, 1999). Factors that may be more specific to rugby injuries are physical characteristics, such as: injury history (previous injury, carrying injury) (Lee *et al.*; 2001); physical fitness levels during different times of the season (Noakes & Du Plessis, 1996); postural/anatomical/biomechanical factors (Twellaar *et al.*, 1997); and anthropometric factors (physical build, size of player) (Olds; 2001).

(a) Injury history

In basketball, a history of ankle injuries was the strongest predictor for the occurrence of ankle injuries (McKay *et al.*, 2001). Previous injury was also an indicator of future injury in body contact sports (Watson, 2001). Proprioceptive disturbances, muscle weakness and persistent instability associated with previous injury were emphasised as the main cause of reinjury (Ekstrand & Gillquist, 1983a; Ekstrand & Gillquist, 1983b). Furthermore, different cross-sectional and longitudinal studies confirmed that individuals who suffered previous limb injuries often exhibited less strength in that limb compared with the uninjured limb (Knapik *et al.*, 1992). In American football, returning to action before pain, tenderness and range of motion returned to normal was found to increase the likelihood of further neck injury (Albright *et al.*, 1985). All of the above emphasise the need for complete rehabilitation before returning to the sports field.

An early study by O'Connell (1954:24) on 600 rugby union injuries suggested that returning players to the game before proper rehabilitation played a role in subsequent injuries. This is probably because, following a serious injury, elements of the injury may persist, whether physically or psychologically (Whiting & Zernicke, 1998). The condition of the repaired tissues are often not equal to their pre-injury condition and for many reasons may be more

susceptible to subsequent injury. A player's psychological status following an injury can also be different, as the prior injury can stay in the mind (Whiting & Zernicke, 1998). It is known that success in returning a person to pre-injury status depends on the nature of the injury, the person's motivation, the expertise of the rehabilitation therapist and the sophistication of the available rehabilitation methods (Whiting & Zernicke, 1998). This is also valid for rugby.

Concerning rugby, the Rugby Injury and Performance Project II (RIPP II) identified the previous injury experience of a rugby-playing cohort in New Zealand in 1993 (Gerrard *et al.*, 1994). The study revealed that a significant number of players could be expected to carry the consequences of a previous injury to the following season. The data showed that players were keen to return to trial games and selection opportunities despite inadequate rehabilitation. Almost 40 percent (39%) of players refused to adhere to the conservative medical opinion and regarded chronic and intrinsic injuries poorly. This underlined the need for trained, experienced and specialised medical personnel in rugby. Also highlighting the effect of previous injury is the fact that the whole Springbok squad – except for three players – was injured at the end of the 1998 tour. More than 50 % of these injuries were previous injuries (Dobson, 1999).

In another rugby-related study Lee *et al.* (2001:412) found a 61% increase in the risk of injury for those players who had been injured or were carrying an injury at the end of the previous season. The authors claimed that this could have been because players did not allow previous injuries to heal sufficiently before returning to the game. It confirms the need for adequate medical advice and rehabilitation following rugby injury. Supporting these findings, early return to play after injury was found to be one of the reasons for a high incidence of recurrent injuries among professional rugby players (Holtzhausen, 2001).

(b) *Physical fitness levels*

It is well known that adequate physical conditioning is necessary to reduce rugby injuries, particularly those that are sustained early on in the season or after the mid-season break (Derman & Schwellnus, 1996). A study by Sparks (1985:71) on school rugby played at

Rugby, England, also blamed a high injury incidence on unfitness. In contrast to this popular belief, Myers (1980:19) stated that players with the highest fitness also had the highest injury rate. According to the author this could probably be attributed to increased vigour, determination, speed of play and possibly increased malice among these players. In general, physiological fatigue has been suggested as the possible reason for rugby injuries related to unfitness (Noakes & Du Plessis, 1996).

It is known that neural and muscular fatigue increases the likelihood of injury because of compromised muscle strength, movement co-ordination, mental attentiveness and concentration (Kersey & Rowan, 1983; Noakes & Du Plessis, 1996). It is common for these fatigue-related injuries to happen later in an activity period (Whiting & Zernicke, 1998). Fatigue due to possible unfitness may be reflected in the time course of injuries within a game (Wekesa *et al.*, 1996). By dividing a rugby match into quarters, it becomes possible to note the amount of injuries that occur in different periods of play.

At Rugby School in England it was found that the majority of injuries occurred in the first and last quarters of matches played (Sparks, 1981). In studies on senior players, most of the injuries occurred either in the third quarter (Williams, 1984; Holtzhausen, 2001) or the last quarter (Davies & Gibson, 1978), while the smallest number of injuries occurred in the first two quarters (first half). In another recent study (Bathgate *et al.*, 2002) the third quarter was again the period of most injuries to elite players (40%) (amateurs and professionals), while the first quarter remained the safest period (9%). One researcher attributed the excess of injuries in the third quarter to a possible influence of “psyching up” at halftime (see paragraph 3.7.1.2 for *psychological* factors) (Williams, 1984), while Bathgate *et al.* (2002:268) showed that the high risk during the third quarter was not due to law changes allowing substitution of uninjured players, but rather to other possible factors such as reduced concentration after the half time break.

Wekesa *et al.* (1996:61) confirmed the excess of injuries in the last two quarters of the game, when he showed that only 38.3 % of injuries occurred during the first half of play, while 61.7% occurred during the second half. These results suggest that players become more

fatigued during the second half, increasing their risk of injury. Today, “impact players” (substitutions) are introduced into rugby matches after an hour’s play, immediately taking advantage of the more tired players and increasing this risk of injury towards the end of matches (Wilson, 2000).

All-in-all, this agrees with recent findings from rugby league, where overexertion is the most common cause of training injuries (Gabbett, 2004). According to Gabbett (2004:850), player fatigue may influence the incidence of injury, with most sub-elite (amateur and semi-professional) rugby league injuries occurring in the second half of matches or the latter stages of training sessions. Practising game-specific attacking and defensive drills before and during fatigue may encourage players to make appropriate decisions under these fatigued conditions and teach them to apply learnt skills during the pressure of competitive matches, possibly reducing the risk associated with fatigue (Gabbett, 2004).

(c) *Anthropometric factors*

These factors have already been discussed in chapter 2, paragraph 2.3.2.

(d) *Abnormal biomechanics / postural malalignment*

There is a significant risk of injury when undertaking physical activities (Neely, 1998). Whatever the severity of injury, however, most injuries have a mechanically related etiology (Whiting & Zernicke, 1998). In this regard, abnormal biomechanics (abnormal postural symmetry, dynamic mobility/flexibility and core stability) has been implicated as a causative factor for injury. Often, a biomechanical abnormality in itself is not an independent risk factor, but the compensatory effects resulting from the abnormality may be of more significance (Neely, 1998).

These biomechanical factors are related to how well an individual copes with imposed mechanical stress (see paragraph 3.8.1.4a) – that is, to how an imposed force creates stress within an individual, and to how well the tissues are adapted to the level of stress (McGinnis, 2005). The underlying biomechanical problems could prevent an athlete from training as long or intensely as another athlete before incurring an intrinsic injury (Hreljac *et al.*, 2000).

The majority of intrinsic injuries occur during sports which involve running (Neely, 1998). When running, one's feet normally contact the ground with between two and five times the bodyweight (Subotnick, 1985; Donatelli, 1987). These excessive forces are normally reduced by the dynamic action of muscle, periarticular tissue strength, flexibility and proper arthrokinematics (Donatelli, 1987; Neely, 1998). Therefore it is clear that proper biomechanics are crucial in absorbing these forces. Indeed, it has been proven that runners who have developed good biomechanical stride patterns are at a reduced risk of incurring intrinsic running injuries (Hreljac *et al.*, 2000). Regarding research into the mechanics of musculoskeletal injury, it has been found that much of the epidemiological information cannot be used easily because it is described according to circumstance (e.g. injury due to a tackle in rugby) rather than by the specific mechanism (how it happened, e.g. the physical process responsible for the tackle injury in rugby) (Whiting & Zernicke, 1998).

Available research does suggest, however, that postural malalignment/poor biomechanical position can be a factor in the occurrence of an intrinsic injury in children as well as adults (Micheli, 1983; Bartlett, 1999). Several studies reviewed by Watson (2001:222) have also demonstrated a link between postural defects (poor biomechanics) and injuries. Furthermore, evidence suggests that biomechanical and postural abnormalities like leg length discrepancy, pelvic obliquity, increased lumbar lordosis, genu valgus, limitation of ankle dorsiflexion, limitation of range of hip eversion, excessive joint laxity, leg length discrepancy, excessively pronated or supinated feet, excessively high or low foot arches, foot kinematics and a large Q-angle are risk factors for injury (Micheli, 1983; Twellaar *et al.*, 1997; Neely, 1998; Jones & Knapik, 1999; Hreljac *et al.*, 2000). These malalignments of the extremities may cause abnormal stress on the joints and muscles involved in sport, causing micro-traumatic damage and ultimately intrinsic injuries (see paragraph 3.8.1.4a). Alternatively, when a person alters his or her movement patterns (biomechanics) in response to the pain or dysfunction of a primary injury, the altered movements distribute loads through other joints in the body (Whiting & Zernicke, 1998). These changes in loading may cause a second injury, remote from the primary injury (Whiting & Zernicke, 1998).

As regards flexibility (subdivision of biomechanics, see paragraph 2.3.3.1), some researchers have found a U-shaped relationship between musculoskeletal injuries and flexibility (Knapik *et al.*, 1992), while others were unable to confirm this relationship (Watson, 2001). However, several authors have claimed that flexibility and stretching are beneficial to injuries (Cahill & Griffith, 1978; Smith *et al.*, 1991; Dalton, 1992; Whiting & Zernicke, 1998). Some recent studies have shown that stretching programmes can significantly influence the viscosity of the tendon and make it significantly more compliant, and when a sport demands a high intensity of stretch-shortening cycles (e.g. soccer and rugby), stretching may be important for injury prevention (Witvrouw *et al.*, 2004).

There is little scientifically based prescription for flexibility training and it is difficult to make conclusive statements about the relationship of flexibility to athletic injury (Gleim & McHugh, 1997). This is probably the result of a lack of consensual definitions and measurements and a lack of scientific understanding of the determinants of flexibility (Gleim & McHugh, 1997). This compares to a degree with earlier researchers, who felt that the absence of significant relationships may have been partly due to the insensitivity of the tests used (Messier & Pittala, 1988). Also, the demands of different sports vary, and it is likely that flexibility patterns which represent risk factors for one sport may not do so for another (Gleim & McHugh, 1997; Witvrouw *et al.*, 2004). Even within the same sport, the demands of different players (position on the field) may vary (Witvrouw *et al.*, 2004).

However, there is more recent scientific evidence to suggest that stretching does increase flexibility (Schwellnus & Derman, 2001b). Researchers from the University of Cape Town's Sports Medicine Division have shown that a permanent improvement in joint range of motion (flexibility) can be achieved after 7-10 days of regular static stretching. This consisted of holding a stretch for 20-30 seconds and repeating it three times. Two to three of these stretching sessions per day were needed to achieve maximum benefit. In another study (Witvrouw *et al.*, 2004) on eight healthy males it was found that an eight-week injury prevention programme (two stretching sessions daily, seven days per week) made tendon structures significantly more compliant. This lessens the load across the muscle-tendon unit during movement, possibly reducing injury risk. However, there is still not enough scientific

evidence to substantiate that stretching can reduce the risk of injury, probably because most injuries are multifactorial, and to isolate one variable like flexibility is very difficult (Gleim & McHugh, 1997, Brukner & Khan, 2001; Schweltnus & Derman, 2001b). Furthermore, the optimum level of flexibility to prevent injury may vary between muscle groups and probably sports (Dadebo *et al.*, 2004). Few studies have reported the kind of flexibility training used by rugby players.

In general, research regarding flexibility concluded that loose-jointed athletes participating in contact sports (like rugby) have an increased likelihood of sprains and luxations, while tight-jointed athletes have an increased likelihood of muscle tears (Twellaar *et al.*, 1997; Neely, 1998; Whiting & Zernicke, 1998). Poor flexibility could also be indicative of muscle imbalance, which would exacerbate improper mechanics and risk of injury, once the athlete fatigues (Hreljac *et al.*, 2000). Future studies must distinguish between measures of flexibility and measures of stiffness (passive, or active, or dynamic) with careful definitions of injury and exposure, and validated indices of performance (Gleim & McHugh, 1997).

To summarise, researchers are still confirming some of the clinically noted associations between biomechanics and injuries (Brukner & Khan, 2001). The area of biomechanics and injury prevention needs to produce additional data over the next few years (Neely, 1998). However, rugby players with poor biomechanics may be at increased risk of developing intrinsic injuries. Loose-jointed rugby players may have an increased likelihood of sprains and luxations, while tight-jointed rugby players may have an increased likelihood of muscle tears. Because of high-intensity training and the nature of rugby, certain muscle groups will develop more than others (Watson, 1981). Favouring certain muscles through training faults or as an intrinsic part of certain sports may also cause muscle imbalance (Micheli, 1983; Norris, 1993; Bartlett, 1999). This may expose the rugby player to increased risk of injury under certain conditions. To decrease the risk of injury associated with poor biomechanics, the modern rugby player needs to pay attention to his total biomechanical position – ideal flexibility combined with appropriate core stability, to give a symmetrical posture.

3.7.1.2 Psychological traits

Physical factors are the primary causes of exercise and sports injuries. However, intrinsic psychological factors such as personality factors, over-estimation of ability, lack of caution, certain predisposing attitudes, trait anxiety, high or low pain tolerance, a history of stressors and coping resources also influence the stress process and, in turn, the probability of injury (Andersen & Williams, 1988; Lysens *et al.*, 1991; Weinberg & Gould, 1999; Kontos, 2004).

Research on these behavioural traits suggests that an aggressive athlete, as well as one who is not motivated, is at higher risk of injury (Schwellnus & Derman, 2001a). This correlates with the opinion of Bird *et al.* (1998:324), who commented that level of competitiveness, increased vigour and increased aggression were possible reasons for an increased injury rate on higher levels. During the qualifying tournament for the 1995 Rugby World Cup in Kenya, much the same phenomenon was observed (Wekesa *et al.*, 1996). In this tournament, the authors observed a decrease in injuries from 38.3% in the opening matches to 23.4% in the final rounds. This was blamed on a decrease in enthusiasm among the participants. Furthermore, during the 1995 World Cup, Jakoet and Noakes (1998:45) did a study on injury rate. The study (Jakoet & Noakes, 1998) supported findings that concluded that superior levels of competitiveness and commitment lead to a higher injury incidence.

Another interesting observation is that dedicated players may be at greater risk of injury than their peers because highly dedicated players may return to play earlier, despite injury (Lee & Garraway, 1996). Additionally, because of their dedication and despite their injury, more of these players might have completed the game or training session in which they were injured. This supports the view that individuals who try to compete despite medical advice and those who continue to “train through the pain” expose their body to increased risk of injury (McGinnis, 2005).

It has also been suggested that when an athlete who possesses few coping skills and little social support experiences major life changes, he or she is at greater risk of athletic injury (Weinberg & Gould, 1999). Furthermore, it has been suggested that an increase in state

anxiety is the culprit that causes distraction and irrelevant thoughts (Weinberg & Gould, 1999). For instance, a rugby player who goes for a tackle after an argument with a team mate might be inattentive to the correct position of his head when making the tackle, and injure his neck. Under these highly stressful situations an individual may also experience considerable muscle tension, which interferes with normal co-ordination and increases the chance of injury (Nideffer, 1983). Furthermore, after someone sustains an injury, these same psychological factors influence the amount of stress the injury itself causes, as well as the individual's subsequent rehabilitation and recovery (Weinberg & Gould, 1999). Moreover, according to Weinberg and Gould (1999:398), people with good psychological skills (e.g. goal setting, imagery and relaxation) deal better with stress and may therefore reduce both their chances of injury and the stress of injury (e.g., pain, physical inactivity, rehabilitating on their own, medical uncertainty), should it occur.

From the literature on psychological traits it is evident that different psychological factors are important influences before, during, immediately following the injury and in the post-injury period. Psychological factors specific to athletes include stress levels, inattention, distraction, fatigue, depression, excitation, human error, risk evaluation, personality factors and coping resources (Whiting & Zemicke, 1998). Rugby players who possess good psychological coping skills will be able to cope more effectively with situations that could increase their injury risk. Players must be taught to recognise these high-risk psychological states. Lastly, it is worthwhile noting that many individuals have a level of risk to which they wish to be exposed (Fuller & Drawer, 2004). In these cases, no matter how safe an activity is made, these individuals will seek other situations or sports that will expose them to the desired level of risk.

3.7.1.3 Demographic factors

(a) Age

From the literature there seems to exist a relationship between player age and the incidence of rugby injuries. In this regard Clark *et al.* (1990:561), in South Africa, concluded that adult players sustained more serious injuries and are more often injured. They were less likely to be injured in training and were not as much at risk than their schoolboy counterparts in the

tackle. This was explained by the suggestion that adults may be more competent tacklers, and therefore less prone to tackling injuries (Clark *et al.*, 1990). However, in total the adult players were more likely to be injured in open play.

Contrary to popular opinion (Williams, 1984; Bottini *et al.*, 2000), Clark *et al.* (1990:560) found that adult hookers were more susceptible to injury than schoolboys. Clark *et al.* (1990:560) suggested that either the players may not have been strong enough to resist the forces of the adult scrum, or that the constitution of the scrum at that time may have been too unstable. The authors (Clark *et al.*, 1990) did not mention if any differences existed between the laws which governed the scrum in adult and schoolboy rugby at the time. This could have been another possible explanation for the difference between adult and schoolboy hookers.

Lee and Garraway (1996:213) were the first to compare injuries in schoolboy rugby to senior club rugby in Britain. They concluded that rugby played at school levels was safer than that played at clubs, confirming the research of Clark *et al.* (1990:561). Furthermore, their prospective cohort study found an increase in school rugby injury incidence associated with aging. The reason for this is that the smaller size and lower strength of younger boys resulted in fewer injuries. When comparing school to club level, the older players were also more dedicated to the game, which led to an earlier return to play despite injury. Because of this dedication, more of the senior club players completed the game or training session in which they were injured (see paragraph 3.7.1.2: intrinsic *Psychological traits*). The results of this study appear to indicate that there may be other facets associated with age as risk factor for rugby injuries.

During the same period of time as Lee and Garraway (1996), the fifth Rugby Injury and Performance Project (RIPP) on injury epidemiology during a full season of club rugby was launched (Bird *et al.*, 1998). This prospective cohort study followed a combination of 356 male and female rugby players throughout the 1993 season. Players were phoned weekly to obtain information on the amount of rugby played and injury experienced (Bird *et al.*, 1998). Higher rates of injuries were identified among senior grade players. Bird *et al.* (1998:324)

explained this through the comments of Williams and Blake (quoted in Bird *et al.*, 1998:324), who identified increased strength and size of players, the higher level of competitiveness, increases vigour, increased aggression, more foul play and more matches during the season as possible reasons for this increased rate. This correlates with other research (Lee & Garraway, 1996; Noakes & Du Plessis, 1996) and consolidates the multifaceted nature of age as risk factor.

Bottini *et al.* (2000:94) studied different age injury tendencies in Argentinean rugby. They found that younger players (8-21 years of age) had a three times higher risk of muscular or ligament injuries of the cervical column than senior players (above 21 years of age) (Bottini *et al.*, 2000). The possible reason for this was lack of game skills and experience. Due to the design of this study, it did not determine if players paid attention to specific neck strengthening. This could have been another possible reason for the above differences. Overall the senior players still had a 1.53 times higher risk of injury, compared to the schoolboy players (Bottini *et al.*, 2000).

According to Noakes and Du Plessis (1996:100) it is important to know if it is possible that the phenomenon of increased injury incidence associated with aging among schoolboys happens because players play a different (more dangerous) game as they grow older, or because only players with a high risk of injury (competitive players) continue to play as they grow older. The authors answered this question by observing that players become faster, stronger and heavier with aging. As a result, when these faster, stronger and heavier players collide, their chances of injury increase. Another point in this regard is that the competitiveness and intensity with which the game is played rises disproportionately with age, so that older age groups are at greater risk of injury (Noakes & Du Plessis, 1996). Again, these observations confirm that age alone cannot explain the increase in injury risk.

To summarize, (see Figure 3.3 for the combined averages of different studies), studies indicate that the frequency of rugby injuries during match play rises with increasing age. It is almost negligible under the age of 11 (Nathan *et al.*, 1983), remains low up to age 13 (Lingard *et al.*, 1976), rises sharply up to age 19 (Roux *et al.*, 1987; Roux 1992; Noakes &

Du Plessis, 1996) and increases even further among senior players (Myers 1980; Clark *et al*, 1990; Holtzhausen, 2001). It is believed that this can be partly explained by the increased maturation, size and speed of the older players (Noakes & Du Plessis, 1996). This same pattern is visible for injury frequency during training, as well as for overall injury incidence, although the corresponding values are lower than those reported during matches. Figure 3.3 also shows that the same injury risk is not shared equally by all players of similar age (A and B teams).

When these players of similar ages play against each other, other factors must explain the differences in injury incidence (see paragraph 3.7.2.1d: *Level of play*) (Noakes & Du Plessis, 1996). It must be pointed out that although injury incidence increases with age, the inexperience of youth is sometimes also associated with an increased risk of muscular or ligament injuries of the cervical column, and concussions. One explanation for this may be that more mature athletes have superior body control and therefore put themselves at risk of injury less frequently than novices (Armsey & Hosey, 2004).

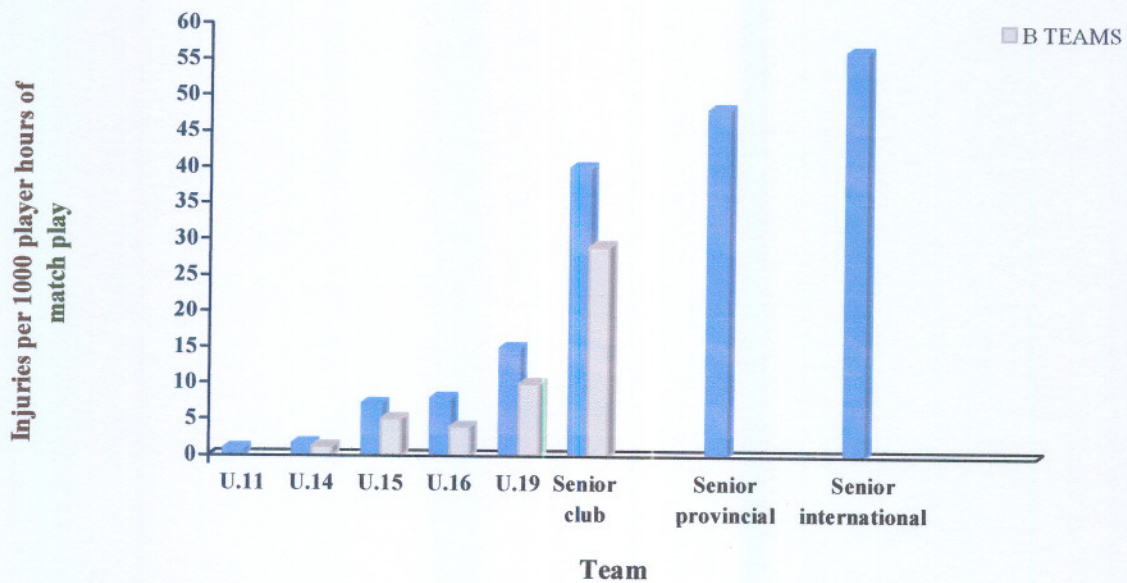


Figure 3.3: The incidence of injuries per 1000 hours of match play in players playing in different age groups and levels of play

(b) *Gender*

Although women's rugby is outside the scope of this study, it will be discussed, though only in brief. Women's rugby only recently became an organised sport (Bird *et al.*, 1998). The injury rates of female rugby players are lower than those of male players. Explanations for this are the lower body mass and sprint speeds of female rugby players (Bird *et al.*, 1998). Consequently, the momentum generated and forces at impact may be lower for female rugby players. Bird *et al.* (1998:324) hypothesised that, as the level of competitiveness in female rugby increased, the differences between the sexes would become less pronounced. It is likely that the increasing popularity of this sport will spark more research into the current scenario.

3.7.2 EXTRINSIC INJURY RISK FACTORS

Extrinsic risk factors are factors that are external to the individual. These characteristics describe the task and the environment in which it is performed and may even include officials, spectators, the media and the public (Fuller & Drawer, 2004; McGinnis, 2005). For the purpose of rugby, task-related factors may include factors associated with the game itself and the way it is played, training parameters and psychological factors, while environmental factors may include equipment, playing environment, medical regimes and refereeing, and law changes.

3.7.2.1 Factors associated with the game itself and the way it is played

When considering external risk factors associated with the game of rugby and the way it is played there are several factors which come to mind. These are player position, phase of play, level of play/level of competitiveness, foul play and rule changes.

(a) *Player position most frequently injured*

There are different ways to determine the relative risk of playing in the different playing positions in a rugby team (Noakes & Du Plessis, 1996; Targett, 1998). Injuries can be described according to the 10 different *playing positions* in a rugby team, or the 15 *individuals* playing in the different positions. It must be remembered that some positions are

represented by two players in the team, whereas others have only one. Taking this into account, the individuals in double positions during a rugby match are exposed to only half the risk of players in single positions. Thus the more relevant way to express the real proportional risk of playing in different playing positions is to correct for unequal numbers of players in the different playing positions, and thus represent the risk according to the individual playing in that position (Noakes & Du Plessis, 1996).

For comparison, Table 3.5 lists the relative risk of injury for *individuals* (after results have been converted to injury total per single player in a position) in the different playing positions in senior and schoolboy rugby. The study of Noakes and Du Plessis (1996:104) is very useful as the results are derived from a review of several other studies (Clark *et al.*, 1990; Roux *et al.*, 1987; Roux, 1992). This data of Noakes and Du Plessis (1996:104) indicate that in both senior and schoolboy rugby the loose forwards and back-line positions are the most dangerous. This is supported by subsequent studies (Targett, 1998; Bottini *et al.*, 2000; Hattingh, 2003). The high injury risk among loose forwards and back-line positions is expected, as these players are mostly involved in those phases of the game which occur at speed (Noakes & Du Plessis, 1996). The high frequency of injury among adult hookers is not supported by studies which followed later (Targett, 1998; Bottini *et al.*, 2000; Hattingh, 2003), indicating that the stability and control of the scrum may have improved.

Table 3.5: The proportional (%) risk of injury for individuals in the different playing positions in rugby

Author	Team/Level	Player position *
Roy (1974)	Schoolboys and seniors combined	Eighth man (14%); Hooker (11%); Lock (11%); Flank (11%).
Walkden (1975)	Teams playing at Twickenham. 1964-1975.	Scrum-half (13.5%); Fly-half (9%); Hooker (9%); Full-back (8%).

Table 3.5 continues

Author	Team/Level	Player position *
Myers (1980)	Senior club and senior representative	Full-back (9.5%); Flank (8.8%); Scrum-half (7.4%); Second row (7.4%);
Nathan <i>et al.</i> (1983)	Schoolboy	Hookers (31.6%); Full-back (14.7%); Eighth man (12.6%);
Sparks (1985)	English public schoolboys	Fly-half (11%); Centres (10.8%); Scrum half (10.8%);
Roux <i>et al.</i> (1987)	Schoolboys	Eighth man (13%); Fly-half (12%); Wing (12%); Full back (11%);
Clark <i>et al.</i> (1990)	Senior clubs	Hookers (19%); Wings (15%); Full-back (11%); Centres (10%);
Noakes & Du Plessis (1996)	Adults	Hooker (19%); Wing (15%); Full-back (11%);
Noakes & Du Plessis (1996)	Schoolboys	Eight man (13%); Fly-half (12%); Wing (12%); Full-back (12%);
Targett (1998)	Professional Super 12	Eighth man (16%); Full-back (10%); Lock (9%);
Bottini <i>et al.</i> (2000)	Senior	Flanker (13%); Prop (11%); Full-back (11%); Eighth man (11%);
Bottini <i>et al.</i> (2000)	Under 16 schoolboy	Flanker (15%); Full-back (15%); Wing (12%);

Table 3.5 continues

Author	Team/Level	Player position *
Holtzhausen (2001)	Super 12 teams	Centre (10%); Full-back (10%); Hooker (8%).
Bathgate <i>et al.</i> (2002)	Senior Australian	Locks (13.5%); Eighth man (12%); Fly-half (11%).
Hattingh (2003)	15 year old elite schoolboys	Flanker (21.62%); Lock (18.92%); Wing (13.51%).
Hattingh (2003)	18 year old elite schoolboys	Lock (13.64%); Eighth man (13.64%); Wing (13.64%).

* Results have been converted to injury total per single player in a position to correct for the unequal number of players in the different positions.

On the contrary, the study of Bird *et al.* (1998:322) – not shown in Table 3.5 – found the player position most often injured was the lock (13/100 player-games). Although this was not similar to findings in previous studies, it is confirmed by subsequent studies of Bathgate *et al.* (2002:266) and Hattingh (2003:149). One explanation for this difference in the study of Bird *et al.* (1998:322) is that earlier studies only reported the proportion of injuries (percentage) attributable to the different positions, whereas the study of Bird *et al.* (1998:324) also took into account exposure to risk (measured as number of games played). Bird *et al.* (1998:324) stated that this should be the preferred method when comparing groups.

Except for reporting which positions are most frequently injured, many of the studies reviewed in Table 3.5 also compared forward players to backline players. In the article by Myers (1980:19), the author reported that forwards and backs sustained approximately the same number of injuries, although the type of injury varied. In contradiction, Gerrard *et al.* (1994:230) in the RIPP II study found that the forward players were at higher risk of injury than back-line players, with a ratio of 2.2:1.8 injuries per player season. Targett (1998:281) verified this for professional rugby players too when he found that 65.3% of injuries were

sustained by forwards and 34.7% by backs. Bottini *et al.* (2000:95) verified this for Argentinean junior and senior players when he found that the forwards (57.3%) were at highest risk of injury. The flanker (15.5%) among the forwards and full-backs among the backs (11.1%) were the most commonly injured players. Young hookers ran a significantly higher risk of injuring the cervical spine than seniors. According to recent data by Hattingh (2003:149), the forwards remain the group of players most at risk of injury in the case of both 15-year old elite players (59.46%) and 18-year old elite players (54.55%).

In contrast with the above findings, but supporting Myers (1980:19), Lee and Garraway (1996:215) found that match injury episodes were evenly distributed between forwards and backs for both school players and senior club players. However, the types of injuries sustained differed. In contrast to all the studies mentioned so far, an epidemiological study found that the back line, which comprises 47% of players, sustained 56% of injuries (Holtzhausen, 2001). Furthermore, the same study found that of all the intermediate and serious injuries recorded, 55% were sustained by the back line (Holtzhausen, 2001).

In summary, total risk (total injuries) for player positions seemingly indicates that forwards are most frequently injured in rugby, while there is some indication that back-line players may be more at risk of severe injuries. The players most at risk are those who are most frequently involved in the high-speed phases of the game. In studies where results differed from the above, authors attribute the reasons for the differences to differences in skill, attitude and the way the game is played at different levels.

When specific player positions are analysed further, it becomes clear that certain positions are more prone to specific types and anatomical sites of injury (Williams, 1984; Roux, 1992; Lee & Garraway, 1996; Noakes & Du Plessis, 1996). This research shows that forwards have a greater risk of suffering lacerations, concussions or dislocations, while back-line players (especially wings and centres) have a greater risk of fractures and muscle injuries. Among forwards, these injuries commonly occur to the back, trunk, head and neck, while in contrast back-line players suffer more upper limb and lower limb injuries.

(b) *Phase of play*

The first scientific study of risk factors causing injuries in any of the football codes (American football, rugby union, rugby league) was published in 1906 (Nichols & Smith, 1906). They reported that most injuries occurred in the “bunch” or “pile” that formed after a tackle situation. As the game developed, the areas in the game that contributed most to injuries also changed.

O’Connell (1954:20-21) in his early article on rugby injuries and their prevention identified the following four phases of play that mainly contributed to injuries:

- *The scrum*: The front row, and particularly the hooker, were highest at risk. Violent impact and scrum collapse were responsible for more serious injuries such as fractures and dislocations of the head and neck. The second and third row had a high risk of injury to the shoulder and ear cartilage areas.
- *The tackle*: The high tackle and “hand tripping” were responsible for dislocations, lacerations and fractures of the facial and upper limb area.
- *Loose play*: Here players were exposed to injury when kicked and, trodden and fallen on.
- *Line-out*: Players were identified as being most at risk when they had the ball. Shoving in the back or shouldering players on their way up were responsible for most of the injuries.

After a 20-year shortage, different studies on rugby epidemiology emerged. The pilot study done by Roy (1974:2323) in Stellenbosch identified tackling without the ball, rucks and mauls and foul play as responsible for 34% of all injuries. Walkden (1975:205) was probably the first medical doctor to express his concern regarding an increase in serious injuries which resulted from the tackle and collapsing of the scrum. Scher (1977:474) also reported that these same phases of play played an important part in cervical spinal cord injuries. Of all players with cervical spine injuries admitted to the Conradie Hospital, Cape Town, 40% were injured during the scrum and 60% during the tackling phase. What made this study so important was the fact that 30% (six players) died shortly after injury. Chances

were that players who did not die would be paralysed, with a high risk of further complications and a poor outlook on the future.

Scher (1977:474) identified that flexion-rotation violence, vertical compression forces and hyperextension forces could contribute to cervical spine injuries. Hoskins (1979:366) found similar results on rugby injuries to the cervical spine in English schoolboys. The author found that scrummaging (40%) and loose play (60%) were the main contributors to these injuries. In a study on cervical injury in rugby football in New Zealand, Burry and Gowland (1981:56) confirmed the scrum as a danger area. The danger during the formation of the scrum was seen to be greater than was previously thought. The younger players were more at risk during the scrums. The ruck and maul were also identified as important danger areas.

A study on school rugby players (Sparks, 1985) reported the tackle (39.6%) to be the most injury-prone phase, followed by rucks (18.7%) and set scrums (11.9%). The study of Roux *et al.* (1987:308) on schoolboys compared well with these findings. The most dangerous phases of play were when the player was tackling or being tackled (55%), and the ruck and maul (18%). An interesting observation concerning schoolboy injuries in the ruck and maul was that the proportion of injuries in the ruck and maul was low (<10 %) at 14 year-old level, but rose progressively to 19-year old level (29%) (Roux, 1992). The probable explanation given for this is increasing competitiveness in this phase of play as schoolboys mature (Roux, 1992).

A survey of Addley and Farren (1988:23) on all rugby played on the Dungannon rugby ground in Ireland during the 1986-1987 season correlated injuries with various phases of play. During the season, 40 matches were played and 84 players presented with injuries. Eighty-seven per cent (87%) of the injuries were associated with contact and 13% with running. Tackling and second-phase ball handling were the most dangerous phases of play. Fixed phases, such as the scrum, only became significant when the probability of spinal region injuries were considered. In South Africa, Clark *et al.* (1990:559) found the phases of play which contributed to injury among adult players were tackling (26%), open play (21%) and the loose scrum (17%). According to Clark *et al.* (1990:560), schoolboy players are at

higher risk in the tackle than adults. When considering only spinal cord injuries, it is interesting that similar phases of play, namely tackling (21%), being tackled (31%), the scrum (21%) and the ruck and maul (18%) accounted for the majority of rugby injuries (Noakes & Du Plessis, 1996).

It is thus clear that the tackle phase (tackling and being tackled) is responsible for the highest frequency of rugby injuries. Studying the predominant patterns of injury (combination of anatomical site and type of injury) experienced in each phase of play will give additional and valuable information regarding the seriousness of injuries that occur in a specific phase of play. The study by Roux (1992) provides the information needed in this regard.

Roux (1992:192) reported that specific sites injured during the tackle phase of play were the upper limb, lower limb, head and neck. These occurred mostly to the player being tackled and involved a disproportionate amount of serious injuries like fractures (40.8%), concussions (13.4%) and ligament (27.5%) injuries. Comparative data for the scrum phase showed that injuries during the scrum occurred mainly to the head, neck and trunk, and were mainly 'less serious' muscle (38%) and ligament (40%) injuries of the neck and trunk (Roux, 1992). For the loose scrum and maul, the author found injuries to the head and neck to be most common. The majority of the head and neck injuries were concussions (50%).

In a comparison between senior club rugby injuries and schoolboy rugby injuries, the risk of schoolboy rugby injuries associated with tackling or being tackled were 64% (Lee & Garraway, 1996). The corresponding value among senior club players was a lower value of 49%. Garraway and Macleod (1995:1486) as well as Bird *et al.* (1998:323) verified this for senior club matches when they too found that the tackle accounted for 49% and 40% of injury episodes respectively. Garraway and Macleod (1995:1486) concluded that more research on the frequency and circumstances of tackling was needed. These findings support most of the above findings.

Considering rugby at professional level, the injury study of Jakoet and Noakes (1998:46) reported that the tackle phase (56%), followed by the ruck and maul (23%), were the most

dangerous during the 1995 World Cup. These findings correlate well with other studies on professional rugby players (Targett, 1998; Holtzhausen, 2001). Holtzhausen (2001:81) was one of the few researchers who distinguished between attempting a tackle and being tackled. The most dangerous phase of play during professional matches was found to be *being tackled* (46%) (Holtzhausen, 2001). Further, these injuries were mostly (56%) of either intermediate or serious nature. *Tackling* was responsible for a low 15% of injuries. This low percentage of *tackling* injuries differed from other research on professional players (Jakoet & Noakes, 1998). Contrary to what one may think, the fixed phases (scrum and line-out) in the World Cup study only contributed to 1% of injuries (Jakoet & Noakes, 1998). The reasons for these discrepancies were not immediately clear (Jakoet & Noakes, 1998). This was also the case in the more recent study of Bathgate *et al.* (2002:268), where the set phases in total caused only 2.1% of injuries to elite Australian players (amateurs and professionals) compared to the 58% caused by tackles. This low percentage of injuries in the set pieces was an indication that the set phases became more controlled (Bathgate *et al.*, 2002).

Wilson (2000) stated that in the modern era, the tackle area is where the game is won or lost. The team that can dominate the tackle area can dominate the second phase. The modern game is played mostly in the second phase. Through gaining territory when attacking and forcing opponents back when defending, a team can win games, regardless of first-phase possession. By creating “turnover tackles”, a team can dislodge the ball and regain possession. In the modern game, players aim for the upper chest in order not only to stop the ball carrier, but also to force him backwards and, if violent enough, make him lose the ball. “Big hit” tackles and “multiple-direction tackles” are also common. This aggressive approach to the tackle area may be good rugby, but it puts the tackled player in danger of serious injury.

It is clear that the highest proportion of injuries occurs in the tackle phase of the game, and that being tackled is the activity that produces most of these injuries. Wilson *et al.* (1999:153) studied the nature and circumstances of injuries occurring in these rugby union tackles. The study used data from the Rugby Injury and Performance Project (RIPP) and

supplementary information from qualitative videotape analysis of tackle injury events (Wilson *et al.*, 1999). Summary statistics were as follows:

- Seventy percent of the videotaped injuries of the New Zealand Rugby Football Union (NZRFU) occurred when the player was diving/falling to the ground. Injuries were most often caused by impact with another player, rather than impact with the ground.
- Thirty percent of injuries occurred with the player stationary on the ground. This was explained as due to holding in the tackle, and falling or stepping on the grounded player.
- Stopping front-on tackles had a 300% higher injury incidence than either side-on tackles, or tackles from behind. Trunk tackles played a much larger role in injury incidence than tackles below the hips.
- The supporting player, helping with the tackle or freeing the ball, played a 21% role in this injury incidence.
- Coaching strategies/rule changes should be introduced to reduce or prohibit the most dangerous tackle situations (also see paragraph 3.8.1.3: *Role of the teacher coach in injury prevention*).

In the previous paragraphs, the phases of play in which injury is most likely to occur have been identified. Next, in the interest of injury prevention, it will be worthwhile noting if any relationships exist between the most dangerous phases of play and the different playing positions (also see paragraph 3.7.2.1a: *Player position most frequently injured*). Research in this regard showed that the back-line players, especially the wings, centres and fullbacks, were most at risk of injuries that occurred as a result of being tackled, tackling and open play (Williams, 1984; Roux, 1992). Among the forwards, the flanks and eighth men were the forwards most likely to be injured while being tackled and tackling, as well as during open play, while during the loose scrums/mauls the locks, flanks and eighth men were most at risk, during the scrum the props and hookers were most at risk, and during the line-out the locks were most at risk of injury (Williams, 1984; Roux, 1992). Predictably, the injuries can be linked to the phases of play in which different playing positions are most often involved.

In summary, the tackling phase is currently the phase which contributes most to rugby injuries. Most tackle injuries are serious or moderately serious. Being tackled is the activity most associated with these tackle injuries. Schoolboys are more at risk during the tackle phase than seniors. Playing positions that are most frequently injured in these phases are those that are most often involved in them. Fixed phases, such as the scrum, only becomes significant when the probability of spinal region injuries are considered. Coaching strategies that concentrate on correct tackling and falling technique should be introduced to reduce the risk associated with this phase of play.

(c) *Foul play*

O'Connell (1954:26), in 1954, concluded that rugby was an amateur game and that players should accept the knocks that came with the spirit of the game. However, when there is undue interference with the spirit or the rules of the game, protection against many avoidable injuries could be lost (Hattingh, 2003).

A South African article by Roy (1974:2321) identified foul play during the game as one possible reason for a high injury incidence. Scher (1991:57) also blamed foul play (the high tackle) for catastrophic spinal region injuries in South Africa. This happened despite law changes to decrease injury rate. Noakes and Du Plessis, (1996:128) agree that illegal tackles around the neck are the sole causes of cervical cord injuries to the tackled player. Illegal "crashing the scrum" as well as "popping" the scrum – where the front-row of one team scrums upwards, thereby lifting the opposing front-row of their feet – are further procedures in which the front-row forwards are susceptible to fracture or dislocation of the cervical vertebra (Noakes & Du Plessis, 1996).

Bird *et al.* (1998:323) reported that foul play was responsible for 13% of all injuries during matches. Noakes *et al.* (1999:544) reported that illegal tackling accounted for 32% of spinal cord injuries. Bathgate *et al.* (2002:267) reported that foul play was responsible for 3.5% of injuries, which is much lower than the previous studies. Hattingh (2003:57) commented that the standard of refereeing at this high level must have been the main reason for this difference. Thus, foul play can be responsible for between 3.5% and 33% of all injuries.

depending on the injury grade and standard of refereeing (Clark *et al.*, 1990; Targett, 1998; Bathgate *et al.*, 2002; Hattingh, 2003).

(d) *Level of play*

In an earlier study on adult rugby players, a significantly increased injury incidence was noticed from lower to higher levels of play (Myers, 1980). There was a relationship between the site, nature and severity of injury and the level of play. Indeed, this was not the only study which linked injury incidence to the level of play.

Several studies made it clear that at all schoolboy ages, A team players (highest level of play) were at a significantly greater risk of injury than players who played in lower teams (see Figure 3.3) (Nathan *et al.*, 1983; Roux *et al.*, 1987; Roux, 1992). This is also true for spinal cord injuries, where the risk is greatest among the first teams of schools and clubs (Noakes & Du Plessis, 1996). One explanation for this is that competitive expectations and pressure to perform are felt more intensely by A team players (Noakes & Du Plessis, 1996).

It should be noted that the differences between different levels of play increased as players grew older (also see Figure 3.3; the effect of age is explained under paragraph 3.7.1.3a: *Demographic factors*). The general argument is that physical maturation also explains a large part of the growth in risk of injury with increasing age (Noakes & Du Plessis, 1996). Furthermore, Upton *et al.* (1996:531) observed that the high school A team players were taller and heavier than their counterparts in the lower teams. This is compatible with the belief that increased size, mass and speed are in some way related to injury risk.

Jakoet and Noakes (1998:45) did the first study on the frequency and nature of injuries at the highest level of the game. At senior level, players of similar age play against each other, and consequently any differences in injury risk cannot be explained by age alone. Jakoet and Noakes (1998:45) found that the frequency of injury in the 1995 World Cup was the highest ever recorded in any group of rugby players. The larger size, greater speed, superior competitiveness and commitment of the best players in the world were singled out as the

reasons for the high injury rate. This study confirmed the conclusion that the prevalence of rugby injury rises with level of match play (competitiveness).

The high level of skill and fitness of international rugby union players were not enough to protect against injuries caused by the more physical and faster nature of the modern international game. This agrees with Noakes and Du Plessis (1996:104), who believe that other factors, such as the competitiveness of the game, extreme expectations and national pride, are important when explaining the sudden rise in injury risk at the highest level of the game. The finding that injury rates increase with increasing grade of rugby is similar to other findings on professional players (Targett, 1998).

Garraway *et al.* (2000:348) did one of the few comparative studies on the professional (post-1995) and amateur (pre-1995) eras. The authors found that during that period the prevalence injury rates rose in all age groups. The proportion of players injured almost doubled from 1993-1994 to 1997-1998. The professional players also showed a much higher recurrent injury rate, particularly during early season (recurrent injuries are discussed in paragraph 3.7.1.1a: *Injury history*). Further research by Bathgate *et al.* (2002:265) produced one of the most recent epidemiological studies that compared amateur players to professional players. Statistics from this study not only supported findings by Garraway *et al.* (2000:348), but highlighted an increase in severe injuries among professional players (Bathgate *et al.*, 2002:268-269). This in turn confirms earlier research, which found that injured school players (Sparks, 1981; Roux, 1992) take less time to recover from injury than either senior club players (Clark *et al.*, 1990) or senior Welsh players (Williams, 1984), also supporting findings which state that higher levels of play are associated with increased severity of injury.

Another factor associated with a high level of play is *match play*. Matches encourage very high levels of competitiveness, which increases injury risk (Noakes & Du Plessis, 1996). In a study on the nature and incidence of injuries to eight first-division senior rugby teams, 85% of injuries occurred during matches, and the rest during training (Clark, *et al.*, 1990). Bathgate *et al.* (2002:267) supported this when he found that 88% of injuries occurred during

the game, and the rest during training. Consequently, schoolboys are 11 times (Roux, 1992) and senior players 13 times (Clark *et al.*, 1990) more likely to be injured in matches than in training. Again, this risk of injury during matches is greater in A team players (higher level of play) (Roux, 1992). Furthermore, a disproportionate number (more than 80%) of head and neck injuries, facial fractures, neck muscle injuries, concussions and neck vertebral fractures has been associated with match play (Roux, 1992). The latter data showed that fractures, dislocations and ligament injuries kept players out of the game for between 20 and 40 days (Roux, 1992). The time of recovery (time out of rugby) resulting from the above injuries indicates that the injuries sustained during matches were not only higher but also of a more severe nature. Finally, almost all spinal cord injuries and foul play occurred during matches (Roux, 1992; Noakes & Du Plessis, 1996).

Figure 3.3 summarises the effect that different levels of play have on injury incidence. In this figure, in order to compare results, different injury incidences was converted to injuries/1000 player-hours where possible. Figure 3.3 as well as all the literature referred to above confirm that the risk of injury increases with increases in level of competition, to a point where high levels of skill and physical fitness alone cannot provide complete protection from injuries (Noakes & Du Plessis, 1996). Also supporting the risk associated with high levels of play is the sharp peak in male injury rate during the end of the season, due to the competition finals being played at a greater intensity than earlier games (Alsop *et al.*, 2000). In summary, research concludes that a high level of play and competitiveness leads to a higher injury incidence. This finding is similar to a recent review on rugby league injuries (Gabbett, 2004). Finally, it must be remembered that other factors, such as competitiveness and speed of play, are related to level of play.

3.7.2.2 Training parameters

The possible errors associated with training will be discussed under training parameters.

(a) Preseason preparation

From as early as 1905, American football teams were required to develop good physical condition prior to the start of the season (Nichols & Smith, 1906). It was believed that this

would protect against the risk of injury. O'Connell (1954:24), in the first epidemiological study on rugby union injuries, confirmed this when he identified that improper pre-season preparation of players played a role in injuries. Similarly, a study in South Africa shows that the recent situation has not changed much. This study recorded that the incidence rate of 133/1 000 player hours for the pre-competition preparatory matches levelled out to 44/1 000 during competition (Holtzhausen, 2001).

Research found that 36% of the injuries to English schoolboys at Rugby School occurred in the first four weeks of the season (Sparks, 1981). Therefore, it was concluded that there is a relationship between the high injury incidence seen in the earlier weeks of the season and unfitnes (Sparks, 1981). It seems that these two factors are interrelated. Consequently, it is possible that unfitnes at the start of the season, rather than the pre-season phase of the season, is the culprit responsible for this phenomenon.

Nathan *et al.* (1983:133), in their study on rugby injuries at a school in South Africa, found that the months of April and July (in the southern hemisphere) had the highest incidence of the season. Again improper pre-season preparation was blamed. The authors blamed the July mid-winter break in particular. Roux *et al.* (1987:308) confirmed this increased injury incidence for the months of April and July, when he studied schoolboy rugby injury epidemiology in South Africa.

In studies on players in the northern hemisphere the same phenomenon is visible. For example, injuries in Welsh players occurred most often in October and November (beginning of the season in the northern hemisphere) (Williams, 1984). Garraway and Macleod (1995:1486) (in the northern hemisphere) also found injuries more frequent at the beginning of the season, with injuries more frequent during the spring (September-October) and autumn periods (March-April). This is supported by the findings of Lee and Garraway (1996:213), who found that a third (33.3%) of schoolboy rugby injuries occurred in the month of September (northern hemisphere).

Targett (1998:283) verified the high pre-season injury incidence for professional rugby players in the Rugby Super 12 competition, while Alsop *et al.* (2000:104) confirmed the findings of the above researchers and highlighted that the types and severity of injuries remained relatively constant through the season, but that the proportion of injuries in the backline fell significantly over time. The authors concluded that this may have resulted from a reduction in “back-play” over the course of the season, due to deteriorating field conditions. In 2001, data which show peaks in injury at the beginning of season and just after the winter break were once more published, this time in a country where rugby is not as popular (Babic *et al.*, 2001).

Lee *et al.* (2001:412, 415) were the first to study the influence of preseason training, fitness, and existing injury on subsequent rugby injury in a large cohort of adult rugby union players. Lee *et al.* (2001:412) found a 3.9% increase in injury rate for each additional preseason training week attended, and a 61% relative increase for those players who had been injured or were carrying an injury at the end of the previous season (see paragraph 3.7.1.1a: *Injury history*). They concluded that there was no clear reason why players who attended preseason training for more weeks had an increased risk of subsequent injury (Lee *et al.*, 2001). Because Lee *et al.* (2001:416) collected data on the level of preseason physical activity retrospectively, information may have been affected by the players’ memory recall. Different methods of collecting data also may have introduced bias into the survey. Because the response rate was high (84%) it is unlikely that such bias affected the results of the survey (Lee *et al.*, 2001).

Lee *et al.* (2001:416) reported that there were many other reasons why players who attend more preseason weeks may have a higher risk of subsequent injury. For example, players who attend more preseason weeks may become more confident and practise more tackling, attempt more injury-prone manoeuvres, play more intensely and attempt more power activities. Consequently the researchers decided that it is unclear whether more preseason training is a true risk factor or a consequence of the relations among other risk factors. It was suggested that injury risk is far more related to the type, frequency and intensity of activities

undertaken in this period, or to personalities and characteristics of players undertaking pre-season training (Lee *et al.*, 2001).

In an attempt to be rugby fit in time for the start of the season, it is easy for players to suffer training errors. In relation to this, it was found that players should guard against an insufficient preseason break and over-training, as these were some of the main reasons for a high incidence of recurrent injuries among professional players (Holtzhausen, 2001). Factors which can be added to these are incorrect training techniques, such as increasing the training load too rapidly, and introducing high-risk training techniques such as plyometric (jumping) training too early (Schwellnus & Derman, 2001a).

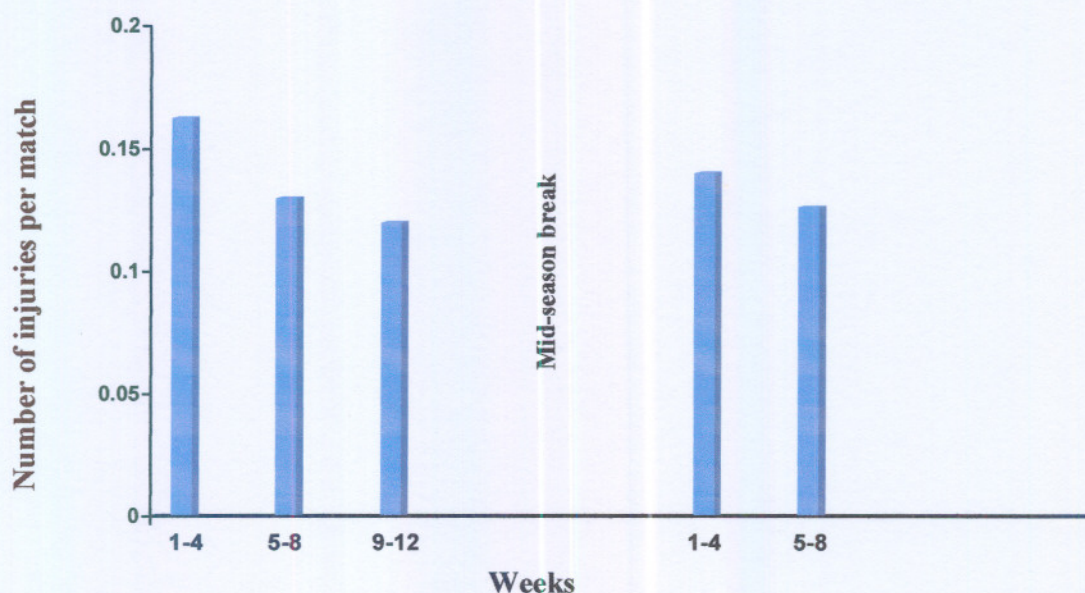


Figure 3.4: Number of rugby injuries per match suffered by schoolboys in different four week parts of the season

To summarise: the incidence of injury in rugby has been reported to vary over the course of a season. It is clear that most senior and schoolboy rugby injuries occur at the beginning of the season, and again after the mid-season break. In Figure 3.4 the data of Roux is used to visually summarise this phenomenon (quoted from Noakes & Du Plessis, 1996:110). The most likely explanation for this is that players are not match-fit at the start of the season and

they lose match fitness during the mid-year break (Noakes & Du Plessis, 1996). There is a shortage of research on exactly which fitness variables are important during these periods of 'detraining'. It also remains uncertain whether this phenomenon is a result of reasons such as resuming activity after rest, increased activity, changes in activity, inappropriate training programs or simply chance.

3.7.2.3 Psychological factors

Psychological parameters may influence injury incidence. Sports psychologists working with injured athletes have identified certain attitudes that predispose players to injury. Parental and coaching attitudes such as "act tough and always give 110%", "if you're injured, you're worthless" and "no pain no gain" may encourage players to play hurt or take undue risks and increase the probability of injury (Rotella & Heyman, 1986; Weinberg & Gould, 1999). This does not mean that players should not play assertively and hard. But the act-tough orientation should not be emphasised so much that players overstrain or believe that they must train through pain (Weinberg & Gould, 1999). Hard physical training does involve discomfort, but players must be taught to distinguish between normal discomfort that accompanies overloading, increased training volumes and the pain that accompanies the onset of injuries (Weinberg & Gould, 1999). Furthermore, other factors such as pre-match team talks should not be used to promote excessive levels of aggression, as this too could lead to an excessive risk of injury (Australian Rugby Football Union, 1993).

The following words of the South African team doctor in 1990, Uli Schmidt (1990:30), summarises two main psychological problems in rugby: "*It is my opinion that, in rugby, there are two potentially dangerous attitudinal problems. These are the pressure to succeed at all costs, which often results in a player being poorly prepared, and the pressure to start playing too soon after injury.*" Both of these are psychological risk factors, often external to the individual. This is not a new problem, as can be seen from the following statement by Nichols and Smith (1906:8) in 1906: "*... in many cases it was impossible to make the players see the severity of the injuries they had received, and in many cases where men were forbidden to play unless their parents assumed the responsibility, their parents appeared equally indifferent.*"

3.7.2.4 Equipment

Improper protection of certain body parts (insufficient strapping, padding, etc.) as well as rigid corner flags and unpadded goalposts were already identified by O'Connell (1954:21) as causes of rugby union injuries. More recently it was believed that shoulder padding, ankle braces and soft helmets should be used to reduce the risk of injury (Noakes & Du Plessis, 1996), while the wearing of mouth guards should be compulsory for all players, and shin guards for forwards would be advisable (Derman & Schweltnus, 1996). The rugby boots of players may also cause problems (Noakes & Du Plessis, 1996). The following shoe characteristics increase the risk of intrinsic injuries:

- Low-heeled boots, with heel height less than 12 to 15 mm;
- worn-out boots;
- shoes inappropriate to the individual player's specific biomechanical needs;
- shoes with a stiff sole that fails to bend easily at the forefoot; and
- excessively hard shoes that fail to absorb shock adequately.

Noakes and Du Plessis (1996:180) agree that, to reduce the incidence of concussion, all players should wear gum guards. However, there is no evidence to suggest that shoulder pads reduce the incidence or severity of shoulder injuries (Bathgate *et al.*, 2002). Neither is there sound epidemiological proof that protective rugby headgear adequately protects the brain and neck against the range of impact forces that may be generated in contact (Wilson, 1998). Also in a recent study on protective rugby headgear, Hrysomallis (2004:156) concluded that all but one of the different commercially available soft headgear provided inadequate impact energy attenuation, and consequently inadequate protection. Furthermore, when shoulder pads and other protective equipment were used for the first time, it was hoped that they would provide some cushioning, but in some ways they had an opposite effect (Wilson, 2000). Instead of using padding to protect themselves, players were entering contact situations recklessly, endangering themselves and others. Lastly, the use of bracing and taping has been used to prevent new injuries (primary prevention) and recurrence of

injuries (secondary prevention) (Derman & Schweltnus, 2001a). In general, these devices are more suitable for secondary prevention of injuries.

3.7.2.5 Playing environment

Under playing environment, different risk factors are found that are associated with the weather and the venue of play. During earlier times debris (stones and animal faeces) on the playing field were a hazard to players (O'Connell, 1954). Although this situation has changed, it has been hypothesised that wet or soft playing surfaces may cause the scrum to collapse and therefore be more likely to cause spinal cord injuries. Data from the Cape Province, South Africa, however, did not produce any evidence supporting this (Noakes & Du Plessis, 1996).

Lee and Garraway (2000:91) wrote an article with the aim of establishing the influence of weather and pitch conditions on the frequency and nature of rugby injuries. Although they found that environmental conditions (wet weather) could affect the performance of players and the frequency of injuries, the state of the pitch did not appear to affect the injury risk. The reasons for this could possibly be that the measures used to establish pitch conditions were not objective, and because of inter-observer variations in subjective judgements between different examiners. Concluding research on the quality of pitches and their effect on injury does exist, however. Most researchers attribute an almost equal amount of injuries to hard and soft playing surfaces (Noakes & Du Plessis, 1996). However, Williams (quoted by Noakes & Du Plessis, 1996:111-112) found differences in the type of injury sustained on a hard versus a soft surface, with fractures and ligament injuries occurring more frequently on hard surfaces.

3.7.2.6 Medical regimes and refereeing

The study by Roy (1974:2321) identified poor refereeing during the game as a possible reason for a high injury incidence. He also concluded that improving medical/first aid protocols and improving medical attendance at matches and training could make rugby a safer game.

This statement by Roy (1974:2326) regarding improved medical regimes concurs with research on American football, which states that improved on-site medical care is probably an additional factor in the reduction of catastrophic injury (Saal, 1991). Early identification and correct early management of serious spinal cord injury may significantly influence recovery (Noakes & Du Plessis, 1996). It has been proven that on-site quality care (doctor) and immediate treatment by an orthopaedic surgeon enhance the chances of recovery without paralysis (Noakes & Du Plessis, 1996). The availability of a good quality stretcher and cervical collar are also essential (Derman & Schweltnus, 1996).

Rules that govern the high tackle and engagement of the scrum, and rules that ensure players stay on their feet during rucks and mauls should be more strictly applied by referees in order to prevent cervical injuries (Noakes & Du Plessis, 1996). Specific concerns for referees also include the following (Noakes & Du Plessis, 1996):

- Referees must ensure the safety of the playing field, ensure that goalposts are padded and that corner flags are flexible but unbreakable;
- players with bleeding wounds must leave the field;
- front rows may only be substituted by another trained front row; and
- the field must be cordoned off to prevent spectators from approaching the players.

3.7.2.7 Law changes

In 1963 new rules with the objective of protecting backline players from being “marked” were introduced (Noakes & Du Plessis, 1996). The law that stated that the ball determined the offside line in the scrum was changed so that the hind foot of the last player in the scrum was defined as the offside line. This resulted in the attacking team keeping the ball behind the back foot of their eighth man for longer. Consequently control of the scrum became more important. To weaken the quality of ball, opponents employed more tactics like charging, bumping and turning of the scrum. Instead of the short “heave” when the ball was thrown into the scrum, a continuous push became the common tactic. All of these tactics

meant an increase in forces in the scrum. This meant that players were at increased risk of neck and spinal cord injuries.

From the late 1970s, medical officers in several countries were concerned about the increase in rugby injuries in general and broken necks in particular (Hattingh, 2003). As a result, they influenced the International Rugby Football Board to change the rules. The new rules were only adopted in 1986. The new rules were aimed at the following three areas: collapse of the scrum, prolonged rucks or mauls, and high tackles. These changes assured a safer environment in the first phase of play, and as a bonus, a more fluent and spectacular game.

Between 1980 and 1986, the local New Zealand rugby authorities successfully reduced neck and spinal cord injuries. This was achieved by changing the local rules that controlled play after the *tackled ball* (Noakes & Du Plessis, 1996). With this change, they hoped to reduce the high risk of injury associated with the dangerous mauls which developed after tackles. In 1984 success in reducing injuries was achieved when the New Zealand Rugby Football Union managed to change the rules that influence the collapse of the scrum. The new rules did not allow for "crotch binding", movement of the scrum for more than 1.5 metres or turning the scrum through more than 90 degrees. These rules also reduced the duration of scrums and the speed at which players engaged (Burry & Calcinaï, quoted by Noakes & Du Plessis, 1996:30).

Unlike other major rugby-playing countries, catastrophic spinal cord injuries in South African school players did not decrease during the early 1980s (Haylen, 2004). This happened because the South African authorities failed to adopt the rule changes that were so successful in these countries (Noakes & Du Plessis, 1996). A decrease in the number of spinal cord injuries among schoolboys in South Africa was only visible after appropriate rules had been introduced in 1990.

As a result of the success with which England, Australia and New Zealand changed certain domestic rules, the International Rugby Board (IRB) at a meeting in March 1988 legislated to make some of these rules applicable to all rugby-playing countries (Noakes & Du Plessis,

1996). The IRB suggested that front rows should touch each other on the upper arms and then pause prior to the engagement in the sequence: “crouch-touch-pause-engage” (Noakes & Du Plessis, 1996). They also emphasised that:

- Only when the front rows were stable should the back five players join them;
- popping of the scrum should be outlawed;
- wheeling of the scrum beyond 90° before the emergence of the ball should not be allowed;
- the duration of the scrum should be limited;
- players jumping for the high ball should be protected from multiple tackles by ensuring that attacking players also jump for the ball; and
- correct techniques for scrumming, tackling, and going into rucks and mauls should be coached (see paragraph 3.8.1.3: *Role of the coach/teacher in injury prevention*).

Scher (1991:57) remarked that although spinal cord injuries in Europe and New Zealand decreased after the 1988 law changes, the same did not happen in South Africa. He blamed an infringement of the laws (the high tackle) for this. A study by Badley (1990:7) hypothesised that the laws that governed the collapse of scrums and mauls (introduced in March 1988), together with new laws related to the engagement of the scrum and the more precise definition of dangerous tackles, should be sufficient to reduce the injury incidence of senior players, if applied correctly. Unfortunately, this was not the case. Badley (1990:7) stated that the introduction of further law changes as well as stricter refereeing and enforcement of the laws were necessary in order to control the safety of the players. In contrast to the findings of Badley (1990:7), Noakes *et al.* (1999:542) reported that spinal cord injuries among South African schoolboys decreased by 46% following the 1990 law changes. However, the reduction of these injuries did not result from the specific law changes, but rather from a reduction in illegal play, supporting the findings of Scher (1991:57).

Although the law changes introduced in the late 1980s were followed by decreases in catastrophic spinal cord injuries, these changes also brought about a shift in injury incidence from the fixed phase to more open play and tackle (Hattingh, 2003:58). O'Brien (1992:244)

blamed these law changes as part of the reason why injuries on senior players in Leinster province, Ireland were more than double the number reported by O'Connell (1954:21-22) in the same province more than thirty years earlier. O'Brien (1992:243-244) said there were law changes in rugby union allowing:

- A more fluent game where the ball is more often run or kicked as a "Garry Owen kick", thus creating more situations where opponents are directly engaged, or where players are engaged at high speed, near a dropping ball;
- More running of the fullback and three-quarters out of defence in counterattack, leading to an increase in "open-field" and tackle injuries.

These findings supported the work of Scher (1991:58).

Garraway and Macleod (1995:1487) as well as Garraway *et al.* (2000:350) supported the statement of O'Brien (1992:244) when they too blamed recent law changes (1988) that encouraged open play conducted at higher speeds, which enhanced the game as a flowing spectator sport, for the increased incidence in tackle injuries. According to Garraway *et al.* (2000:350) the law changes resulted in more tackles involving a higher degree of momentum and force. Garraway and Macleod (1995:1487) concluded that the challenge of future law changes would be to sustain the popularity of the game while lessening the hazard of high-velocity contact in the tackle (tackle injuries were discussed previously in paragraph 3.7.2.1b under *Phase of play*).

In conclusion, most law changes were introduced with the aim of reducing catastrophic spinal cord injuries. Although this was effective, different authors reported an increase in injury incidence after recent law changes. Laws which changed the game into a high-speed, fluent and more entertaining sport also led to more tackle injuries and more injuries resulting from running at high speed or changing direction at speed. Therefore, the focus in rugby should also be to identify and legislate against other dangerous phases of play. Furthermore, there is a need for continued monitoring of rugby injury incidence and mechanisms of injury, so that rule changes which reduce injury risk can be introduced at appropriate times.

The lesson here is that although timely rule changes help reduce injury incidence, the changes by themselves, are not enough; the rules must be strictly enforced and players must be properly coached (also see paragraph 3.7.2.6: *Medical regimes and refereeing*; and paragraph 3.8.1.3: *the Role of the school coach/teacher in injury prevention*) (Calcinaï, 1992). Then there are also those who argue that laws at school level should be changed so that games are played either by body mass or by Tanner stage (different categories related to biological age and level of maturation rather than chronological age), as is the practice in New Zealand (Noakes & Du Plessis, 1996). Finally, it is this author's opinion that there has been a lack of public records of the incidence of rugby injuries in South Africa since 2000, so it is uncertain whether the changes introduced so far have had a lasting impact.

3.8 PREVENTION OF RUGBY INJURIES

The most significant public health trend during the last two decades of the previous century, as well as the beginning of the 21st century has been the *prevention* of disease and ill-health, the promotion of health and a reduction in the cost of medical treatment. However, according to Brukner and Khan (2001:84) injury prevention remains largely neglected. In rugby, the magnitude of the injury problem is a strong argument for the implementation of a systematically co-ordinated, training injury prevention programme.

By 'prevention' is meant preventing the injuries from occurring and preventing the injury processes from developing (Lysens *et al.*, 1991). There are three different levels of prevention (Lysens *et al.*, 1991):

- Preventing an injury from occurring is known as '*primary prevention*'. Primary prevention reduces the incidence of injuries. This is the task of everyone involved in sports training: athletes themselves, trainers and coaches, physiotherapists, physical education teachers and physicians;
- '*Secondary prevention*' means preventing or delaying the development of irreversible structural damage by therapy. This reduces the prevalence of injury, while the

incidence remains constant. Athletes with previous injury are generally at high risk of recurrence. Consequently, correct diagnosis, treatment and a rehabilitation programme are important in the prevention of re-injury;

- ‘*Tertiary prevention*’ means preventing an injury from becoming chronic or a deficiency from becoming persistent. This can reduce both the incidence and the prevalence of long-term dysfunction and disability. A progressive functional rehabilitation programme can prevent permanent functional disorders. Physicians should warn injured athletes of the possible effects of prolonged sports participation.

In sports, primary intervention can be categorised as a preventative intervention, as it attempts to minimise the effects of intrinsic and extrinsic risk factors on participants prior to injury (Fuller & Drawer, 2004). These interventions are used to reduce the likelihood of an injury occurring. Secondary and tertiary prevention can be seen as therapeutic interventions, as they are applied after injury. These interventions only have an indirect effect on future injuries and are mainly effective in reducing the consequences of an injury (Fuller & Drawer, 2004).

In contact sports, a sudden impact to the body can often not be prevented, because of the nature of the specific sport (Derman & Schweltnus, 2001b). However, there may be certain “modifiable” factors, such as incorrect training, incorrect use of protective equipment, pre-existing muscular weakness, skeletal muscle imbalances, faulty biomechanics, inadequate rehabilitation after a previous injury or muscle fatigue that may increase the risk of developing an injury, or increase the severity of an injury (Derman & Schweltnus, 2001b). To address these risk factors and causes of injury, one or other form of intervention or risk reduction strategy is needed (primary prevention/preventative intervention).

It is clear that the identification of risk factors is only part of injury prevention. Once the risk factors have been identified, promising prevention strategies must be devised and tested (Jones & Knapik, 1999). The findings from the implementation of these strategies may then be used to prevent injuries. Therefore some injury prevention strategies that were previously implemented or tested will be discussed in the next section of this chapter. *Firstly,*

recommendations on how the teacher, etc. can help reduce injuries will be discussed. *Secondly*, some of the different prevention protocols will be discussed from the literature.

3.8.1 RECCOMENDATIONS FOR INJURY PREVENTION

In any prevention programme, different strategies are available to control or prevent injuries. Injury prevention in rugby may either be specific to the sport (e.g. providing specific equipment to reduce impact injuries and coaching of specific tackling techniques) or more general (e.g. education of coaches, better first aid, pre-season physical conditioning and adequate rehabilitation to reduce the recurrence of an injury) (Noakes & Du Plessis, 1996; Derman & Schwellnus, 1996; Whiting & Zernicke, 1998). Alone, neither of these strategies is wholly successful in achieving injury prevention. Some recommended components of a complete prevention strategy are next be discussed in more detail.

3.8.1.1 Prevention through education

Education is the first step on the way to changing any behaviour. The education of players, parents, coaches and referees concerning the prevention of rugby injuries can have a significant effect on the occurrence of these injuries (Derman & Schwellnus, 1996). Therefore, the aim of education in rugby should not only be to develop player skills and physical performance, but also to prevent injuries.

Through education, information is provided. When speaking of sports education, the important aspects are competence, literacy and enthusiasm (Van Gent, 2003). Initial steps to educate the rugby fraternity include the provision of written materials and the screening of films (Wessels 1980; Noble, 1988). This education process should include rugby players, coaches, administrators, referees, medical personnel and the public (Du Toit, 1993). Firstly, the education of coaches and teachers needs to improve, to ensure that players will be better educated and more aware of dangers and of safety techniques (Muir-Gray, 1983; Du Toit, 1993). This education must focus on improved player, coach and referee awareness of the injury-prone phases of play (Myers, 1980). It is the duty of the supervising body as well as clubs to promote awareness of the injury-prone phases in rugby (Myers, 1980).

Education should be based on research (Lyle, 2003). Therefore, coaches need to be educated in how science and scientific findings can be used to their advantage (Noakes & Du Plessis, 1996). Lyle (2003:285) also suggests that there has been very little research into coach education and some aspects of coaching practice. The author makes it clear that part of the educational process should be to make coaches in all sports more aware of scientific research that has been conducted.

In summary, the provision of information alone has rarely proved to be an adequate preventative strategy. Although education on injuries is important, many injuries result less from a lack of knowledge than from failure to apply what is known (Whiting & Zernicke, 1998). This may be because the more difficult a preventative strategy becomes, the less likely players are to use it (Whiting & Zernicke, 1998). Therefore it is clear that education on rugby injuries should not only focus on players but rather on everybody involved in rugby. Education on rugby injuries has to be very practical and should focus on recognising dangerous situations during play and training, complete rehabilitation after injury, early recognition of symptoms of intrinsic problems, and the provision of scientific training guidelines. When educating players on injury prevention, it is important to remember that younger players (<13 years) are more receptive to advice aimed at their self-preservation (Noakes & Du Plessis, 1996). When reaching adolescence, many believe that risk-taking behaviour is “macho”, hence injury prevention strategies must be taught to children the moment they begin to play the game, before they reach the age where they are at increased risk of injury.

3.8.1.2 Role of the sports medicine team in injury prevention

Sports medicine is a wide-ranging discipline. It is difficult for one person to develop all the skills required to care for the exercising individual. It is therefore ideally suited to a team approach. Members of the sports medicine team may include a variety of sports therapists, as well as health and fitness professionals. Professionals from different disciplines can provide their own specialised skills and utilise skills offered by other members of the team.

This team approach is recommended because it provides the best athlete care (Brukner & Khan, 2001).

All professionals in the team should be encouraged to increase their knowledge in areas other than the one in which they received their basic training (“multiskilling”), because the athlete’s primary medical contact may not necessarily be with the team doctor, but with anyone in the team (Brukner & Khan, 2001). Therefore all practitioners in the sports medicine team must know their own strengths and limitations and be aware of when to refer the athlete to other members in the team who offer the required skill to help the athlete.

Descriptive studies confirm that the holistic approach is to be recommended for injury treatment and recovery (Weinberg & Gould, 1999). The medical team can fulfil this holistic role. The medical team can facilitate the rehabilitation process, through building rapport with injured players, educating them about the injury and recovery process, teaching specific psychological coping skills, preparing them to cope with setbacks and learning from other injured athletes (Weinberg & Gould, 1999).

Because individuals differ in their reaction to exercise and injury, it is also important that suitable members of the medical team frequently evaluate individuals for fitness and injury risk. Furthermore, frequent evaluation by this team will allow for comparison of test results with the appropriate norms. Another important task of the team is to monitor injured players and to provide advice and supervision on “what to do and what to avoid” when returning to play after injury. In this regard, it is important that the team doctor first gives medical clearance to players who wish to return to rugby after injuries. In the case of cervical injuries, this becomes very important, as the risk of neck injury increases progressively after each previous injury (Albright *et al.*, 1985; Calcinai, 1992; Noakes & Du Plessis, 1996).

In South Africa the nucleus of the multidisciplinary team in rugby mainly consists of coaches, biokineticists, sports scientists, physiotherapists and medical practitioners (Hanekom, 2003). This is the same group that will be utilised for the purpose of this study.

Finally, it is important that everyone in the team should have a good understanding of the sport involved, in this case, rugby.

3.8.1.3 Role of the school coach/teacher in injury prevention

A coach can be described as a trainer, teacher, instructor or tutor (Encarta World English Dictionary, 2006). A coach is a teacher who works with those who are willing to pay a price for excellence, and who is willing to do more than that which is required (Bond, 1999).

Interestingly, many international rugby coaches started out as teachers – coaching school teams. In fact, Dr Danie Craven (former president of South African rugby), Nick Mallett (former South African coach), Graham Henry (new All Black and former Wales coach) and Eddie Jones (former Australian coach) were all schoolmasters (Colquhoun, 2004). This can best be described in the following words of the current Springbok coach, Jake White (also a schoolmaster): “Coaching is teaching rugby and that’s why great schoolmasters have become great coaches” (Colquhoun, 2004). Many South African schools make use of this dual role of the teacher-coach.

The job of the teacher is, among other things, to fully develop the potential of children (Karstens, 2002). Many schoolteachers have difficulty with the concept that children should play sport to enjoy themselves (Noakes & Du Plessis, 1996). Consequently, they subject children to adult expectations and pressures when they try to act out their own ambitions through the children. If the child is pushed too far, he or she may choose injury as a way of escape (Noakes & Du Plessis, 1996). By being “injured”, the child does not have to confront the teacher/coach/parent; the child can now make them feel guilty for pressurising him or her to frustrate their misplaced aspirations, and avoid undesired competition.

To coach young players should be a privilege (Noakes & Du Plessis, 1996). Teachers, coaches and exercise leaders influence the character and values of players, intentionally or not (Weinberg & Gould, 1999). The physical or sports educator/teacher/coach stands in a person-to-person relationship with players (Zakrajsek, 1991; Van Gent, 2003). The days when the coach’s sole responsibility was to teach the tactics of the game are past (Noakes &

Du Plessis, 1996). Through physical and sports education, the teacher/coach has a chance to positively influence the basic movement skills, motor abilities, physical fitness, mental and social abilities and injuries, and consequently the health, of his players.

According to the opinion of Roy (1974:2326), rugby injuries, specifically injuries occurring during practice sessions, should decrease in the presence of adequate coaching techniques and supervision. Scher (1977) published one of the first scientific studies about neck injuries among rugby players. This article was followed by suggestions that the prevention of these injuries was dependent on the coaching of correct tackling techniques. These suggestions stated that special attention had to be paid to the position of the head when making the tackle (Editorial, 1977). In light of the above, a survey of 25 South African high schools found that fewer than 30 minutes were devoted to tackling and falling techniques prior to the first full-contact match (Upton *et al.*, 1996). Furthermore, Burry and Gowland (1981:56) in a 6-year New Zealand survey on cervical injuries, stated that only one injured player was aware of this danger at the time of his accident. The authors suggested that coaching with an emphasis on awareness and precautionary measures would be effective in the prevention of cervical injury.

More data, this time from the South African study by Roux (1992:111), suggest that 75.5% of the schoolboy players who suffered a concussion injury did not follow the international ruling that players may not return to rugby for at least 21 days after an initial injury. The coach should see that this does not happen. Furthermore, the coach should never condone foul or violent play, even among the exceptionally talented (Noakes & Du Plessis, 1996).

As stated in paragraph 3.8.1.1 (*Prevention through education*), educated teachers and coaches are better equipped to educate and make players more aware of safety techniques and dangers. The IRB, in addition to the 1988 rule changes, emphasised that coaches should consider the following (Noakes & Du Plessis, 1996):

- Choosing players with appropriate physical attributes to play in the scrum and ensuring that they undergo specific training programmes to increase their upper body, neck and shoulder-girdle strength;
- only specialist front-row forwards should be used to substitute other front row players;
- teaching players to tackle correctly, “ride a tackle” and fall correctly;
- the coach should emphasise the danger of posting the ball between the legs while going forward. The player can injure his neck if it gets caught in a flexed position between attacking and defending players. Therefore players must be coached to keep their heads up and necks extended when going into the loose scrum. This will prevent injury by *vertex impact* (striking the top of the head when it is lowered); and
- similar to the previous point, players should be coached not to dive blindly into the loose scrum to collect the ball, post it or add weight to the scrum.

Other research confirmed that players caught in the ruck and maul should be taught to keep their necks extended, protect their head with their arms, crawl out of the ruck as quickly as possible and scream if they think they are in trouble (Akapata, 1990). Furthermore, front-row players should be taught to “sight” where they want to place their heads before the scrum engages (Calcinai, 1992). Again, they should be coached not to allow the head to be struck when the neck is straight, for example during tackles, engagement or collapse of the scrum and when entering a ruck or maul (Noakes & Du Plessis, 1996). The reason for this is to avoid dangerous positions where a player is at risk of striking his head while his neck is in a flexed position (Noakes & Du Plessis, 1996). Therefore, coaches should constantly be on the lookout for dangerous training techniques which may put player’s necks at risk of cervical cord injury.

Noakes and Du Plessis (1996:139) concluded that better coaching was needed in all types of tackles, especially among back-line players. The authors foresaw that head-on tackling would become more common in the future, hence players should be rigorously coached in tackling from the front. Wilson *et al.* (1999:159-160) also suggested possible reasons in the tackle that may cause injury. In the light of these findings, it would make sense for coaches

to implement strategies which decrease the likelihood of these situations occurring. The following might be useful coaching strategies (Sugerman, 1983; Australian Rugby Football Union, 1993; Noakes & Du Plessis, 1996; Wilson *et al.*, 1999):

- Teaching players to protect themselves against injury when going to ground in tackle situations. Contacting the ground with the major bony structures and muscle groups will ensure better absorption of impact forces and avoid upper limb injuries associated with falling on the outstretched hand. Players should be taught how to fall and possibly learn “break-falls”;
- coaching techniques which reduce the likelihood of front-on tackles to the trunk. Unless it serves a tactical purpose, players should be taught to avoid being tackled, especially at high speed;
- teaching the actions of “going with the impact” or turning in the tackle;
- coaching the proper technique of “the low tackle”;
- instructing players to roll away from the tackle situation when grounded;
- teaching the tackler to turn the head from the tackled player’s body – to the side when tackling from the front or behind, or behind the buttocks when the tackle is from the side;
- the tackler must drive off his legs and ensure firm contact with the shoulder while gripping firmly with the arms;
- keeping both hands on the ball through the tackle allows for more passing options and reduces the risk of injuring the wrist, forearm or shoulder if the tackled player tries to break his fall by stretching out his hand;
- driving through the tackle may break the tackle and increase the chances of staying on one’s feet; and
- coaching players to avoid dangerous and illegal tackling, for example crash-tackling defenceless players; tackling the player without the ball; early, late and stiff arm “tackling”; and high tackling (around the head and neck).

Garraway and Macleod (1995:1487) confirmed that coaches should teach players tackling techniques that are safe for themselves and their opponents.

With regard to some other risk factors in rugby, it has already been mentioned that not all rugby players run the same risk of injury. The coach must realise this and create opportunities for individual players to work at reducing this risk. Furthermore, coaches should be on the lookout for individuals with high psychological risk factors (internal risk factors). Players experiencing major life changes should be watched closely for signs of increased muscle tension or abnormal attentional difficulties when performing (Weinberg & Gould, 1999). Teaching these individuals stress-management techniques with the specialised help of a sports psychologist may reduce their risk of injury. Because state anxiety (discussed in paragraph 3.7.1.2: *Psychological traits*) may predispose players to injury, the teacher or coach should recognise when and with whom arousal and state anxiety need to be enhanced, reduced, or maintained.

It is clear that the coach fulfils a leadership role within sport (Lyle, 2003). Because of the rise in rugby injury incidence, present-day coaches will increasingly be confronted with injuries at vital stages of the playing season. Today, the coach has to play his part in ensuring availability of players throughout the season. Coaches see athletes on a daily basis, whereas other members of the sports medicine team do not (Weinberg & Gould, 1999). Thus they are in the best position to administer injury prevention strategies over the course of the season.

Evidence confirms that the contributions of sport scientists (and other specialists) can be less effective when not integrated into the coaching process (Lyle, 2003). This can happen when sports science or injury prevention programmes are 'imposed' by a governing body and/or when the coach is unwilling or unable to utilise the information provided. Therefore, in order to promote injury prevention, an excellent practitioner-coach relationship is required. The coach must be involved in the medical decision-making, as the coach will be a valuable aid in supervising recommended rehabilitation programmes.

Yet it is obvious that no single individual can provide the range of sophisticated, in-depth and specialist tasks needed to enhance performance as well as prevent injuries. Therefore it is necessary to take a team approach to the optimal execution of the coaching process (Lyle, 2003). The coach should be aware that if too many specialists are “brought in” to assist the athletes, there is a potential for lack of direction and role clarity (Lyle, 2003). To prevent this from happening, excellent communication has to be achieved between the coach and exercise specialist, as well as recognition of their respective roles in relation to the coaching process.

Concerning the coaching atmosphere, negative responses from coaches and team members can devastate some athletes (Weinberg & Gould, 1999). Coaches should not convey the message that he has no use for players who are hurt. These players want to feel worthy, so they may feel pressured to play while injured and sustain even worse injuries (Weinberg & Gould, 1999). Some may even take drugs to attenuate pain, to cope psychologically and to speed up the recovery process (Weinberg & Gould, 1999). Positive feedback from the coach lessens feelings of incompetence and pressure among athletes (Horn, 1985; Putter, 1996). This may also be helpful in reassuring injured athletes of their role in the team.

In summary, the long-term goal of school sport must be defined. It must be remembered that the school also has to play the role of caregiver (Zanga, 1990). Schools should ensure that school children are the main beneficiaries of sport at school (Noakes & Du Plessis, 1996). Furthermore, schoolboys should be at liberty to choose whether to participate in rugby or not. There needs to be a balance between the recreational needs of all members of a school and the pressure at some schools to focus exclusively on the talented few in a small group of high-profile sports (Noakes & Du Plessis, 1996). The skills of those with talent should be allowed to develop at appropriate pace, while those without the same skills should be encouraged to participate for their own pleasure. It is the responsibility of the school to ensure that appropriate coaches are appointed for these tasks.

Armed with the latest knowledge on the causes of rugby injuries, coaches today should be better able to structure training and coaching methods to reduce the risk of injury to players who are most at risk. Coaches should start to implement these improved conditioning, fitness

and skills programmes early on, during the pre-season. This paragraph is best summarised by the following statement of the English Rugby Football Union (Noakes & Du Plessis, 1996): “The successful coach is concerned more with the well-being and interests of the players than in their win-loss record.”

3.8.1.4 The relationship between biomechanics and the prevention of injuries

The following section aims to explain that a positive relationship exists between a poor biomechanical position and an increased risk of injury, that timely biomechanical assessments/screenings are needed to identify this injury risk, and that the abnormalities picked up during the biomechanical assessments can be corrected, thus decreasing risk of injury.

As mentioned in Chapter 2 (paragraph 2.3.4) correct biomechanics results in a good posture, provides efficient movement and reduces injury risk. A biomechanically poor position increases stress on certain muscles and should be considered a potential cause of non-traumatic sports injuries (Brukner & Khan, 2001). A list of biomechanical abnormalities related to injuries has been mentioned under paragraph 3.7.1.1d. These defective biomechanics may result from *static* (anatomical) or *functional* (secondary) abnormalities (Brukner & Khan, 2001). Static abnormalities cannot be altered, but the secondary effects of these abnormalities can be minimised by compensatory devices and appropriate exercise. It seems that if an individual has biomechanical deficiencies around a joint, the position of the structures around the joint could be altered dynamically with treatment to maintain homeostasis and a symptom-free joint (McConnell, 1999).

Timely biomechanical assessments are needed to identify and treat intrinsic biomechanical risk factors, thereby minimising injury. Abnormalities detected during assessment which may require correction include muscle tightness, weakness or lack of co-ordination, joint stiffness and increased neural tension (Brukner & Khan, 2001). Muscle weakness or lack of co-ordination can be corrected via strengthening and retraining. Muscle tightness and joint stiffness can be corrected with active or passive mobilisation, while neural tension can be

treated with neural stretching exercises and correction of probable causes (Brukner & Khan, 2001).

One way of reducing muscle tightness is through stretching. It has been noted that stretching programmes may greatly decrease the probability of injuries in adolescents, and that these programmes are critical during rapid growth spurts, when muscle lengthening falls behind bone growth and weakened biomechanics consequently occur (Fielding, 1990; Whiting & Zernicke, 1998). This is confirmed by Armstrong and McManus (1996:27-28), who believe that exercises for increased joint mobility should be prescribed pre-puberty, as long as it is carried out with a concern for the safety of joints and the vertebral column. Older children and adolescents, however, can enhance their flexibility with a regular programme of static stretching exercises (Armstrong & McManus, 1996; Van Gent, 2003). Furthermore, proper flexibility training and pre-exercise stretching can reduce joint stiffness, muscle and tendon tightness, and exercise-related muscle soreness (Whiting & Zernicke, 1998). However, it is important to develop muscle stability, strength and power through this new increased range of motion, to avoid muscle injuries (Brukner & Khan, 2001). However, in light of the above, data to support the practice of stretching are lacking and the ideals for stretching and flexibility have not been fully quantified (Neely, 1998).

When using stretching to improve flexibility, one should keep in mind that acute, passive, static stretching results in decreased passive stiffness and attenuation of the stress relaxation response (Gleim & McHugh, 1997). Baseline *stiffness*, however, is restored in less than one hour. For lasting increases in ROM (range of motion), athletes need to follow a stretching programme of several weeks (Gleim & McHugh, 1997). However, research also indicates that improvements in ROM may not necessarily equate to a decrease in passive stiffness of muscle (Gleim & McHugh, 1997). Rather, improvements in ROM were attributed to increased "stretch tolerance". More concluding research that differentiates between ROM and stiffness within the muscle is needed in this regard.

It is recommended that routine biomechanical screenings be used as part of an injury prevention strategy. In this way, players with abnormalities could be discouraged from

playing in high-risk positions if necessary. These evaluations will not only protect players already at risk of injury, but may also serve to educate them on the necessity for mobility and stability training. Furthermore, organisations need to be developed to administer research on injury mechanisms, injury biomechanics and to ensure a supply of scientists trained in injury biomechanics (Whiting & Zernicke, 1998). Exploration of the biomechanics of injury is an interdisciplinary endeavour (Whiting & Zernicke, 1998). Individuals like physiotherapists, biokineticists, physicians, occupational therapists, kinesiologists, prosthetists, orthotists, nurses, physical therapists, chiropractors, osteopaths, ergonomists, safety engineers, sports scientists, coaches, athletes and other sports therapists can provide different but valuable perspectives that are necessary for addressing the biomechanics of injury.

Because routine biomechanical screenings are recommended to detect the risk of sports injuries, especially intrinsic injuries (related to overuse of the body), a brief discussion of biomechanics and the prevention of intrinsic injuries follows below.

(a) *Biomechanics and intrinsic injuries*

Although most rugby injuries occur due to sudden, external forces acting on the body, there is also a group of injuries in which external trauma plays no part (Noakes & Du Plessis, 1996). These are intrinsic injuries which develop from stresses placed on the body, especially by running. Data from an Argentinean study indicate that rugby players experienced several slowly developing degenerative joint lesions (intrinsic injuries) resulting from overweight and chronic joint use (Bottini *et al.*, 2000). With most intrinsic injuries, some underlying anatomical or biomechanical problem exists that would prevent an athlete from training as long or intensely as another athlete before incurring an intrinsic injury (Hreljac *et al.*, 2000). The treatment of intrinsic injuries almost never requires surgery, but rather correction of intrinsic as well as extrinsic risk factors (biomechanics, environmental factors, training factors).

Athletes are in constant interaction with their environment (Van Mechelen *et al.*, 1992). Body tissues continuously experience mechanical loads (sum of all the forces acting on the body) during normal activity with no obvious injury (Whiting & Zernicke, 1998; Bartlett,

1999). These loads are all referred to as being within the physiological range. When loads exceed the physiological range, the tissue experiences overload and the probability of injury increases (Whiting & Zemicke, 1998; Zemicke & Whiting, 2000). Injury can result from a single overload or repeated overload (overuse). Overuse (intrinsic) injuries exemplify a broad class of conditions distinguished by an etiology of repeated force application, often with insufficient time for recovery (Hreljac, 2004). Chronic loading may weaken a tissue, lower its maximum strength and increase the likelihood of an acute injury (Whiting & Zemicke, 1998).

Inappropriate volume or intensity of exercise load (overload) may cause a maladaptive cellular or tissue response to occur due to an imbalance between load and recovery (Derman & Schweltnus, 2001c). During this time, prolonged elevation of muscle tone often develops in both the resting and contractile states (Brukner & Khan, 2001). This increased muscle tone can alter the relationship of agonist to antagonist muscles. The elevated muscle tone may also contribute to biomechanical abnormalities, especially if the “tightness” is asymmetrical. Increased tone further limits the extensibility and shock absorbency of soft tissue and may cause microtrauma to develop.

Repetitive microtrauma may cause bulky connective tissue to develop, which further reduces mobility. These changes can impair training and competition and will progress to injury locally or further along the “*kinetic chain*” if they remain untreated (Brukner & Khan, 2001). When different tissues are now loaded through further exercise, the weakest-link phenomenon typically occurs (Whiting & Zemicke, 1998). This means that when a combined structure is mechanically loaded, it is likely to fail at the weakest link in the structural chain. In the human body the factors that contribute to the weakest-link phenomenon are many, interrelated, and often not easily identified or well understood (Whiting & Zemicke, 1998).

From the above it is clear that there is a probable relationship between mechanical stress along the structural kinetic chain and intrinsic injury. The “stress continuum” (Figure 3.5) gives a better understanding of this relationship (McGinnis, 2005).

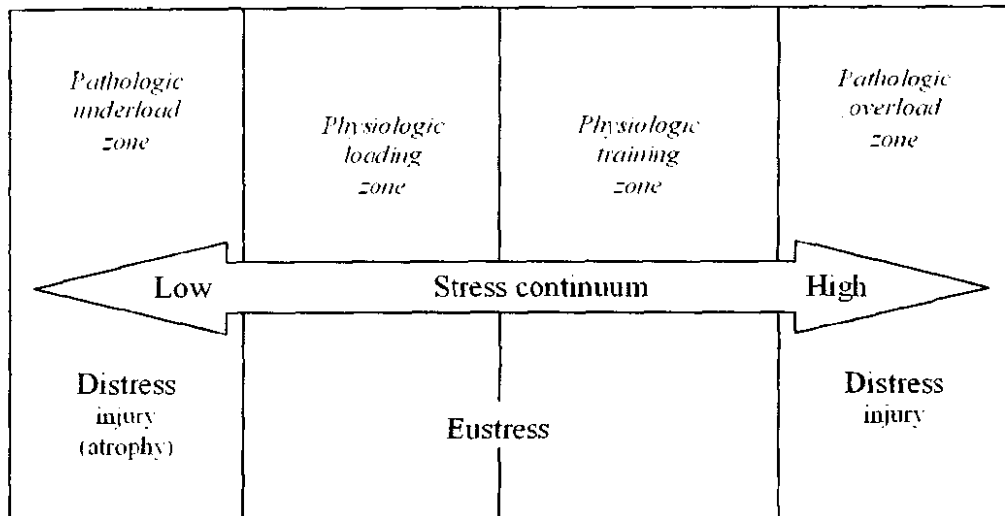


Figure 3.5: The stress continuum (McGinnis, 2005)

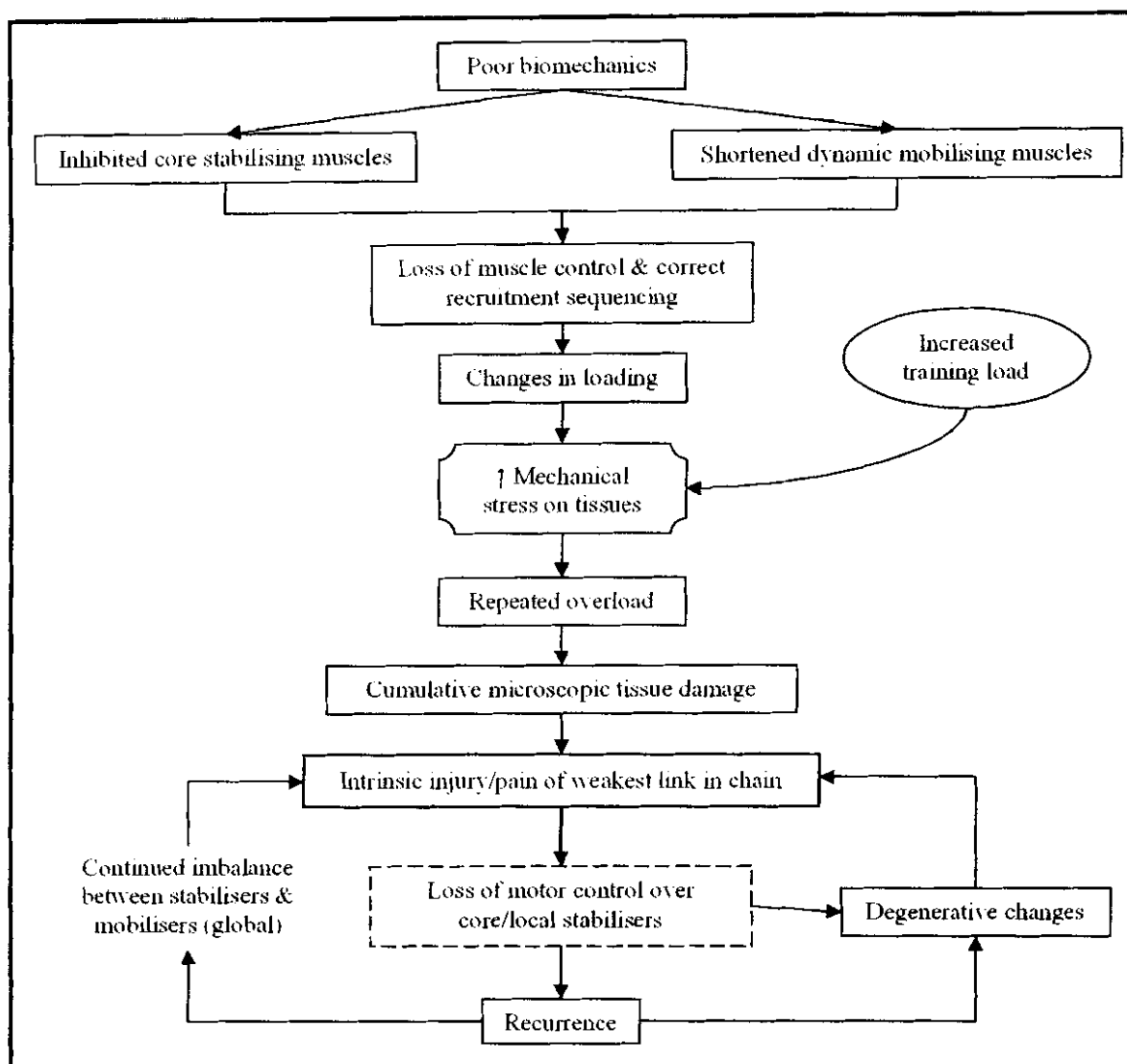
According to the stress continuum, the human body is subject to complex loading – a combination of the compressive, tensile and shear stresses imposed at the same time. A tissue adapts to the level of stress imposed on it, the level of adaptation in a tissue reflects the level of typical loading (McGinnis, 2005). The magnitude of stress on a tissue may range from a very low level (*pathologic underload zone*), or no stress, to a very high level (*pathologic overload zone*) (see Figure 3.5 above). When stress is kept within the *physiologic loading zone*, muscles, bone, tendons and ligaments maintain their ability to withstand stress.

Controlling the level of stress is important in training various tissues to avoid injury (McGinnis, 2005). A stress within the *physiologic training zone* exceeds the strength of the tissue and causes microscopic damage within the tissue. If adequate rest is allowed, the tissue will be rebuilt and strengthened. In the *pathologic overload zone* the level of loading causes substantial damage to tissue. A single high level of stress can cause an accidental or traumatic injury (McGinnis, 2005). Repeated application of a stress lower than that required to cause traumatic injuries can cause intrinsic injury (McGinnis, 2005). Intrinsic injuries generally occur when a structure is exposed to a large number of repetitive forces, each

below the acute injury threshold of the structure, producing a combined fatigue effect over a period of time beyond the capabilities of the specific structure (Stanish, 1984; Hreljac *et al.*, 2000).

Thus intrinsic injuries are caused by the frequency and magnitude of loading combined with inadequate rest to allow remodelling (McGinnis, 2005). Once the individual is healed, the probable cause of the intrinsic injury must be eliminated to prevent recurrence (McGinnis, 2005). That is, the frequency or magnitude of stress must be reduced and adequate rest allowed. The role of biomechanics in this model of McGinnis (2005:343) is that abnormal biomechanics that are not corrected may cause off-angle forces, which will result in abnormal or unaccustomed loading, and consequently increased mechanical stress on tissue (also see Figure 3.5).

Figure 3.6 was developed as a basis for the literature review, in order to serve as a summary of the relationship between biomechanics and the development of intrinsic injuries. In short, each one of us can function without symptoms in a certain range of activities, but once we exceed that range, symptoms will occur (McConnell, 1999). As mentioned, intrinsic injuries happen during periods of increased volume and intensity of training (usually at the start of the season) when the players are not sufficiently strong to cope with the training demands (Brukner & Khan, 2001). These intrinsic injuries may become even more common if future rugby players – in order to keep up with the demands of the modern game – do additional strength and endurance training. Future research in the area of intrinsic injuries though should still focus on establishing criterion tolerance levels of the body to repetitive impact loading, in terms of magnitude and number of repetitions (Hreljac *et al.*, 2000; Hreljac, 2004).



↑ = increased

Figure 3.6: Summary of the relationship between biomechanics and intrinsic injuries

The key to reducing the risk of intrinsic injuries is gradually to increase training loads and to correct the biomechanical and environmental factors which may predispose players to injury. Individual limits in terms of stress that can be tolerated before an injury occurs are also dependent on biomechanics. Poor biomechanics may mean that the level of stress will fall in the pathological overload zone instead of the physiological loading zone (see Figure 3.5). Furthermore, there an interdependence of body parts exists in biomechanics. When performing a movement pattern a combination of body parts forms a structural kinetic chain.

Injury will commonly result at the weakest link in this kinetic chain. It is recommended that rugby players undergo timely biomechanical screenings as a precautionary measure. In this way biomechanical weaknesses in the kinetic chain may be identified and corrected, ahead of periods of increased frequency and intensity of training. The consequence of this may possibly be that individuals will experience decreased mechanical stress and less intrinsic injuries during periods of increased training volume. Research on intrinsic injuries in rugby is still unexplored, probably because research in biomechanics and intrinsic injuries in team sports is more difficult than individual sports due to the number of variables that can influence results.

3.8.2 CURRENT INJURY PREVENTION PROTOCOLS

The *stress-strain-capacity* model of Van Dijk *et al.* (described in Van Mechelen *et al.*, 1992:95) is useful in understanding injury prevention protocols. According to this model “*capacity*” is defined as the sum of all the intrinsic factors (skill, motivation, attitude, age, sex, etc.) that allow an athlete to perform in sport at a certain moment. The “*stress*” is the external load (external, environmental factors, etc.) experienced by the individual. In contrast to classical models, a notable concept associated with this model is that of “*personal control*”. Personal control means sportspersons are no longer just passive recipients of stress. They now have the ability actively to influence the amount of stress that is imposed on them by the sports activity, thereby actively influencing the effect of that activity. For the purpose of this study, this means that the rugby player is able to alter his capacity by mastering of various injury prevention techniques. Although the player is then seen as the active manipulator of stress, he may need help from the trainer/biokineticist/physiotherapist, etc. to implement prevention strategies.

In this stress-strain-capacity model of Van Dijk *et al.*, the individual will experience an amount of “*strain*” (fatigue, decreased reaction time, etc.) as a result of the interaction between stress and personal control. When strain has gone beyond the limits of individual capacity, the effect may be injury. The result of a long term strain effect may be intrinsic

injuries. Therefore, injury prevention programmes should strive to maintain a balance between strain and capacity.

According to Brukner and Khan (2001:84) injury prevention remains largely neglected. They define prevention as “primary”, “secondary” and “tertiary” prevention. These are described as:

- Primary prevention – health and disease prevention;
- Secondary prevention – diagnosis and treatment (limit the development of disability);
- Tertiary prevention – rehabilitation (reduce/correct existing disability).

The proactive clinician must initiate general and athlete-specific injury prevention strategies, give prevention advice during consultations where treatment is being sought and devise in-season strategy planning sessions with coaches and during screening of athletes (Brukner & Khan, 2001). Correct biomechanics can be a major factor in the prevention of these sports injuries (Brukner & Khan, 2001). Other factors that may assist injury prevention in sports (Brukner & Khan, 2001) are:

- Warm-up;
- stretching;
- taping and bracing;
- protective equipment;
- suitable equipment;
- appropriate surfaces;
- appropriate training;
- adequate recovery;
- psychology; and
- nutrition.

Because of the different methods of preventing injuries, some of the past injury prevention protocols followed by different countries, as well as the situation in South Africa and

schools, are reviewed next. To date, the precise nature of a rugby injury prevention programme has not been established.

3.8.2.1 Internationally

The US Army has already demonstrated the power of simple screening and survey methodologies in injury prevention. The US Army developed comprehensive injury prevention programmes through the steps of surveillance, research, programme implementation and monitoring (also see Figure 3.1) (Jones & Knapik, 1999). The findings from their programmes and the general principles of injury control contained therein have wide application and can also be useful in civilian sports such as rugby. Their systematic injury control requires that 5 primary questions be answered:

- (i) Does a problem exist?
- (ii) What causes the problem?
- (iii) What works to prevent the problem?
- (iv) Who needs to know and what do they need to know?
- (v) How effective are the preventative measures put in place?

The key to their prevention/control programme is continuous surveillance and research (Jones & Knapik, 1999). This information provides the necessary basis for targeting injuries and disease with a view to prevention or research. By first doing research, they are able to determine modifiable risk factors and causes of injuries. Subsequently, strategies for intervention are devised and their effect tested before implementation.

Following implementation, ongoing surveillance of the effectiveness of strategies is kept up. Examples of potentially modifiable risk factors for physical training that were identified by this process are high volumes of running, low levels of physical fitness, high and low levels of flexibility, etc. (Jones & Knapik, 1999).

According to Jones and Knapik (1999:122), a study by the US Naval Health Research Center provides an example of a successful intervention – based on one of the risk factors identified – that was adequately tested before implementation. This study examined the effectiveness of reducing stress fractures by reducing running activity (Jones *et al.*, 1994). Firstly, the US Naval Health Research Center started out with observational studies, which indicated a relationship between training mileage and high cumulative injury incidence (Jones *et al.*, 1994). This then resulted in the testing of a prevention strategy.

The naval research personnel divided trainees into three groups with more than 1000 marine recruits in each (one high mileage group, a low mileage group and one control group) and obtained their 4.8 kilometre run times, as well as the incidence of stress fractures (Jones *et al.*, 1994). Comparing high and low mileage groups showed that reducing running distance considerably (by 40%) resulted in a slightly slower run time (2.5%), but also in an important reduction (54%) in stress fractures. Thus, they indicated that a prevention strategy could reduce stress fractures, with minimal losses in cardio-respiratory endurance.

Except for the above-mentioned study, several other studies up to 1999 have also outlined programmes for injury prevention. However, few assessments of their actual effectiveness were done. The same general principles of injury prevention and control as identified by different military studies apply to civilian sports and exercise (Jones & Knapik, 1999; Sherrard *et al.*, 2004). Thus, the prevention strategies implemented by the US Army could also be applied to rugby.

One programme which has been assessed as effective is the so-called ACC (Accident Compensation Cooperation) Sport Smart 2000 programme. The New Zealand Rugby Union managed to reduce their injury rate by approximately 47% through the implementation of this prevention programme. It is a longitudinal programme that paid attention to the following 10 pointers (Quarrie *et al.*, 2001):

- (i) Screening.
- (ii) Warm-up/cool-down.

- (iii) Physical condition.
- (iv) Technique.
- (v) Fair play.
- (vi) Protective equipment.
- (vii) Hydration and nutrition.
- (viii) Injury surveillance.
- (ix) Environmental factors.
- (x) Injury management.

Furthermore, since 2000, the following injury prevention strategies were covered in a recent publication, *Complete Conditioning for Rugby* (Luger & Pook 2004):

- Exercises should be based on the specific demands of rugby, be functional, and mimic the movement patterns of rugby;
- drills which enhance balance, core stability, muscle and joint stability, and control should be added;
- start with stabilisation and progress to strength and power training;
- incorporate drills which help players build resistance to fatigue;
- pay attention to flexibility and posture;
- begin each training session with an appropriate warm-up and use recovery strategies such as cooling-down, and contrast bathing;
- focus on using correct technique during difficult drills, such as explosive exercises; and
- individualise the training programme and its conditioning targets, and introduce appropriate fitness-testing protocols.

The authors called this *prehabilitation* or *body protection*. The effectiveness of these strategies still remains to be formally tested on rugby.

3.8.2.2 South Africa

As regards South African as well as international rugby studies, credit must be given to Noakes and Du Plessis (1996) for their coverage of most of the rugby studies up to 1996. The following discussion of the South African situation up to 1996 has mainly been derived from their publication.

According to Noakes and Du Plessis (1996:43) it must be remembered that South Africa is unique in its demographics of rugby. According to the authors, there are more players in South Africa than in Australia or New Zealand. Secondly, in contrast to other major rugby-playing nations, players in South Africa come from a more diverse social background. Thirdly, a large part of South African rugby is played outside the control of the official governing bodies. This means that control over the risk of injury and adequate medical care will be less. Finally, there are discrepancies in playing facilities and coaching opportunities among different South African players.

According to Noakes & Du Plessis (1996:43) it is assumed that the players who are not as well coached and who play on poorly prepared surfaces will be at greater risk of injury. Overall, the results of these four points mean that it may be more difficult to implement and control adequate preventative programmes in South Africa than in other big rugby-playing nations. With new developments and research initiatives constantly being implemented by the South African Rugby Union, this situation will hopefully improve.

After the 1974 British Lions had beaten the South Africans 3-0 in a four-test series, Noakes (quoted from Noakes & Du Plessis, 1996:185) commented that there was a vast gap that existed between sports science and sports practice in South Africa. This comment was not received favourably, and the general situation (with one or two exceptions) in South Africa remained unchanged until 12 years later, when exercise specialists were used to assist with the preparation of provincial sides.

In 1990 a South African doctor, Uli Schmidt, gave the following advice to those involved in rugby (Schmidt, 1990:30):

“If I had to send a message to all involved in sport in this country, it would be that alteration of the rules to make the game safer is one thing. But that is the job of the administrators, and it is only the tip of the iceberg – rule manipulation will only achieve so much.

The real challenge that faces administrators, coaches and the players themselves is in their whole approach to their sport. Firstly, there must be a far greater commitment to hard work and physical development. We cannot allow ourselves to become lazy and take short-cuts in training. This is a recipe for disaster.

Secondly, we must eradicate the pressure to start playing again before injuries are properly healed. This macho approach to life is extremely dangerous.

Finally, physicians handling sportsmen need to understand the psychology and motivation of the serious athlete. To do this they need to become involved in sports medicine associations and congresses. Anything less and they will be doing their patients a grave disservice.”

Coming from an ex-Springbok rugby player and team doctor, this message of Schmidt's becomes even more important

In 1996 Noakes and Du Plessis (1996:1-363) published a practical guide to the prevention and treatment of rugby injuries. Some of the data reviewed by the authors showed that 55% of injured players in the Western Province of South Africa thought spinal cord injuries could have been prevented either by stricter refereeing, greater awareness of dangerous situations, improved coaching, better first aid or medical facilities and rule changes (Kew *et al.* quoted by Noakes & Du Plessis, 1996:138). This did not reflect very well on the standard of injury prevention in South Africa. Luckily, the book by Noakes and Du Plessis (1996) was a step in the right direction. One of the major goals of their book was to encourage all players to be match-fit well before the start of the rugby season. To determine if some of these ideals have been implemented by different South African sides, specific pre-season fitness of different

teams and the techniques and protocols they employ to reach this pre-season status should be researched.

A few years later a South African physiotherapist proposed certain injury prevention strategies, based on an analysis among adolescent rugby players of different ages (Hattingh, 2003). Many of the suggestions made by Hattingh will also be utilised for the purpose of this study. Shortly after the study of Hattingh (2003), another study proved that schoolboy rugby players presenting with biomechanical dysfunction of the cervical spine could benefit from a manual physiotherapy technique as well as a therapeutic exercise programme for the correction of biomechanical dysfunction (Steyn, 2005). It is recommended that researchers now implement follow-up studies to test the effectiveness of all these latest recommendations in the prevention and treatment of rugby injuries.

3.8.2.3 Schools

Because the risk of injury rises sharply after age 13 (see paragraph 3.7.1.3a: *Age*), it would make sense to put more emphasis on preventative measures when schoolboys reach this age. According to Noakes and Du Plessis (1996:100) the age of 13 years may already be too late to teach schoolboys how to avoid injury. The authors express the opinion that whereas young children are very receptive to advice aimed at their self-preservation, adolescents believe that risk-taking behaviour is “macho”. According to them, the safety-first approach must be taught to young players the moment they begin to play the game, and not when they are adolescents who are already at increased risk of rugby injury.

Strengthening of the neck muscles as a preventative measure is recommended by many (Scher, 1977; McCoy *et al.*, 1984; Scher 1985, Noble, 1988). This may reduce the risk of cervical spinal injuries. Although school boy rugby players have been found deficient in areas of upper back flexibility and strength, strengthening these muscles among forwards is largely neglected (Watson, 1981; Du Toit, 1993). Neck strengthening exercises must already be implemented at junior level and be well supervised (Noble, 1988). The neck exercise programme for the correction of biomechanical dysfunction developed by Steyn (2005:181-209) may be a good starting point.

The relationship between pre-season fitness and injury incidence at school level has been noted more than twenty years ago (see paragraph 3.7.2.2a: *Pre-season preparation*). In the light of this, Upton *et al.* (1996:533) during the 1990s still reported that the majority of high schools in South Africa did not undertake adequate pre-season or neck-strengthening programmes before the start of the rugby season. It is probable that the current situation in most South African schools remains unchanged.

Internationally, in May 1979 the Medical Office of the Schools Associations (MOSA) in the United Kingdom prepared a memorandum which included certain suggestions to reduce rugby injuries at school level (quoted from Noakes & Du Plessis, 1996:32). This document immediately caused some controversy, mainly because one of the suggestions was that schools should be forced to insure their players against accidents before the next season. There was concern that this could lead to lawsuits if some schools did not comply with the suggestion, consequently this document was not accepted as an official document. In July, 1980 an official document to replace the previous one was decided on. The ten suggestions contained in this revised document were the following:

1. More attention should be paid to pre-season preparation. Schoolboys should be *fit for rugby*, instead of hoping to become fit by playing rugby;
2. Coaches should be fully involved with fitness coaching and injury prevention and be aware of coaching aids like posters and wall-charts. Coaches should be encouraged to improve their knowledge of physical conditioning and first aid through attending sports medicine seminars;
3. Coaching the correct techniques of the tackle, scrum, ruck and maul from an early age;
4. Substitution of up to six injured players per game should be allowed, to reduce the risk of boys playing out of position;
5. Levels of experience should always be matched;

6. Teams should be of equal age, strength and maturity. Traditional games involving older pupils may be allowed if the selecting of the team and the supervision are left in the hands of the school coach. Games between schools and clubs should only be allowed if there is a strong element of coaching involved;
7. Psyching-up of players by the coaches or anyone else should be opposed;
8. Players with serious concussions should only be allowed to play after complete recovery and medical clearance;
9. Although mouth guards decrease the risk of injuries to the face, chin and teeth as well as concussion injuries, they should always be fitted by a dental surgeon;
10. Studs should be made of rubber, and the fifth stud (toe stud) must be eliminated.

Because these changes did not really affect the incidence of spinal cord injuries, a working group of The Rugby Football Union (quoted from Noakes & Du Plessis, 1996:34) suggested that the interpretation of rules should be changed so that

- any player in the scrum, ruck or maul had to keep his shoulder joint above the level of his hip joint;
- players who arrived at the point of breakdown and then entered the maul had to stay on their feet and not be allowed to fall on top of or over the ball;
- Play had to be stopped immediately when the scrum collapsed.

Although the combination of the above changes was effective in reducing the incidence of spinal cord injuries admitted to one specific hospital used in a study, there are those who believe that these changes had a smaller preventative effect on the incidence of injuries if the total United Kingdom were looked at (Noakes & Du Plessis, 1996).

In Australia, the same concerns about increases in spinal cord injuries were raised (Noakes & Du Plessis, 1996). The Australians decided the best way to prevent such injuries was to introduce *law changes* for all ages up to under-19. All of the seven law changes were aimed at decreasing the dangerous situations associated with scrums, rucks and mauls. As a result

of these changes, for the period 1985-1992 not one serious spinal cord injury occurred in under-19 Australian schoolboy rugby played under the new rules (Noakes & Du Plessis, 1996).

At school level, the availability of health services poses a problem because it is often difficult to have qualified medical help at hand when it is needed (Arnheim & Prentice, 2000). The school should see to it that an effective method is established for handling all players requiring medical care or a medical opinion. This includes the availability of emergency care, planned access to a physician and transportation (Arnheim & Prentice, 2000).

In summary, since the start of the modern era (post-1996) there has been a lack of research on schoolboy rugby injury incidence (Hattingh, 2003). This shortcoming was again highlighted by unfortunate cervical neck injuries in South Africa, for example the paralysis of the schoolboy Shawn Ramos during a regional match in 2004. A taskforce of the South African Rugby Football Union (SARFU) has already been assigned to research and deal with this disconcerting trend (Hattingh, 2003). The implications of this may possibly be that South African schoolboy rugby players will benefit if preventative measures are introduced as a result of the research.

The literature indicates that although a single preventative measure – law changes for example – may be effective in preventing certain schoolboy rugby injuries; a combined preventative strategy is recommended. In South Africa, Hattingh (2003:182) has already proposed a prevention programme for rugby injuries based on anthropometric, physical and motor, and biomechanical and postural shortcomings among adolescent players, while Steyn (2005:305) devised a safe and effective therapeutic programme for the correction of cervical biomechanical dysfunction of schoolboy rugby players. It is now time for injury research in South Africa to become more experimental. School rugby players should also be educated on how they as individuals can reduce their risk of injury. Opportunities remain for the multidisciplinary sports medicine team to educate South African schools on injury prevention. These problems are some of the primary motivations for undertaking this study.

3.8.2.4 The purpose of pre-participation screening

From the previous sections of this chapter it has become clear that the ability to participate in sports activities without injury depends on many factors. Genetic endowment and environmental factors cannot be changed (Kibler *et al.*, 1989). Psychological factors are difficult to measure, but can be changed. Finally, some physiological factors like speed, strength and biomechanics are measurable with relative ease and may be modified by appropriate training. These factors can be measured through the implementation of a *pre-participation screening* system.

The use of pre-participation screening to assess a player's proneness to injury could potentially decrease his injury incidence (Kibler *et al.*, 1989). The pre-participation screening is the first step in ensuring the health and safety of athletes (Lombardo & Baolato, 2001). The National Collegiate Athletic Association (NCAA) also lists it as the first component of a safe athletic programme (Prentice, 1999). The study by Watson (2001:224) failed to support the value of a general medical evaluation for injury prevention in high-level sport. In contrast, the results suggested that a clinical examination that concentrates more on the detection of musculo-skeletal defects could be useful in the prediction of future injuries. Today, this pre-participation *physical* examination has become an annual undertaking in the sports-medicine community (Armsey & Hosey, 2004).

The purpose of pre-participation assessment is to screen an athlete for an existing injury or disease, and secondly to screen for identifiable underlying injury risk factors (Schwellnus & Derman, 2001a). Conditions that restrict athletic participation can be identified through this evaluation. The pre-participation physical examination should provide the athlete and sports medicine team with information that could prevent injury (Kibler *et al.*, 1989). This should be a screening process, with further referral and evaluation when conditions of concern are found. Tests chosen for the screening should be based on the demands of the sport, the practicality of administering the tests and the availability of normative data (Kibler *et al.*, 1989). In addition, because of increased legal and insurance requirements of the present day, the pre-participation physical evaluation is essential (Armsey & Hosey, 2004). This screening meets important medicolegal considerations through providing a valued

documented assessment, both at the start and end of an athlete's career with any team (McCrorry, 2004).

The focus of the pre-participation screening should be on those aspects of athletic fitness that can be easily and efficiently measured, and that are most directly related to the particular group of athletes (Kibler *et al.*, 1989). The pre-participation physical examination should be designed to screen for potential problem areas, for example muscle imbalances, weakness of joint stabilisers, joint function and lack of full recovery from previous injury, cardiovascular disease and concussions (risk of further concussions increases with each subsequent head injury) (Prentice, 1999; Watson, 2001; Koester & Amundson, 2003). Thus, areas important to the specific sport can be identified and deviations pointed out (Kibler *et al.*, 1989). Ideally, the pre-participation physical examination should be conducted 4 to 6 weeks before the start of the season, to allow time to address problem areas (Armsey & Hosey, 2004).

The ideal pre-participation screening incorporates the help of the multidisciplinary sports-medical team (Arnheim & Prentice, 2000). This team approach fosters a line of communication between the members of the sports-medical team (Armsey & Hosey, 2004). Screening provides an opportunity for the multidisciplinary sports-medical team to offer advice regarding the reduction of injuries (Brukner & Khan, 2001). The role of the team physician is to assess the status of the cardiorespiratory and musculoskeletal system and review potential contraindications to participation (Prentice, 1999). This also allows the physician to counsel youths on personal and health questions (Kibler *et al.*, 1989). In this way the athlete is acquainted with the local sports-medical system and a doctor-patient relationship is established (McKeag, 1985; Kibler *et al.*, 1989). The role of the sports therapist is to assess the strength, fitness and biomechanics of an athlete relative to the specific demands of the sport (Prentice, 1999).

It is now clear that a well-planned pre-participation screening, followed by an adequate conditioning programme, may reduce the number of injuries in sport. This is especially true for intrinsic injuries. The development of a screening process which utilises proven tests that are easily administered may assist medical practitioners in identifying players who are at a

high risk of intrinsic injury. In order to reduce rugby injuries effectively – intrinsic injuries in particular – the pre-participation screening have to be targeted at different important links in the kinetic chain. There remains a need for the development of a standardised pre-participation physical evaluation in South African rugby.

3.9 CONCLUSION

Can rugby injuries be eliminated? The answer is no. Can the incidence and severity of these injuries be reduced? In light of the literature as discussed in this chapter, especially when considering biomechanics and intrinsic injuries, the answer must be yes.

The first step of preventing rugby injuries (see Figure 3.1) is to determine whether a problem exists. Injury definition, the causes of injury and injury incidence have changed with the evolution of rugby. However, epidemiological surveillance data indicate that injuries remain an important problem in rugby. Professionalism, a more sensitive injury surveillance system and certain law changes can be seen as the main reasons for the high injury rates seen today. The increased intrinsic and extrinsic injury rates may hold several consequences for the modern rugby player.

As a result of the above, greater emphasis has been placed on injury surveillance and injury prevention in rugby. The result is that several modifiable risk factors and causes of rugby injuries have been documented. Table 3.6 summarises the major risk factors for serious injury in modern rugby. These factors which influence the risk of injuries do not act in isolation, but are multifaceted and complex. It can be said that although any single one of these factors may be responsible for a particular injury, mechanisms often act in combination. Therefore, in order to better understand this specific influence on injuries, future quantitative studies regarding the measuring of exercise and training factors must be more detailed in documentation and statistical design (Jones & Knapik, 1999).

Although the literature has been helpful in finding the circumstances (risk factors) under which rugby injuries occur, it does not always explain why this is so. For example, it is

known that players suffer more injuries during certain times in the season, but there is no explanation if this is due to poor endurance, strength imbalances or biomechanical factors. The only way to answer these questions is to conduct scientific studies in which, for example, specific fitness variables of a group of players is increased before – and maintained during – a rugby season (Noakes & Du Plessis, 1996). The injury incidence of this group can then be compared to a similar group of players who do not undertake the training programme. Only if the experimental group shows a decrease in injury incidence compared to the control group can we prove that this is because of the specific “fitness” variables. Thus, future rugby research needs to practically apply and test risk-mitigation measures.

Table 3.6: Summary of the major risk factors for injury in modern rugby

Risk Factor	Effect
Injury history	Players previously injured or carrying an injury are most at risk
Physical fitness	Risk increases as players become more fatigued
Anthropometric	Heavier players tend to be injured more frequently
Biomechanical	Risk increases among those with abnormal biomechanics
Psychological	Intrinsic and extrinsic attitudes and psychological skills may influence injury
Demographical	Risk increases in male players and older age groups
Playing position	Positions involved most in the high-speed phases of the game are most at risk
Phase of play	Tackling and being tackled account for most injuries
Foul play	Foul play increases the risk of injury
Level of play	Risk is greatest at highest levels of play, and during match play
Training	Training that is not scientifically based increases risk of injury
Time of season	Players who are not conditioned early in the season and those who don't maintain their conditioning during the mid-season break are at high risk
Equipment	Suitable protection reduces the risk of injury
Playing environment	The playing environment may increase the risk of certain types of injury
Medical regimes and refereeing	Poor refereeing and poor on-site medical care increases the risk of injury
Law changes	Laws which encourage open play increase injury risk. Laws which ensure a safer environment in the set phases decrease risk of injury

However, research does suggest that the most certain causes of rugby injuries are the speed of the game combined with the momentum that players generate. The following points demonstrate this conclusion (Noakes & Du Plessis, 1996):

- The fast, mobile but heavier players playing in the best teams are more often injured;
- A high percentage of players is injured during the phases of tackling and being tackled, both of which occur at speed;
- Players in the older age groups playing in the best teams are most often injured;
- There is a significant difference in injury incidence during match play and during training.

After the injury problem, its etiology and the mechanisms of injury have been established, the next step in injury prevention is to propose prevention strategies and to determine which ones are effective. Many rugby nations already have strategies in place to address both intrinsic and extrinsic injury risk factors, especially for senior players. However, in the authors' experience, many South African schools are still lacking in this regard, notably as far as intrinsic injury risk factors are concerned. Although a number of preventative measures have been suggested in the literature, very few studies have formally tested their effectiveness in preventing injuries. This study aims to help fill this gap.

In order to design the most effective rugby injury prevention strategy, different programmes should be implemented, and their effectiveness monitored. According to their effectiveness, these programmes should be modified and retested. Armed with all the latest information from these studies, players and coaches will be able to anticipate high-risk situations and implement strategies to reduce future risk of injury.

The next key to ensure effective injury prevention in rugby is to distribute practical information from the research programmes directly to those who can use it to prevent injuries (teachers, coaches, referees, headmasters, medical and first aid officials, etc.), as well as to the public. Once in place, programme effectiveness should be monitored. In South Africa,

infrastructure for a comprehensive injury prevention programme, integrating surveillance, research, intervention, programme implementation and programme monitoring should be developed. Furthermore, an international injury register could greatly facilitate a closer working relationship between rugby authorities and researchers worldwide (Haylen, 2004).

If rugby injuries are to be reduced, a comprehensive approach must be taken to define the problem, establish the injury risk factors, establish protective factors and prevent injuries through well-designed intervention programmes. Future studies need to standardise research design, data collection, definitions and terminology, and reporting systems. Obstacles in injury prevention cut across educational, legal, scientific, political and economic disciplines suggesting that the most effective injury solutions will likely be interdisciplinary in scope (Whiting & Zernicke, 1998). Although this review points at the possibility of predicting high-risk situations for rugby injuries, it must be remembered that an unpredictable element will always be present (Lysens *et al.*, 1991). Injuries will still occur, and therefore continued monitoring is needed.

4

EMPIRICAL INVESTIGATION: METHODS AND MATERIALS

- 4.1 Introduction
 - 4.2 Choice of subjects
 - 4.3 Questionnaires/survey forms
 - 4.4 Procedures and methods of data collection
 - 4.5 Assumptions
 - 4.6 Definitions of terminology used
 - 4.7 The injury prevention programme
 - 4.8 Implementation of the injury prevention programme
 - 4.9 Battery of tests
 - 4.10 Statistical analysis
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4.1 INTRODUCTION

From the previous chapters it is evident that an injury problem exists in modern rugby. It is also clear that there are multiple risk factors which contribute to the probability of incurring a rugby injury. Furthermore, it is imperative to implement rugby injury prevention strategies early on, before rugby players are introduced to senior rugby. However, a lack of research on the effectiveness of rugby injury prevention programmes exists.

The aim of this study is to determine the effectiveness of a scientifically based injury prevention programme on the incidence of rugby injuries (overall, intrinsic and extrinsic injuries) of 15- and 16-year old schoolboys. Furthermore, the effects that this injury prevention programme has on the selected anthropometric, physical and motor, and biomechanical and postural variables of all the subjects were measured. According to the

results of this study, the programme can be modified in order to address possible shortcomings.

The aim of this chapter is to explain all methods and materials used for the purpose of the study. In this chapter the following will be discussed: tests, techniques and equipment used to attain the anthropometric, physical and motor, and biomechanical and postural status of all participants, as well as those used to implement and test the accepted injury prevention programme.

4.2 CHOICE OF SUBJECTS

The initial subjects were 160 schoolboy rugby players, of which 120 could be included in the first year of the study. Forty players were not included due to events such as players who switched schools, no desire to continue playing rugby, stopping participation due to injury/illness, not showing up for tests/evaluations and not complying with the experimental exercise protocol. During the second year of the study, one team could not participate. Consequently 105 players were included during this period. The North West provincial rugby union and the Rugby Institute of the North-West University were consulted to identify schools to include in the study. The schools chosen had a tradition of excellence in rugby, and were located in close proximity to Potchefstroom (and thus the Potchefstroom campus of North-West University).

Furthermore, to ensure that the teams selected were coached according to uniform, scientific principles, only schools that were involved in the training courses presented by the Rugby Institute of the North-West University were eligible for inclusion in the study. This ensured that all the coaches involved coached according to the technical and fitness guidelines advocated by the Rugby Institute.

Two secondary schools in the North-West province were selected, namely Klerksdorp High School, and the Volkskool high school. Players who participated as experimental groups were the year 2004, 15- (n=30) and 16-year old (n=30) elite A teams. The relevant B teams

(n=60) acted as controls. New players admitted to the team after the commencement of the study and players leaving the team were excluded from the study. To ensure an adequate supply of subjects in instances where players were lost from the respective groups, the team reserves were included in all the training sessions and the data collection phases. Players were also excluded where incomplete data were obtained.

4.3 QUESTIONNAIRES/SURVEY FORMS

Before data were collected, all questionnaires/report forms/evaluation sheets were piloted and adjusted as appropriate. All questionnaires/report forms/evaluation sheets were completed under the supervision of the researcher. There were five forms in total: the player information questionnaire, current and previous injury experience questionnaire, injury report form, biomechanical and postural assessment form, and rugby data sheet.

4.3.1 PLAYER INFORMATION QUESTIONNAIRE

Personal and emergency contact details were obtained by administering a questionnaire to all players involved in the study. This *player information* questionnaire is outlined in Annexure A.1.

4.3.2 CURRENT AND PREVIOUS INJURY EXPERIENCE QUESTIONNAIRE

All subjects were requested to complete a *current and previous injury experience questionnaire* on the previous twelve months' rugby injuries (Hattingh, 2003) (Annexure A.2). Data pertaining to current and previous injuries of players were obtained by means of this questionnaire and a direct interview process.

This questionnaire is designed to obtain information regarding the type of previous injury and body parts affected. Furthermore, the questionnaire was designed to obtain the current medical status of the injury, i.e. whether any signs or symptoms might still be present or

whether the injury had fully recovered. Information was also gathered on whether medical consultation had been required and if any rehabilitation of the condition had taken place.

For the purpose of this study; in order to be more specific with regard to body part affected, the questionnaire used by Hattingh (2003:71) was used, but extended in certain areas. This questionnaire was completed in late February 2004, before the first anthropometric, physical and motor and biomechanical and postural testing were performed. Only injuries which were severe enough to cause the player to leave the field of play or training session, or secondly, to prevent the subject from participating in a subsequent rugby match or training were noted (Hattingh, 2003). This is according to the injury definition of Garraway and Macleod (1995:1485). If multiple injuries were sustained, the details of each injury were recorded, but for statistical processing it was noted which was the primary (most incapacitating) injury (Lee & Garraway, 1996).

4.3.3 INJURY REPORT FORM

For all the players a *free* sports-medical clinic was run from the first week of February to the last week of August each year. The sports clinic was held weekly on Mondays or Wednesdays. These clinics were staffed by a qualified sports physician/sports physiotherapist, a qualified biokineticist and the relevant school's sports scientist (fitness and conditioning specialist, if available).

The purpose of these clinics was to screen injured players, collect injury data, refer players for further treatment if necessary and manage the players' rehabilitation. Before a player was screened by the medical team, a standard coded *injury report form* (Annexure A.3) had to be completed. The player had to document information on:

- Player team/age group;
- time of season when injury occurred (date);
- number of matches played this season;
- player position;

- player grade;
- injury history (background to injury);
- anatomical site of injury;
- mechanism of injury;
- phase of play which caused injury;
- protective equipment used; and
- if injury occurred during match or training.

The medical team, after screening the player, had to complete the following information:

- Diagnosis of injury;
- severity of injury;
- type of injury;
- intrinsic/Extrinsic injury;
- time of from training/playing games;
- recommended treatment;
- instructions to player; and
- when to revisit.

- whether the player is referred for:
 - Special tests/medication;
 - number of physiotherapy treatments;
 - rehabilitation with biokineticist; and
 - sport-scientific exercises/tests.

At the end of each season, the relevant data needed for the study were extracted from the form and analysed.

4.3.4 EVALUATION SHEETS

Biomechanical and postural data collected was noted on a coded biomechanical and postural assessment form (Annexure A.4), while a rugby data sheet (Annexure A.5) was used to record anthropometric plus physical and motor data. Together, these data sheets recorded data on the following topics:

1) The *biomechanical and postural assessment form*:

- Postural symmetry;
- dynamic mobility (flexibility); and
- core stability.

This assessment protocol evaluated the following five different body zones: lower limb, pelvic girdle, spinal column, upper limb and neurodynamics (Hattingh, 2003).

2) The *rugby data sheet* compiled data on the following:

- Anthropometric data:
 - Stature;
 - body weight;
 - breadths;
 - girths; and
 - skinfolds.
- Physical and motor data:
 - Speed;
 - agility;
 - explosive power;
 - cardiovascular fitness;
 - speed endurance;
 - muscle endurance; and
 - strength.

4.4 PROCEDURES AND METHODS OF DATA COLLECTION

This programme was tested for feasibility on two high school teams one year prior to the start of the intervention. Before the study began, an information letter which explained the aims of the study as well as an informed consent form was handed out to be signed by each player and parent. Only players who completed their consent were included in the study. Once the various schools and parents gave their approval, the testing commenced.

Testing was done over a two-year period. The study lasted from February 2004 to August 2005 (period of two school rugby seasons). During each of the two years there were three testing occasions where all players were tested: pre-season (T1), during the mid-season break (T2) and at the end of season (T3), giving six testing occasions in total. These different phases and types of data collection are illustrated in Figure 4.1. Only the first year is illustrated, as the same phases and types of data were repeated during the second year.

The first pre-season data collection commenced after participants had completed a *current and previous injury experience questionnaire* (paragraph 4.3.2, Annexure A.2). After completing the questionnaires, players were given a pre-season physical assessment (T1) that included an anthropometric, physical and motor, and a biomechanical and postural evaluation. All these pre-season measures were repeated during the mid-season break (T2), and again at the end of season (T3). The same process was repeated during the second year (T4-6). This gives six assessments during the two-year period.

The results of these tests were used to monitor changes in anthropometric, physical and motor, and biomechanical and postural variables in various stages of the training programme and to provide a profile for each player which highlighted his strengths and weaknesses. Based on the strengths and weaknesses, test results could then also be used to plan training programmes.

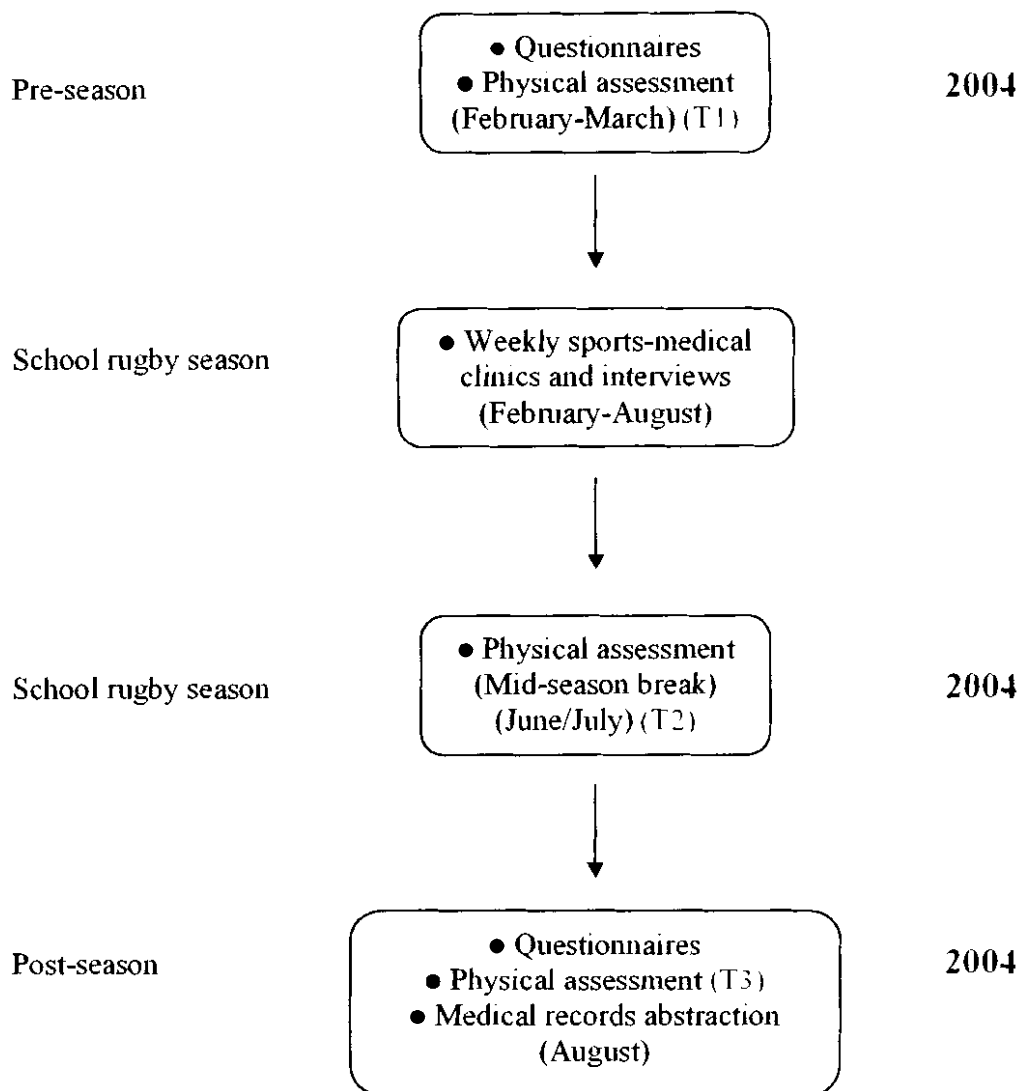


Figure 4.1: Data collection phases for each year

At the end of every evaluation, the performance of each rugby player was reviewed and the experimental group received appropriate compensatory and corrective exercises from the biokineticist. The guidelines provided by Hattingh (2003:182-188) were mostly considered before players in the experimental group received their general prevention programmes. However, in order to improve the effect of this programme, the protocols were combined with a few other exercises (Turnbull *et al.*, 1995; Noakes & Du Plessis, 1996; Twist, 1997; Hazeldine & McNab, 1999; Prentice, 1999; Arnheim & Prentice, 2000; Brown *et al.*, 2000; O'Sullivan, 2000; Brukner & Khan, 2001; Mottram & Comerford, 2001; Schwellnus &

Derman, 2001b; Sahrmann, 2002; Luger & Pook, 2004). The implementation of the prevention programme is discussed in more detail under paragraph 4.8.

At the end of the first season, injury and performance (anthropometric, physical and motor, and biomechanical and postural) data were compiled; deficits in the programme were identified; adjustments made; and players in the experimental group received a generic injury prevention programme to complete during the off season.

Data on injuries were collected from the players each week through sports-medical clinics (Figure 4.1) (discussed under paragraph 4.4.1: *Injury registration system* and paragraph 4.3.3: *Injury report form*). If a player did not participate fully during a match or training session, the coach had to record the reason (e.g. being injured or ill) on a form. Completed forms were returned to the researcher on a weekly basis. If a player did not participate fully, he was obliged to report to the first scheduled sports-medical clinic before he could be cleared for participation. At this sports-medical clinic a qualified sports physician/physiotherapist (assisted by the researcher) identified details of injuries on the injury report form (Annexure A.3). For the purpose of the study, injuries were then classified according to the following variables: severity of injury, type of injury, anatomical region, and intrinsic or extrinsic injury.

4.4.1 THE INJURY REGISTRATION SYSTEM

A previous study on rugby injuries showed an underreporting of injuries at high-school level (Roux, 1992). It is known that if injuries are recorded through purely medical channels (injuries treated at hospital etc.) a large percentage of serious acute injuries and less serious and/or overuse injuries will not be recorded (Van Mechelen *et al.*, 1992). Furthermore, overuse injuries, which are becoming more common, are not included in instances where data are gathered through the injury records of casualty departments (Van Mechelen *et al.*, 1992). Research has shown that close monitoring of schoolboy rugby players through direct contact between the researcher and the injured player results in the most accurate injury reporting (Roux *et al.*, 1987). Furthermore, it appears that the direct interview offers the best

way of gathering injury data (Thompson *et al.*, 1987). Therefore, in this study *sports-medical clinics* were decided on to collect injury data. These sports-medical clinics are discussed next.

4.4.1.1 Sports-medical clinics

Injuries were screened and injury data collected by making use of *free* sports-medical clinics. These direct interviews were held once a week, either on the Monday after a rugby match, or during the rest of the week (Wednesdays). The ideal would have been to have two clinics a week, one on the Monday after a rugby match, and another during the rest of the week (Wednesdays), but due to logistical reasons this was not possible. Each clinic was manned by a registered sports physician/physiotherapist, biokineticist (specialist in preventative and rehabilitative exercise) and sports scientist (if available). All injuries were seen by the physiotherapist or sports physician who made a diagnosis of each injury and recommended when each player should return to sport. The function of the clinics was to diagnose, refer and manage all players who reported injured (for data-gathering purposes only).

The standard *injury report form* (Annexure A.3) was completed during these clinic sessions. The definition of injury was according to the definition of Garraway and Macleod (1995:1485), while the severity of the injury was classified as mild, moderate or severe (Garraway & Macleod; 1995). A separate injury report form was completed for each injury sustained. In the case of multiple injuries, a clinical decision was made on which injury was primarily responsible for incapacity (Lee & Garraway, 1996). All injuries sustained were recorded and related to severity, type, site, match/training and mechanism of injury. Information relating to the injuries was abstracted from these medical records after the end of each rugby season.

4.5 ASSUMPTIONS

During this study different assumptions were made. For instance, it was assumed that all players were truthful in their reporting of exercise compliance.

Players were required to self-report their home exercise compliance and previous injury history. This means that a chance of recall bias existed. The author tried to minimise self-reporting bias by informing subjects at the initial evaluation that there would not be any personal consequence from the reports. Furthermore, although direct contact was made twice a week with the coaches and teams to demonstrate exercises and to ensure that players and coaches stay motivated, the author did not have concrete evidence on how the players complied with the intervention programme when certain exercises had to be done at home or during the holiday period. Therefore, even though players were asked to report their compliance, home exercises were kept to the minimum.

It was also assumed that players reported to the sports-medical clinics when injured and did not “hide” any injuries. Furthermore, it was assumed that players who returned to play after injury were fully rehabilitated. Therefore, subjects were only allowed to return to sport after being cleared by a physiotherapist, biokineticist and sports physician. All subjects who had undergone rehabilitation were also encouraged to continue their rehabilitation at least three days per week for eight weeks after returning to sport.

Further assumptions were that all matches were high-school matches played according to the rules of the International Rugby Board, controlled by a qualified referee, and that the risk of injury was equal for players who had the three variables of age, grade and playing position in common.

4.6 DEFINITIONS OF TERMINOLOGY USED

For the purpose of this study, a recordable *injury* was defined as “an injury sustained on the field during a competitive match or during training, or during other training activities directly associated with rugby, which prevented the player from playing or training from the time of injury or from the end of the match or training session in which the injury was sustained” (Garraway & Macleod, 1995), while a *re-injury* was defined as an identical injury sustained at least one month after the return to the sports activities (Lysens *et al.*, 1991).

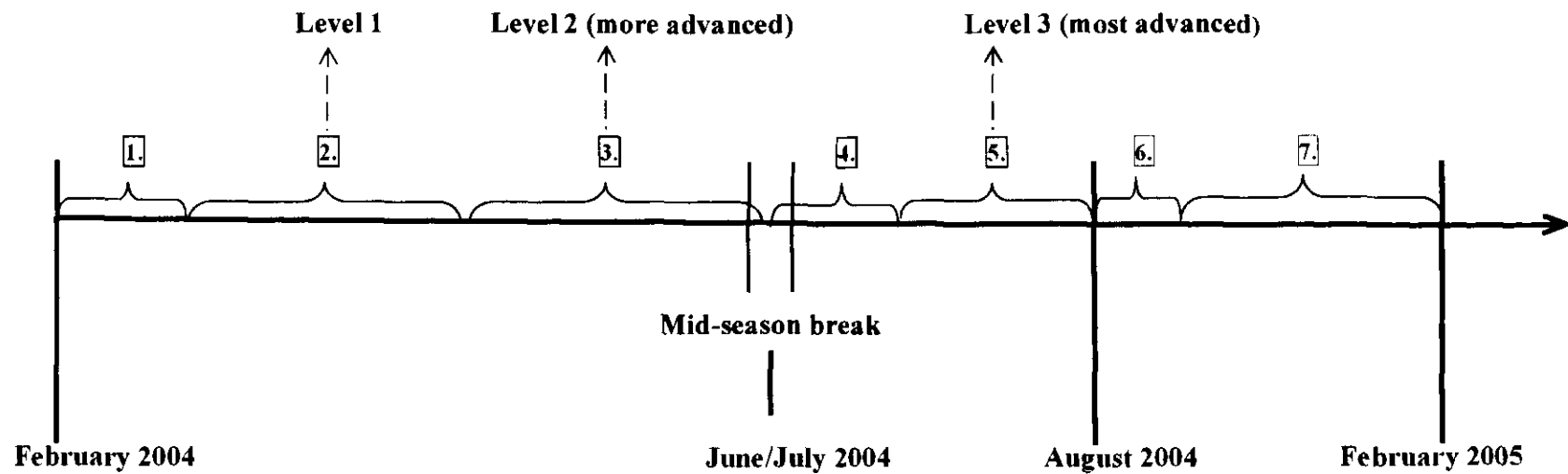
The description of *injury incidence* as reported in this study is based on the definition of injury incidence rate provided by Garraway and Macleod (1995:1485), while the description of the severity of injury is also based on the definition of Garraway and Macleod (1995:1485).

Injuries were divided into two types: intrinsic and extrinsic injuries. *Intrinsic* (overuse) injuries are injuries associated with repetitive overuse of the body (Noakes & Du Plessis, 1996). *Extrinsic* (external trauma) injuries are caused by external forces applied directly to the body by someone or something (Noakes & Du Plessis, 1996). The sum of the intrinsic and extrinsic injuries is the *overall* injuries.

4.7 THE INJURY PREVENTION PROGRAMME

It is known that most soft-tissue injuries can be prevented by following injury prevention strategies, and a well-structured conditioning programme (see Chapter 3, paragraph 3.8) (Luger & Pook, 2004). The training programme used during this study was divided into different phases/cycles to help organise the programme and ensure that training remained effective (periodisation). In general, the periodisation of the programme used during this study was developed according to the guidelines supplied by Hattingh (2003:182). However, for the purpose of this specific school season, the duration of some of the phases had to be adjusted. Furthermore, a *post-season transition phase* was added to the other existing periods (see Figure 4.2) (Twist, 1997). The programme was periodised so that the groups of exercises were combined in such a way as to give the optimum result (Walsh, 1990).

The modern school rugby season in the Southern Hemisphere usually starts early March with a 2–3 week prior preparation phase (Hattingh, 2003). Most South African high schools have rugby training camps in late March or early April (during the Easter holiday period), with the first part of the competitive season commencing after this short holiday. The June–July holiday period provides a short rest period for players, after which follows the secondary competition rounds as well as the prior identification and selection of provincial players. Most competitive schools are now playing rugby over a 5–7 month period (Hattingh, 2003).



1. Pre-season programme (3-week preparation programme)
2. Start-of-season programme. *Level 1.* (6-week maintenance programme)
3. Start-of-season programme. *Level 2.* (advanced maintenance programme)
4. Mid-season programme. (1-week conditioning programme)
5. Mid-season programme. *Level 3.* (most advanced conditioning programme)
6. Post-season transition programme (3 weeks active rest, recovery and corrective biomechanical/postural exercise)
7. Off-season programme (low key programme)

Figure 4.2: Prevention programme phases (periodisation)

It is clear that the school rugby year consists of different periods. Therefore, in order to optimise conditioning results and prevent overtraining, the prevention programme had to be structured into different cycles, i.e. it had to be periodised. Periodisation is an important component of any training program, both in the long term and short term. For the purpose of this study, the annual training period was organised into 7 different phases (see Figure 4.2). The 7 phases were the following (also refer to paragraph 4.8: *Implementation of the injury prevention programme*):

1. Pre-season programme (3-week preparation programme)
2. Start-of-season programme *Level 1* (6-week maintenance programme)
3. Start-of-season programme *Level 2* (advanced maintenance programme)
4. Mid-season programme (1-week conditioning programme)
5. Mid-season programme *Level 3* (most advanced conditioning programme)
6. Post-season transition programme (3 weeks active rest, recovery and corrective biomechanical/postural exercise)
7. Off-season programme (low key programme)

Exercises in the same phase (Figure 4.2) were of similar difficulty and intensity, with a gradual increase in difficulty and intensity during the season. Phases 1 and 4 (numbers 1 and 4 on Figure 4.2) are programmes with a higher volume but lower intensity than the phases which follow them (aim: to regain some lost condition and prepare for the more difficult levels which follow). Number 7 is a low-volume maintenance programme. Level 1 to 3 (numbers 2, 3 and 5) are programmes lower in volume than numbers 1 and 4, but higher in difficulty level (the difficulty rises progressively from level 1 to level 3, with the latter being the most difficult of the three).

For the exercise composition and exercise protocols used in this study the author primarily used the exercises suggested by Hattingh (2003:210-276). However, this study also made use of exercise and guidelines suggested in various other publications (Turnbull *et al.*, 1995; Noakes & Du Plessis, 1996; Twist, 1997; Hazeldine & McNab, 1999; Prentice, 1999; Arnheim & Prentice, 2000; Brown *et al.*, 2000; O'Sullivan, 2000; Brukner & Khan, 2001;

Mottram & Comerford, 2001; Schwellnus & Derman, 2001b; Sahrmann, 2002; Luger & Pook, 2004). The exercises used in this study were developed by the author (biokineticist), while keeping to the general principles of periodisation, specificity, overload and individuality (Brukner & Khan, 2001).

4.8 IMPLEMENTATION OF THE INJURY PREVENTION PROGRAMME

Although this intervention consisted of the prescription of specific exercises to players in the experimental group, it must be remembered that the successful implementation of the programme also relied on the testing of players at specified intervals, as well as the monitoring of injured players through the available sports-medical clinics. A booklet in combination with an instructional group session with the author acting as an instructor was used to provide exercise information.

4.8.1 THE IMPLEMENTATION OF EXERCISES

Descriptions of all the exercises used in this study are given in Annexure B.1. The majority of pictures were acquired from a computer software programme (Saunders Group Inc., 1996).

At the start of each season, the coaches and team captains of the relevant teams were educated in the use of the prescribed exercises by the author. Each experimental group was then provided with an instructional booklet. The author demonstrated all relevant exercises to the players before the start of each training phase. The author visited teams at least twice a week to monitor exercise technique and supervise exercise sessions. On the remaining two or three days of the week, training was supervised by the coach and team captain. The players did the relevant exercises on their own on days when there was no official training. If players did not understand any of the exercises, they were free to contact the author. The author then repeated the demonstration of the relevant exercises.

Exercises were incorporated into the warm-up and cool-down periods of normal rugby training. The teams all followed their own warm-up of 15 minutes to produce mild sweating without fatigue (Brukner & Khan, 2001). Generally, active movements were used to prepare all the major muscle groups for activity, while more sport-specific warm-up movements were used to concentrate on the muscle groups which were expected to be used in the specific day's rugby training activity. After this 15-minute warm up session, the prescribed exercises commenced (see Annexure B.1). This continued for 20 minutes. Immediately after training, each coach allowed for a period of active cool-down to provide the body with a period of adjustment from exercise to rest. The length of the cool-down varied from 10 to 20 minutes and included jogging and walking (Hazeldine & McNab, 1999; Brukner & Khan, 2001), as well as the remaining preventative exercises.

Certain exercises which required weights or other gymnasium apparatus were completed as a daily home exercise programme (this constituted a small part of the total programme). Subjects could choose to complete these exercises either at home, in the school gymnasium, at the local gymnasium or at the injury rehabilitation centre (biokinetics centre) of their choice. Subjects were asked to report their home exercise compliance by noting the days they performed the complete prescribed exercises on a log and to report their compliance weekly. If subjects performed their exercises on fewer than 70% of the required days, they were not included in the study. To promote honesty, the subjects were allowed continued guidance in their exercise programmes, even in the case of non-compliance. To control the effect that other resistance training might have on the effect of the prevention programme, all experimental and control groups of players followed the basic age-specific resistance programme of the NWU Rugby Institute in the gymnasium.

4.8.2 THE IMPLEMENTATION OF THE TESTS AND TRAINING PHASES

The different phases of training have already been outlined under Paragraph 4.7: *The injury prevention programme* (Figure 4.2). The implementation of these phases as well as the incorporation of the different testing occasions into the phases are next discussed in more detail.

(a) *Pre-season testing*

Pre-season tests were done in the 2–3 week period (pre-season preparation phase) before the initiation of the first rugby games in March (Hattingh, 2003). These tests served as a baseline by which changes could be measured.

(b) *Pre-season programme (3 week period)*

The pre-season programme commenced after the pre-season testing (Hattingh, 2003). The aim of the pre-season phase is to bring the players to a high level of fitness at the start of the season. This transitional period is characterised by a shift to work of increased intensity, more explosive movements, high speeds, intervals and sport-specificity as the player progresses closer to the in-season (Twist, 1997).

Each individual player was now issued with a personalised biomechanical and postural and physical and motor programme, then briefed and instructed by the author, the coach and other personnel on the various regional shortcomings and how to overcome these potential hazards. Programmes were then followed intensely over the next 3 weeks, up to the start-of-season programme.

(c) *Start-of-season programme*

The focus in this phase of the season was to maintain overall conditioning while improving on aspects which were still lacking. The first 3–4 weeks of this phase is usually characterised by warm-up matches.

Although the competitive school league only started after the Easter holiday period (March–April), players in this study already began their ‘start-of-season prevention programme’ at the beginning of March. Because the teams also trained during the short Easter holiday period, it was ensured that all exercises were continued throughout the holiday period.

A standardised maintenance biomechanical and postural and physical and motor protocol for adolescent rugby players was followed up to the mid-season break in June–July. The programme started with level 1, and after 6 weeks progressed to a more intense level 2. The level 2 programme was followed until the next testing occasion (mid-season) (Hattingh, 2003).

(d) Mid-season programme

The theme for this part of the programme is intense maintenance. The goal is not only to prevent any possible de-conditioning that may be associated with the mid-season break, but also to prepare for the more difficult level which follows.

Therefore, during the June-July break, test batteries as implemented in the pre-season phase were repeated and conditioning adapted accordingly (Hattingh, 2003). Individual biomechanical and postural shortcomings were once again identified and programmes adjusted for a 1-week period, whereafter level 3 (most advanced) was implemented according to known adolescent norms, and followed until the post-season transition phase.

(e) Post-season transition programme (3 weeks)

This period starts as soon as the final games end. After the last games, test batteries as implemented in the pre-season phase were repeated. The results of these tests served as the basis for the post-season transition programme, and off-season programme.

In this study the post-season transition phase is not a gap in training, but rather an essential link between competitive and preparation phases (Twist, 1997). This phase has many different purposes (Twist, 1997), namely to recover from the physical demands of the season, to provide a mental break from stress, and to provide a transition period from the intensity and stress of the final games to the generality of the off-season phase.

During this period the players did not suddenly start complete rest immediately after the last game, but they continued very light workouts or other sports activities for two weeks to gradually taper down toward passive rest, recovery and relaxation (Twist, 1997). During this 2-week period of “active rest” some form of exercise (jogging, swimming, squash, etc.) was performed twice a week on non-consecutive days (Turnbull *et al.*, 1995). Furthermore, individuals with identified biomechanical and postural shortcomings (non-ideal/unsatisfactory) performed personalised exercises twice a week, on non-consecutive days. This was followed by a break from any formal exercise for another week, whereafter the players progressed to the off-season phase.

(f) Off-season programme

The aim of this out-of-season phase was to acquire and maintain a general physical fitness base until the more intensive pre-season training. Furthermore, recovery from injury and limitations and weaknesses from the previous season were also addressed.

A standard, low key biomechanical and postural and physical and motor programme was implemented during this period (Hattingh, 2003). Dynamic mobility as well as core stability exercises concentrated on the already identified postural shortcomings within these age-groupers. Programmes were followed up to the start of the next pre-season.

4.9 BATTERY OF TESTS

The tests and protocols which were used in this study were chosen from the literature; their usefulness had been proven in previous rugby studies (Hare, 1997; Hare, 1999; Hanekom, 2000; Hanekom, 2003; Hattingh, 2003; Spamer & Winsley, 2003; Van Gent, 2003; Plotz, 2004). Only tests that were suited to the specific age, gender and sport were used.

Before testing started, the test protocol was explained to the players. The station method was used to perform the tests. On the day of testing, players were divided into groups which rotated among different testing stations. Players were allowed to first get used to the execution of the tests. These tests were completed in a sequence of exhaustion, so that the

most exhaustive tests were completed last. The players were allowed enough rest between tests for adequate recovery. The testing sequence and rest periods between tests were also developed in such a way that no previous test would influence subsequent tests (Van Gent, 2003).

All tests in this study were done in the afternoon, before training commenced. Players were in a rested state, with no residual fatigue from training, before each testing occasion (Luger & Pook, 2004). Players did the same, appropriate warm-up before each testing occasion. Players did not warm up or exercise before the biomechanical and postural evaluation or anthropometric measurements. These biomechanical and postural evaluations as well as the anthropometric measurements were each done on a separate day from the other tests. In order to gather the best possible results, players were allowed three opportunities during speed, agility and explosive power tests.

Furthermore, the verbal commands were standardised during testing, and knowledge of results were withheld until all tests had been completed. The same experienced technicians/assessors performed the tests and retests to exclude any potential examiner-related variability. To ensure accuracy of data, only trained, professional personnel performed the tests. The examining staff consisted of a trained physiotherapist, biokineticist (specialist in preventative and rehabilitative exercise), sports scientist (fitness and conditioning specialist) and students in human movement sciences. For the anthropometric measurements, fitness professionals who were certified as level 1 or level 2 anthropometrists with ISAK (International Society for the Advancement of Kinanthropometry) were used.

The test protocol can be divided into three main groups: an anthropometric, a physical and motor and a biomechanical and postural group. The procedures for measuring all selected variables are discussed next.

4.9.1 ANTHROPOMETRIC COMPONENTS

The anthropometric measurements were taken in an assembly hall of the relevant school. To calculate the anthropometric variables in this study, the internationally standardised measuring protocol prescribed by the International Body on Kinanthropometrics was used (Ross & Marfell-Jones, 1991). For the anthropometric measurements, four standardised variables were used: body fat percentage (Forsyth & Sinning, 1973) by using the 4 skinfolds recommended for 14–19 year old male athletes (subscapular skinfold, abdominal skinfold, tricep skinfold, midaxillary skinfold); stature (Norton *et al.*, 1996), by using a stadiometer; body mass (Norton *et al.*, 1996), by using a calibrated electronic mass meter; and somatotype (endomorph, mesomorph, ectomorph), by using the Heath-Carter anthropometric method for adolescents (Carter & Heath, 1990).

Apparent anthropometric definitions, variables and methods are discussed below.

4.9.1.1 Terminology

(a) *Anatomical position*

This position is where the participant is in the erect position, arms next to the side, palms and feet facing forward (Norton *et al.*, 1996).

(b) *The Frankfort plane*

When body length is measured the head has to be held in the Frankfort plane. The head position is in the Frankfort plane when a horizontal line can be drawn from the orbital (inferior border of the eye socket) to the tragion (indentation above the tragus of the ear) (Norton *et al.*, 1996).

(c) *Vertex*

When the head is positioned in the Frankfort plane, the vertex is the highest position on the skull (Norton *et al.*, 1996).

(d) *The acromial landmark*

This landmark is the point on the most superior lateral border of the acromion when the subject is standing erect with the arms relaxed (Ross & Marfell-Jones, 1991).

(e) *The radial landmark*

This is the point at the proximal and lateral border of the head of the radius (Ross & Marfell-Jones, 1991).

(f) *The subscapular landmark*

This is the point directly below the inferior angle of the scapula (Ross & Marfell-Jones, 1991).

(g) *The iliospinal landmark*

This mark is found on the lowest (most inferior) tip of the anterior superior iliac spine (Ross & Marfell-Jones, 1991).

(h) *Xiphoidal/infrasternal landmark*

This mark is found on the bottom part of the sternum and is the inferior tip of the xiphion (Ross & Marfell-Jones, 1991).

(i) *Ilio axilla line*

This is an imaginary vertical line joining the observed mid-point of the armpit with the lateral superior edge of the ilium (Ross & Marfell-Jones, 1991).

4.9.1.2 Anthropometric variables, measuring methods and apparatus

The measuring protocols, as well as the measuring methods and apparatus used, are discussed next. All anthropometrists in this study were right-handed. All anthropometric measurements were taken on the dominant side of subjects.

(a) *Girths*

Equipment: Mabis measuring tape

Technique: The cross-hand technique was used for measuring all girths (Norton *et al.*, 1996). During this way of measurement, the case of the measuring tape is held in the right hand, while the left hand pulls out the measuring tape. Facing the body part to be measured, the stub end of the tape is passed around the back of the limb and passed to the right hand. The right hand then holds both the stub and the casing. The right hand has to apply sufficient tension on the tape to hold it in position. At this point the left hand is free to manipulate the tape to the correct level and to ensure the tape is held parallel. The middle fingers of both hands are free to locate the tape exactly at the landmark for measurement and to orient the tape so that the zero is easily read. Before reading, the tape is pulled tight, but not so tight as to cut into the skin. To avoid any error of parallax, the measurer's eyes must be at the same level as the tape when reading the tape. All girths in this study were measured to the closest 0.1 cm.

The different girths measured in this study are discussed below.

- *Arm flexed and tensed girth*

The maximum circumference of the upper arm has to be measured while the subject lifts his arm anterior to the horizontal position, with the forearm flexed. The measurer stands to the side of the subject with the tape loosely in position. The subject is then asked to "clench your fist and to bring your hand toward your shoulder so your elbow is at 45° to the upper arm, then fully tense the biceps and hold it" while the measurement is made (Norton *et al.*, 1996).

- *Calf girth*

This is the maximum girth of the calf with the subject standing upright and the weight distributed evenly on both feet. The subject stands facing away from the measurer on a box or stool. This elevated position makes it possible for the measurer to align the eyes with the tape. The measurement is taken from the lateral aspect of the leg. The maximal girth is

found by using the middle fingers to manipulate the tape in a series of up or down measurements to identify the maximal girth (Norton *et al.*, 1996).

(b) *Breadths*

Equipment: Small sliding bone callipers

Technique: To measure breadths, the callipers have to be positioned on the back of the hands with the thumbs against the inside edges of the calliper arms, and the index fingers along the outside edges of the arms (Norton *et al.*, 1996). In this position the fingers are able to apply pressure to reduce the thickness of any underlying soft tissue and the middle fingers are free to palpate the bony landmarks on which the callipers are placed. The measurements are taken when the callipers are in place, with the pressure maintained along the index fingers. All breadths in this study were measured to the closest 0.1 cm.

- *Humerus breadth*

Here the maximum distance between the medial and lateral epicondyles of the humerus is measured with the arm raised anterior to the horizontal and the forearm flexed at a 90° angle to the upper arm (Norton *et al.*, 1996). The callipers are used with the arms pointing upward at an angle of about 45° to the horizontal plane. With the sliding callipers gripped correctly, the middle fingers are used to palpate the epicondyles of the humerus, starting proximally to the sites. The bony points first felt are the epicondyles. Firm pressure must be obtained with the index fingers as the value is read.

- *Femur breadth*

The maximum distance between the medial and lateral epicondyles of the femur is measured with the subject seated and the knee flexed to form a 90° angle (Norton *et al.*, 1996). With the subject in this seated position and the callipers in place, the middle fingers are used to palpate the epicondyles of the femur, beginning proximally to the sites. The bony points first felt are the epicondyles. The calliper faces are placed on the epicondyles so that the arms of the callipers point downwards at about 45° angle to the horizontal. Firm pressure is maintained with the index fingers until the value is read.

(c) *Body mass*

Equipment: A calibrated, electronic Nagata FAT-302 mass meter

Technique: The subjects were dressed down to their rugby shorts, and stood erect in the middle of the mass meter with their weight equally distributed on both feet. The subject had to stand with the head up, eyes facing forward and arms relaxed for measurement. Body mass was recorded to the nearest 0.1 kg (Norton *et al.*, 1996).

(d) *Stature (body height)*

Equipment: A portable Holtain stadiometer.

Technique: With this measurement the maximum distance between the standing surface and the vertex of the skull was obtained (Norton *et al.*, 1996). The measurement was taken with the subject standing erect, barefoot with heels together, body weight equally distributed and arms relaxed. In this standing position, the heels, buttocks, upper trunk and back of skull had to touch the measuring apparatus before measurement, while the head was held in the Frankfort plane. Finally, before measuring, the subject was instructed to inhale and to elongate himself without lifting his heels from the platform. Firm contact was made between the index meter and the vertex of the skull for measurement. The measurement was recorded to the nearest millimetre (0.1 cm).

(e) *Skinfold measurements (Body fat percentage)*

Equipment: Harpenden skinfold calliper with a constant pressure of 10 g/mm²

Technique: First, the correct anatomical landmarks were marked with a clear pencil mark that did not wipe off easily. The skinfold positions were then carefully located, using these anatomical landmarks. Before measurement, a double layer of skin with its underlying adipose tissue was firmly gripped on the marked area, between the index finger and thumb. In order to ensure that there was a sufficiently large grasp of the skinfold, but that no underlying muscle tissue was grasped and measured, the skinfold was rolled slightly between the finger and thumb. Before pulling away the skinfold, the thumb and finger were positioned in line with the marked site, with the back of the hand facing the measurer. Then the fold was pulled away from the underlying musculature and the mouth of the skinfold

calliper applied approximately 1 cm below the two fingers and 1 cm deep into the fold, with the calliper positioned at 90° to the surface of the skinfold. Now, the trigger was completely released, while a firm grip was maintained on the skinfold. Two to three seconds were allowed throughout the procedure to ensure full pressure measurement (Norton *et al.*, 1996).

The skinfold measurements were taken in a specific pre-planned rotational manner. To improve accuracy, two measurements of each skinfold were taken. If a discrepancy of more than 1 mm occurred between the two, a third measurement was obtained. When two measurements were taken, the mean value was used, and in instances where three measurements were needed, the median value was used. All measurements were rounded off digitally to the nearest 0.1 of a millimetre (for the Harpenden calliper). The skinfold method of measuring fat percentage is considered by researchers to be an accurate, valid and reliable field method ($\pm 3\%$ error) (Heyward & Stolarczyk, 1996). The skinfolds measured were the following:

- *Triceps skinfold*

This fold is halfway between the acromion and radial landmarks on the posterior surface of the triceps. For measurement the subject had to relax the arm while keeping the shoulder joint slightly externally rotated and the elbow extended at the side of the body. This vertical skinfold was then taken parallel to the line of the upper arm, on the most posterior surface of the arm, over the triceps muscle when viewed from the side (Norton *et al.*, 1996).

- *Subscapular skinfold*

The thumb palpated the inferior angle of the scapula to determine the lowermost tip. This fold should be taken at a site 2 cm along a line running laterally and obliquely downward from the subscapular landmark at an angle (approximately 45° to the horizontal) as determined by the natural lines of the skin. The skinfold was raised at this marked site (Norton *et al.*, 1996).

- *Midaxillary skinfold*

A vertical fold was taken on the midaxillary line (ilio-axilla line), at the level of the xiphoidal/infrasternal mark. The measurement was taken with the subject's arm at 90° to the vertical (Norton *et al.*, 1996).

- *Supraspinal skinfold*

A diagonal fold was taken in a downward and medial direction at an angle of 45° to the horizontal. The measurement was taken approximately 5–7cm above the anterior superior iliac spine, depending on the size of the subject. The fold was raised at the point where a line from the iliospinal mark to the anterior axillary border intersected with a horizontal line from the superior border of the ilium at the level of the iliocristal (Norton *et al.*, 1996).

- *Abdominal skinfold*

This vertical fold was taken approximately 5 cm lateral to the midpoint of the umbilicus. This skinfold was measured on the right-hand side of the subject (Norton *et al.*, 1996).

- *Medial calf skinfold*

This is a vertical fold taken on the medial aspect of the calf at the point of largest circumference of the calf muscle. The subject was measured standing with the knee at 90° and the foot supported on a box, with the calf relaxed (Norton *et al.*, 1996).

(f) *Transformation*

Some anthropometric variables (such as fat percentage and sum of the skinfolds) of the players were determined by transformation. The transformations were as follows:

* *Age* = test date – birth date;

* Fat percentage (skinfold method for male adolescent athletes)

For calculating the percentage of body fat, the following formula specifically for male adolescents participating in sports, was used (Forsyth & Sinning, 1973):

1. Boys (13–16yr) %BF = $[(5.07/D\mathbf{b}) - 4.64] \times 100$

2. Boys (17–19yr) %BF = $[(4.99/D\mathbf{b}) - 4.55] \times 100$

where $D\mathbf{b}$ (g/cc) for boys (14–19yr) = $1.10647 - 0.00162(\text{subscapular SKF}) - 0.00144(\text{abdominal SKF}) - 0.00077(\text{triceps SKF}) + 0.00071(\text{midaxillary SKF})$, and

$D\mathbf{b}$ = *Body density*

SKF = *Skinfold*

According to research, the standard deviation of this equation closely resembles actual measured $D\mathbf{b}$ (Thorland *et al.*, 1984; Heyward & Stolarczyk, 1996).

* Somatotype

Somatotyping is one of the methods used to describe and categorise the human body as a whole (especially its form and composition) (De Ridder, 1993). According to Ross *et al.* (1988:240), somatotype is the single best method used to classify the form of the human body. When performing morphological studies on sports participants, the method developed by Heath and Carter is recommended (De Ridder, 1993). Carter and Heath (1990:352) themselves defined the Heath-Carter somatotype as follows: “*The Heath-Carter somatotype is a semi-quantitative description of the existing relative shape and composition of a human body*”. The somatotype consists of three different number components. The three components should always be discussed as a unit otherwise the unique concept and meaning of somatotype will be lost (Coetzee, 1999). These three components are (De Ridder, 1993):

- Endomorphy (first component) describes relative fatness.
- Mesomorphy (second component) describes musculoskeletal robustness relative to body length
- Ectomorphy (third component) describes relative slenderness.

The grading of the scale is as follows:

- ½ to 2½ = low value
- 3 to 5 = average value
- 5½ to 7 = high
- >7 = exceptionally high

In this study, the Heath-Carter anthropometric method was used to calculate somatotype. According to Carter and Heath (1990:367) the anthropometric method is an objective method for calculating somatotype. This is a good field method that allows for fast calculations. It is a reliable somatotyping method when the subject desires to wear the minimum amount of clothing. This method uses a formula as well as the following anthropometric variables to calculate somatotype: stature (body length), body mass, triceps skinfold, subscapular skinfold, supraspinal skinfold, calf skinfold (medial), upper arm girth (tensed), calf girth, humerus breadth and femur breadth (Carter & Heath, 1990).

For calculating the components of body composition in this study, data were transformed with the help of computer software. The following formula was used to calculate endomorphy (Carter & Heath, 1990):

$$\begin{aligned}
 \text{Endomorphy} = & -0.7182 + 0.1451 \left(\sum \text{ of skinfolds} \times \frac{170.18}{\text{height}} \right) \\
 & -0.00068 \left(\sum \text{ of skinfolds} \times \frac{170.18}{\text{height}} \right)^2 + 0.0000014 \left(\sum \text{ of skinfolds} \times \frac{170.18}{\text{height}} \right)^3
 \end{aligned}$$

where: \sum of skinfolds = sum of triceps, subscapular and supraspinal skinfolds

The following formula was used to calculate mesomorphy (Carter & Heath, 1990):

$$\text{Mesomorphy} = 0.858(\text{humerus breadth}) + 0.601(\text{femur breadth}) + 0.188(\text{corrected arm girth}) + 0.161(\text{corrected calve girth}) - 0.131(\text{height}) + 4.50$$

where: 1) *corrected arm girth* = *upper arm girth (tensed)* – *triceps skinfold*

2) *corrected calf girth* = *calf girth* – *calf skinfold*

The following formula was used to calculate ectomorphy (Carte & Heath, 1990):

Ectomorphy =

where: $\frac{\text{height}}{\sqrt{\text{body weight}}} = \text{HWR}$ (*height-weight ratio*)

IF:

1.) $\text{HWR} \geq 40.75$

$$\text{Ectomorphy} = 0.732 \times \text{HWR} - 28.58$$

2) $\text{HWR} < 40.75$ but > 38.5 , then:

$$\text{Ectomorphy} = \text{HWR} \times 0.463 - 17.63$$

3) $\text{HWR} \leq 38.25$, then:

$$\text{ectomorphy} = 0.1$$

Following the anthropometric assessments, a battery of 10 physical and motor performance assessments was undertaken. These components are discussed next.

4.9.2 PHYSICAL AND MOTOR COMPONENTS

For the physical and motor evaluation a battery of ten tests was completed. The ten tests administered were the following: the 10 m and 30 m dash for *speed* (Hazeldine & McNab, 1998); the Illinois *agility* run (Kirby, 1991); vertical jump (Kirby, 1991) for *explosive power*; the bleep test (Brewer *et al.*, 1988) for *cardiovascular fitness*; a standardised test for *speed*

endurance (Hazeldine & McNab, 1999); maximum push-ups in 1 minute (Turnbull *et al.*, 1995), as well as maximum pull-ups (Turnbull, *et al.*, 1995) for *muscle endurance*; and for *strength*, seven-stage abdominal strength (Ellis *et al.*, 1998) and grip-strength (Kirby, 1991).

These physical and motor tests were done on the rugby field. In this scenario it is possible for strong wind to influence test results. This can be seen as a possible limitation to this as well as other rugby studies. The ideal situation would be to have a large enough indoors testing facility set up at the relevant schools. For different reasons, such a facility was not available during this study. However, physical and motor tests were only done on days with little to no perceptible wind.

4.9.2.1 Speed over 10 m and 30 m

Equipment: 30 m tape measure; markers; Brower time-light system.

Directions: The testing of speed required simple electronic timing, using the beam of a photo-electric cell (Hazeldine & McNab, 1999). For this study, subjects were submitted to a maximum speed test measured over 10 m and 30 m. From a standing position with one foot behind the starting line, the subjects were allowed two attempts with the Brower time-light system measuring time at 10 m and 30 m. The best result was recorded and rounded off digitally to 0.01 seconds (Kirby, 1991; Hazeldine & McNab, 1998).

4.9.2.2 Illinois agility test

Equipment: Tape measure, 9 markers; stopwatch; rugby ball; an assistant.

Directions: The different markers were set up in the correct positions (Figure 4.3). The markers from C to D were spaced with 2 m between them. Markers were high enough to ensure that players moved around instead of over the markers (Hanekom, 2003).

For clarity of the following explanation, see figure 4.3 below. The subject stood at marker A and on command sprinted from marker A and around marker B. He then continued to and turned left around marker C, then zigzagged through the three allocated markers (between C and D) and around marker D, whereafter he zigzagged back down to C. He then sprinted around C and progressed at full speed to and around E, and then finally to F where he

finished. The subject held the ball in both hands. If the subject slipped or touched one of the markers, the test was repeated. The subjects were allowed three attempts and the best time was recorded. Time was measured and rounded off to the nearest 0.1 second (Kirby, 1991).

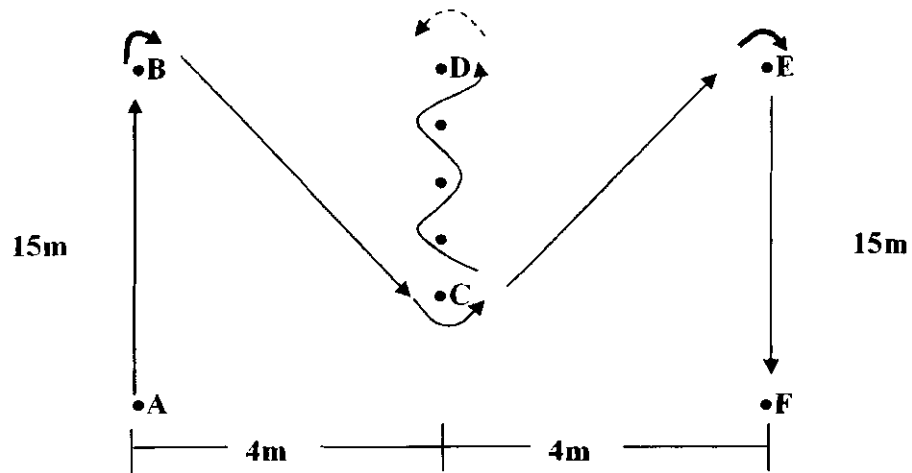


Figure 4.3: Graphic description of the Illinois agility test

4.9.2.3 Vertical jump

Equipment: Magnesium powder; tape measure; a smooth wall at least 4 m high.

Directions: With magnesium powder applied to the middle finger, the subject was positioned with one side standing against a wall, with the arm nearest to the wall vertically stretched out as high as possible, while keeping the heels on the floor. The highest distance was marked (first mark). With magnesium powder applied to the middle finger, the subject was then ordered to semi-crouch and to jump maximally. The subject jumped as high as possible and made a second magnesium powder mark against the wall (Kirby, 1991). The subject was allowed to use his arms when jumping, but was not allowed to take a “double jump”. The distance between the first and second mark was recorded. The best of three attempts was recorded. For the measurement of explosive power, the factors of force and velocity were not measured as such; only the resultant distance achieved (centimetres) was recorded. Distances were rounded off to the nearest centimetre.

4.9.2.4 Seven-stage abdominal strength test

Equipment: Level surface, loose weights of 2.5 kg and 5 kg.

Directions: This test is designed to determine the absolute strength of the abdominal muscle groups (Ellis *et al.*, 1998). The test protocol has seven stages. To continue with the next stage, the subject first has to successfully perform the previous stage. During all tests, the subject lies supine on a level surface, with legs together and knees bent at an angle of approximately 45°. This is the stationary/starting position. The subject also fails if the feet lift off the ground.

The position of the arms and hands will vary the resistance and thus the difficulty of the stage. The players were not allowed to use momentum by throwing the arms or jerking the trunk when curling up.

The seven stages were as follows:

- Stage 1:** Subject completed stage one if he was able to sit up with extended elbows, touch the outside of the knees with both wrists and return to the stationary position.
- Stage 2:** Subject completed stage two if he was able to sit up with extended elbows, touch the outside of the knees with both elbows and return to the stationary position.
- Stage 3:** Subject completed stage three if he was able to sit up with the palms of his hands on the temporal area of his skull, touch the outside of the knees with both elbows and return to the stationary position.
- Stage 4:** Subject completed stage four if he was able to sit up with his arms crossed over his chest, touch his knees and return to the stationary position.
- Stage 5:** Subject completed stage five if he was able to sit up with his hands behind his neck, his chest open, touch his knees with his chest and return to the stationary position.

Stage 6: Subject completed stage six if he was able to sit up with a 2.5 kg weight placed behind his head and, keeping the weight there, touch his knees with his chest and return to the stationary position.

Stage 7: Subject completed stage seven if he was able to sit up with a 5 kg weight placed behind his head and, keeping the weight there, touch his knees with his chest and return to the stationary position.

4.9.2.5 Pull-ups

Equipment: A fixed horizontal bar at 2.5 m from the ground.

Directions: Subject began by hanging from a bar using an overhand grip (palms facing away from him) with the legs and arms fully extended. The feet were not allowed to touch the floor. On the starting order, he lifted himself until his chin was clearly above the bar. He then lowered himself until his arms were fully stretched. This represented one pull-up. This activity was allowed until failure (Turnbull, *et al.*, 1995).

During testing, no stoppage for longer than 2 seconds was allowed, nor were unnecessary swinging, lifting or kicking with the legs. The testing personnel counted each successful repetition out loud. In failure of clear chin lifting or improper full stretching of the arms, the particular attempt was discarded.

4.9.2.6 Push-up test (1 minute)

Equipment: A level surface and a stopwatch.

Directions: Players performed an “extended” push-up (Turnbull *et al.*, 1995; Hanekom, 2000). The position of the hands affects the difficulty of this activity. The position of the elbows determined where the hands were placed for the performance of the test. In order to standardise the placement of the hands, players had to lie on the gymnasium mat in a prone position, with arms out to the side and elbows flexed at 90 degrees. Players started with arms extended and feet together.

The examiner placed his fist under the subject’s rib cage, level with the sternum. The subject had to touch the examiner’s fist upon lowering. The test started as soon as the examiner gave

the order to “go”. The subject had to keep his body in a straight line during the test. The subject did as many correct push-pus as possible in 1 minute.

4.9.2.7 Bleep test

Equipment: Compact disk-player; compact disk (CD); markers; tape measure.

Directions: This 20 m shuttle run test can be used to determine indirectly each player’s maximum oxygen uptake (VO_{2max}). The test involves running 20 m shuttles at speeds dictated by a sound signal emitted from a compact disc player (Brewer *et al.*, 1988; McArdle *et al.*, 1991). The speed of the shuttle is increased approximately every minute. The player must keep pace with the sound signal for as long as possible. The point at which the player can no longer keep up is recorded and is used to determine VO_{2max} .

For this test, two markers were placed 20 m apart on a level grass surface. Before the test procedure was conducted, proper instructions about the test protocol were given to participants. The subject started running from the first towards the second marker on the first audible “bleep”, aiming to reach this at the sounding of the second “bleep”. This procedure was continued until the player failed to keep up the required pace. The last completed level and stage were then recorded.

4.9.2.8 Speed endurance test

Equipment: One measuring wheel, markers, two assistants; two stop watches.

Directions: This test provides an estimate of speed endurance based on a fatigue index (Hazeldine & McNab, 1999). Each player was required to sprint at maximum speed over a 40 m shuttle, with a 20-second recovery period between sprints. Each player had to complete the procedure six times in total. The time for each shuttle sprint was recorded by hand, using a stop watch.

Three markers were positioned 10 m apart in a straight line (Figure 4.4). One assistant was positioned at the middle marker A. The player was positioned with his feet behind the centre line. At a given signal the player sprinted from marker A to marker B (10 m), turned and sprinted to marker C (20 m), turned and sprinted to centre marker A (10 m), thus producing a

total distance sprinted of 40 m. The assistant started his stopwatch at the signal (to “go”) and stopped it once the subject had completed the full test (passing marker A from marker C). The time was then recorded.

The second assistant started his stopwatch once the player stopped at marker A. After a 20-second rest period the player had to repeat the test procedure as described above. All players had to repeat this six times in total. Maximal effort was required. All six test episodes were recorded and speed endurance calculated as follows:

1.
$$[(X1 + X2)/2] - [(Y1 + Y2)/2] = Z$$

2.
$$Z \div \frac{(Y1 + Y2)}{2} \times 100 = X\% \text{ where:}$$

- $(X1 + X2) \div 2 = \text{average X}$ (where X1 and X2 are the two slowest recorded sprints)
- $(Y1 \div Y2) \div 2 = \text{average Y}$ (where Y1 and Y2 are the two fastest recorded sprints)
- $\text{Average Y} - \text{Average X} = Z$
- $X\% = \text{decrease in speed endurance (fatigue index)}$

The lower this percentage, the better the speed endurance.

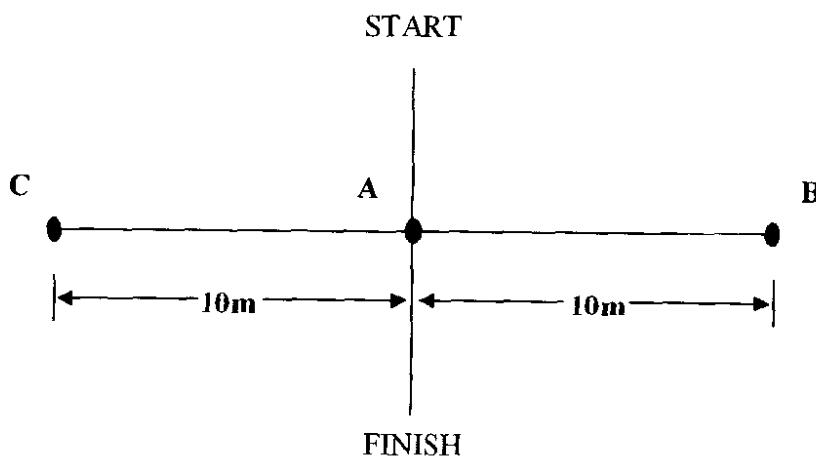


Figure 4.4: Illustration of the speed endurance test

4.9.2.9 Left and right grip strength

Equipment: A Jamar grip strength dynamometer.

Directions: The subject's hand as well as the handle of the dynamometer has to be dry each attempt. The needle should be on 0 before the start of every test. The subject takes the dynamometer in his hand with the back of the handle in the palm of his hand and the front part of the grip in the middle of his fingers. The subject then extends his arm next to the side of his body and squeezes the grip as hard as possible. No part of the subject's arm is allowed to touch or lean against his body. Three attempts are allowed with each hand and the best result out of the three is recorded for each hand. The grip strength is recorded to the nearest 0.5 kg (Kirby, 1991).

4.9.3 BIOMECHANICAL AND POSTURAL COMPONENTS

The fourth protocol can be classified under the biomechanical and postural make-up of the players (Annexure) (Kapandji, 1974; Watson, 2001). For this biomechanical and postural data a recent approach which measures a combination of symmetry, dynamic mobility and local stability was used (Hatingh, 2003). Measures were chosen from common clinical measures of posture and flexibility that could easily be used in a standard biomechanical and postural screening. The biomechanical and postural assessment protocol evaluated different zones, namely lower limb, pelvic girdle, spinal column, upper limb and neurodynamics.

Maximal flexibility is defined as the range of motion (ROM) available to a joint or series of joints (Gleim & McHugh, 1997). In most instances, goniometers were used to measure end ROM, because they provide a continuous-level variable for flexibility (Gleim, 1984; Gleim & McHugh, 1997). In previous work on goniometric measurements (using a standard hand-held goniometer), inter-observer error for goniometric measurement of range of motion was found to be 3° to 5° (Smith *et al.*, 1991; Krivickas & Feinberg, 1996).

4.9.3.1 Biomechanical and postural evaluation

No warm-up exercises were done before the BMPE (biomechanical and postural evaluation). For the test protocol subjects were dressed in rugby shorts. All tests were completed indoors. One examiner was used to perform the test procedure and an observer/recorder to assist with measurements (Hattingh, 2003). The recorder also served to verify the accuracy of measurement and measurement sequence. The examiner and observer were properly briefed on each individual test procedure and for consistency the same two trained medical personnel were used for all tests. During the study, all tests were repeated on the left and right hand side of the subject's body. For clarity, tests will be described as if they were measured on the left-hand side of the subject's body.

(a) Lower limb region

Lower limb region: Achilles tendon suppleness test (TA test)

Equipment: Long-arm goniometer; one plinth.

Directions: The subject started in the supine position with both legs straight and the heels just over the edge of the plinth. From this position, the examiner took the posterior ankle with the left hand, while the right hand grabbed the ball of the foot and pushed the forefoot into dorsiflexion. The examiner used the long-arm goniometer on the lateral aspect of the ankle joint to measure degrees of forced flexion. Range of movement (ROM) was graded as 1: a range of 30° or more (ideal); 2: between 10° and 30° (non-ideal); and 3: less than 10° (highly unsatisfactory) (Kapandji, 1970a; McPiol & Brocato, 1990).

Lower limb region: Modified Thomas test:

Equipment: One plinth; a marker; long-arm goniometer.

Directions: From the modified Thomas test, three lower limb flexibility measurements were done (iliotibial band, quadriceps, and iliopsoas). Thus, this test served as a functional combination test for all three measurements.

- For this test, the subject started at the end of the plinth; standing with the posterior aspect of his thighs firmly against the plinth.
- He then flexed his left hip and knee towards his chest; and gripped his ankle at the anterior aspect with the fingers locking around the ankle.
- The subject then lay back in the supine position while keeping the left leg locked in the hand grip and extended his elbows. In this position, the right leg was relaxed and hung over the edge of the plinth. From this position the combined functional mobility of the lower limb (hanging limb) was measured.

▶ *Iliotibial band mobility (ITB)*

The examiner clearly marked the anterior aspect of the ankle joint. He then measured the amount of deviation from the coronal mid-position (the amount of rotation or deviation of the sagittal mid-position from the midline) with the long-arm goniometer. The measurements were classified as: 1: neutral or $<10^\circ$ of deviation (ideal); 2: 10° – 30° of deviation (non-ideal); and 3: more than 30° (highly unsatisfactory) (Kapandji, 1970a; Hunt, 1990; Saudek, 1990).

▶ *Quadriceps mobility*

The examiner clearly marked the midline of the knee joint on its lateral aspect. The examiner placed the long-arm goniometer on the marked point, with the control arm positioned in line with the femoral shaft and the other arm in line with the lower limb. This angle was recorded. Measurements were classified in three categories: 1: $>50^\circ$ (ideal); 2: 30° – 50° (non-ideal); and 3: $<30^\circ$ (highly unsatisfactory) (Kapandji, 1970a; Hunt, 1990; Saudek, 1990).

▶ *Iliopsoas mobility*

For this test, the lateral midline of the hip joint was identified and marked. The examiner placed the long lever goniometer on the identified point, with one goniometer arm parallel to the horizontal and the other arm in line with the femoral shaft. The angle was measured. This was classified as 1: $>30^\circ$ (ideal); 2: 15° – 30° (non-ideal) and 3: $<15^\circ$

(highly unsatisfactory) (Kapandji, 1970a; Hunt, 1990; Saudek, 1990; Arnheim & Prentice, 2000).

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

Equipment: Plinth; long arm goniometer; marker.

Directions: The subject started supine on the plinth with his legs extended, and the examiner positioned him at the side of the plinth, facing the subject's lower limbs. The examiner then flexed the subject's knee closest to him to 90°, and rested the lateral aspect of the ankle on the subject's opposite knee. The thigh closest to the examiner was then dropped into external rotation. From this position of 90° of knee flexion and external hip rotation, the knee was flexed cephalate by the examiner, while the examiner maintained the amount of external rotation of the hip up to maximum hip flexion (end ROM). With the lower limb position maintained at full hip flexion, the long-arm goniometer was used to measure ROM. Measurements were classified into 3 categories: 1: >90° (ideal); 2: 60°–90° (non-ideal); and 3: <60° (highly unsatisfactory) (Kapandji, 1970a; Hoppenfeld, 1976).

Lower limb region: Adductor mobility test

Equipment: Plinth; goniometer.

Directions: The subject was placed on the plinth, supine, with both his knees extended. The examiner stood facing the lower limbs of the subject. The subject's opposite leg was abducted and the heel hooked over the edge of the plinth. The observer then stabilised this limb and controlled its rotation. Thereafter, the limb closest to the examiner was abducted with hip rotation controlled in neutral. The examiner continued this movement until maximum range. The examiner then measured the angle with the long-arm goniometer placed on the umbilicus, with the goniometer's arms representing the femoral shaft positions. Measurements were classified into three categories: 1: >120° (ideal); 2: 100°–120° (non-ideal); and 3: <100° (highly unsatisfactory) (Kapandji, 1970a; Hoppenfeld, 1976).

Lower limb region (hip joint): Internal rotation mobility test

Equipment: Plinth, long arm goniomotor, marker.

Directions: The subject stood at the end of the plinth on his right leg, while the left was supported over the side of the plinth (knee crease at edge). The examiner clearly marked the apex of the patella on the flexed left knee. The examiner then positioned the subject supine on the plinth, with the subject's left knee and left hip flexed to 90°. A neutral thigh position (no rotation) represented the starting position (0°). The left hand of the examiner was used to stabilise the inferior portion of the thigh, while the right held onto the ankle and internally rotated the hip joint to maximum. The observer placed the goniometer on the identified area. The amount of rotation in comparison to the starting position was then measured. Measurements were classified into three categories: 1: >30° (ideal); 2: 15°–30° (non-ideal); and 3: <15° (highly unsatisfactory) (Kapandji, 1970a; Hoppenfeld, 1976; Hattingh 2003).

Lower limb region (hip joint): External rotation mobility test

Equipment: Plinth; long-arm goniometer; marker.

Directions: The subject was positioned in the same position as for the *internal rotational mobility test*. Maximum ROM was achieved and measured for external rotation. Measurements were classified into three categories: 1: >90° (ideal); 2: 60°– 90° (non-ideal); and 3: <60° (highly unsatisfactory) (Kapandji, 1970a; Hoppenfeld, 1976; Hattingh, 2003).

Lower limb region (knee complex): Quadriceps angle test (Q-angle test)

Equipment: Plinth, small goniomotor, marker; tape measure.

Directions: The subject was positioned supine on the plinth with both legs relaxed and extended. The examiner identified the tibial tuberosity and apex of the patella with a marker. The medial and lateral aspects of the patella base were also carefully marked. The midpoint between these two landmarks was then measured and identified. Next, the anterior superior iliac spine was palpated, identified and marked. A straight line was drawn from this high position through the superior patella mid-position, extending caudate. Following this, a second line was drawn from the tibial tuberosity through the apex of the patella, extending cephalate. The point at which these two lines intersected indicated the Q-angle of the

measured leg. A small goniomotor was placed on the crossing line to measure the angle. Measurements were classified into two categories: 1: $<9^\circ$ (ideal); and 2: 9° and more (non-ideal) (Kapandji, 1970a; McConnell, 1986; Gilleard *et al.*, 1998; Derman & Scwhellnus, 2001b).

Lower limb region (knee complex): Patella squint test

Equipment: One plinth; marker; tape measure.

Directions: The subject was positioned relaxed, supine on the plinth with both legs extended. The examiner positioned him to the lateral side of the subject, at the level of the subject's left knee. The examiner began by identifying and marking the apex of the patella with a marker. Afterwards he carefully identified the medial and lateral aspects of the patella base and identified the midpoint between these landmarks. A line was then drawn from this patella mid-position through the inferior pole of the patella. The examiner now described the amount of patella squint (rotation) in comparison with the mid-limb sagittal line as a 1: $<10^\circ$ (ideal); or 2: $\geq 10^\circ$ (non-ideal) (McConnell, 1999).

Lower limb region (knee complex): Patella tilt test

Equipment: One plinth

Directions: The position of the subject and examiner was exactly as for the *patella squint test*.

Step one: The examiner used an imaginary coronal axis passing through the anterior surface base of the patella to note and document the amount of surface deviation from this line. If there was no deviation, the patella was categorised as 1: not tilted (ideal).

Step two: If deviation was visible, the examiner placed his thumbs on the lateral aspect of the patella and gently glided it medially (<1 cm). Only when the range was still limited, was the patella categorised as 2: tilted (non-ideal) (Wallace *et al.*, 1990; McConnell, 1999).

Lower limb region (knee complex): **Vastus medialis obliquus–lateralis comparison test (VMO -L)**

Equipment: A plinth.

Directions: The subject was positioned supine on the bed, relaxed, with both knees extended. The examiner positioned himself at the lower limb level, facing the subject's knees. The subject was instructed to contract the quadriceps isometrically and hold the contraction. The examiner compared the muscle bulk of vastus medialis to vastus lateralis. Measurements were classified into two categories: 1: no apparent difference (ideal); and 2: apparent difference (non-ideal) (Wallace *et al.*, 1990; McConnell, 1999).

Lower limb region (the foot): **Longitudinal arch status test**

Equipment: None required

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

Lower limb region (the foot): **Fore foot positional test**

Equipment: Marker; goniometer.

Directions: The subject was positioned as for the *longitudinal arch status test*. The lateral aspect of the talus neck was identified and marked. The examiner also identified and marked the Z-axis. Then, a goniometer was placed on the marked area, with the control arm on the Z-axis, and the other arm measuring the degrees of forefoot valgus. Measurements were classified into two categories: 1: 0°–10° deviation from the Z-axis (ideal); and 2: more than 10° deviation from the Z-axis (non-ideal) (Hunt, 1990; Derman & Swchellnus, 2001b).

Lower limb region (the foot): **Rear foot standing test**

Equipment: A plinth; goniometer; marker; tape measure; bench.

Directions: The subject was positioned prone on a plinth with both his feet just over the edge of the plinth. The mid-point of insertion of the Achilles tendon (TA) into the calcaneus was marked. With the index finger and thumb of the left hand on either side of the calcaneus, the mid-position of the posterior calcaneus was also marked. A line bisecting the calcaneus was drawn by connecting these two marks. A third point was marked in the middle of the proximal calf muscle bulk. Finally, a fourth point was identified where the calf muscle bulk inserted into the TA. A line was drawn between these last two points which represented the pulling direction of the calf muscle complex.

Then, the subject was ordered to stand erect with his feet together on the bench, facing away from the examiner. The angle between the two drawn lines was measured. Measurements were classified into three categories: 1: $>9^\circ$ (rear foot pronation); 2: 0° – 9° (ideal); and 3: $<0^\circ$ (rear foot supination) (McPiol & Brocato, 1990).

Lower limb region (the foot): Rear foot lying test

Equipment: A plinth; goniometer; marker.

Directions: The subject was positioned and marked as for the *rear foot standing test* protocol. The examiner positioned him at the end of the plinth, and placed his right hand on either side of the subject's talus, approaching from the frontal aspect of the left foot. With the thumb of the left hand placed on the plantar aspect of the fourth and fifth metatarsal heads, the examiner eased the foot into dorsiflexion, while controlling the neutrality of the talocrural joint system with the index finger and thumb of the right hand. The position was held in neutral (0°) and the rear foot status measured with the goniometer. Measurements were classified the same as the *rear foot standing test* protocol (Kapandji, 1970a; McPiol & Brocato, 1990).

Lower limb region (the foot): Transverse arch area comparison test

Equipment: A plinth.

Directions: The subject was in exactly the same position as for the *rear foot standing test* protocol. The examiner – seated at the end of the plinth – inspected the transverse arch area. The transverse arch areas were classified into two categories: 1: normal plantar aspect with a

slight transverse arch (ideal); and 2: callus plantar aspect with a flat arch (non-ideal) (Kapandji, 1970a; McPiol & Brocato, 1990).

Lower limb region (the foot): Foot mobility test

Equipment: A plinth.

Directions: The position of the subject and the examiner were the same as for the *transverse arch area comparison test*. The examiner first flexed and then extended the subject's medial aspect of the foot maximally. The amount of mobility was categorised into 1: hypermobile status; 2: ideal status; and 3: hypomobile status (Kapandji, 1970a).

Lower limb region (the foot): Toe positional test

Equipment: None required.

Directions: The subject stood erect, facing the examiner, with his feet shoulder width apart. The subject's toe position was evaluated and graded as 1: ideal position (no valgus; rotation or deviation); and 2: non-ideal (present valgus/rotation/deviation) (Hoppenfeld, 1976).

(b) Pelvic girdle region

Pelvic girdle region: Leg length discrepancy test

Equipment: A plinth.

Directions: The subject was in the supine position on the plinth, with his heels just over the edge of the plinth. The examiner first ensured that the subject was positioned symmetrically. The examiner approached the subject from the end of the plinth and placed both his thumbs firmly against the inferior aspects of the medial malleoli. The subject's legs were kept straight, lifted up to 30°, elongated and then replaced in the original position. The differences in malleoli position were observed, recorded and categorised as 1: medial malleoli height left equals right (ideal); 2: >0cm, but ≤1cm discrepancy (slightly displaced) (non-ideal); and 3: >1cm discrepancy (highly unsatisfactory) (Hoppenfeld, 1976; Peers 1994; Rocabado, 2000).

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

Equipment: A plinth; marker.

Directions: The examiner positioned the subject as for the *leg length discrepancy test*. The subject was requested to expose the anterior superior ileac spine. The examiner then carefully marked the inferior aspect of both the prominences. Next, the symmetrical position of the subject was ensured, after which the examiner placed his thumbs on the marked areas and recorded signs of asymmetry. The status was categorised as 1: symmetrical (ideal); and 2: asymmetrical (non-ideal) (Hoppenfeld, 1976; Peers, 1994; Rocabado, 2000).

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

Equipment: A plinth; marker.

Directions: The subject was placed on the plinth, in a four point kneeling position. The examiner then ordered him to sit back on his heels (with the gluteal area touching the heels) and while sustaining this position to flex forward until his head touched the plinth. The examiner carefully exposed, palpated, identified and marked the inferior edges of the two posterior superior ileac spines. The examiner then placed his thumbs on the marked areas and assessed the symmetry. The status was classified as 1: symmetrical (ideal); and 2: asymmetrical (non-ideal) (Hoppenfeld, 1976; Porterfield & DeRosa, 1990; Peers, 1994; Rocabado, 2000).

Pelvic girdle region: Pelvic rami positional test

Equipment: A plinth.

Directions: The subject was positioned supine with the superior pubic area just exposed. The examiner ensured his symmetrical positioning. The examiner placed his thumbs on the superior medial rami, and assessed the area for asymmetry. The status was categorised as 1: symmetrical (ideal); and 2: asymmetrical (non-ideal) (Hoppenfeld, 1976; Peers, 1994; Rocabado, 2000).

Pelvic girdle region: Sacroiliac cleft test

Equipment: A plinth.

Directions: The subject was positioned as for the *posterior superior iliac spine comparison test*. The sacroiliac joint (SIJ) area of the subject was carefully exposed. The examiner then placed his thumbs on the joint margin and assessed it for cleft asymmetry. The status was categorised as 1: symmetrical (ideal); and 2: asymmetrical (non-ideal) (Porterfield & DeRosa, 1990).

Pelvic girdle region: Bilateral pelvis positional test

Equipment: Tape measure; marker; a stool.

Directions: The subject stood erect and relaxed with both the ASIS and PSIS well exposed. The examiner sat on a stool, facing the subject's side. Next, the inferior edge of the ASIS and then the PSIS were carefully palpated, identified and marked. The examiner then measured and recorded the difference in height between these marks (lower ASIS and PSIS). Measurements were categorised as 1: ≥ 2 but < 3 cm discrepancy (ideal); 2: 3–5 cm discrepancy (non-ideal); and 3: > 5 cm discrepancy (highly unsatisfactory) (Kapandji, 1974).

(c) *Spinal region*

Spinal region: Thoraco-lumbar fascia (TLF) mobility test

Equipment: A plinth; tape measure.

Directions: The subject was positioned on his side, lying with his head at the top edge of the plinth. His top leg was bent at 90° angles at both his hip and knee. The subject was then aided first onto his bottom elbow (side-lying) and then onto his hand, which he placed at the top edge of the plinth. The examiner ensured the subject was positioned in a straight line before measurement. The distance between the iliac crest and the superior plinth surface was measured. Measurements were categorised as 1: < 1 cm (ideal); 2: 1–3 cm (non-ideal); and 3: > 3 cm (highly unsatisfactory) (Kapandji, 1974).

Spinal region: Sacral rhythm test

Equipment: A plinth.

Directions: The subject was positioned prone on the plinth with his head close to the top edge of the plinth. His arms were positioned as for a push-up with the hands on the two top corners of the plinth. The examiner, positioned at the side of the plinth, placed both his thumbs on the L5 transverse processes. The subject was then instructed to perform a push-up without lifting his hips, while the examiner assessed the symmetry of the extension movement in this region. This was categorised as 1: symmetrical movement (ideal); and 2: asymmetrical movement (non-ideal) (Gould III, 1990).

Spinal region: Functional extension mobility test

Equipment: A plinth.

Directions: The subject was positioned as for the *sacral rhythm test*. This time, the push-up was performed, and the elbows locked in extension. The examiner then measured the distance between the ASIS and the superior aspect of the plinth. Measurements were classed as 1: <1cm (ideal); 2: 1–3 cm (non-ideal); and 3: >3cm (highly unsatisfactory) (Gould III, 1990).

Spinal region: Functional flexion mobility test

Equipment: None

Directions: The subject stood erect but relaxed with his feet at shoulder width. The subject flexed forward and attempted (with hands crossed) to touch the ground without bending at the knees. The subject was urged to flatten his palms on the floor if possible. Flexion was categorised as 1: palms placed on ground (ideal); 2: touched ground (non-ideal); and 3: unable (highly unsatisfactory) (Kapandji, 1974).

Spinal region: Rotational mobility test

Equipment: A plinth.

Directions: The subject sat erect on the plinth, in a stable position, with his lower limbs over the edge of the plinth and arms crossed with hands on opposite shoulders. The examiner positioned himself behind the subject and then placed his hands on the subject's shoulders

and rotated the trunk to the end of its range. The range in the transverse plane was noted, with the lateral axis (x-axis) representing 0°/180°. Range was categorised as 1: rotation of more than 90° (ideal); 2: rotation of 70°–90° (non-ideal); and 3: rotation less than 70° (highly unsatisfactory) (Kapandji, 1974).

Spinal region: Side flexion mobility test

Equipment: A plinth.

Directions: The subject was positioned as for the *rotational mobility test*. For this test his hands were placed on his shoulders and relaxed. From the rear, the examiner stabilised the pelvic girdle on the left while he laterally flexed the trunk to the right, up to the end of its range (no rotation was allowed). The range was categorised as 1: easy elbow contact with plinth without stretching sensation and resistance (ideal); 2: contact with stretching sensation and resistance (non-ideal); and 3: unable to touch surface (highly unsatisfactory) (Kapandji, 1974; Gould III, 1990).

Spinal region: Coronal axis

Equipment: One high stool.

Directions: The subject stood erect and relaxed, feet at shoulder width, with the examiner seated on a high stool, on the lateral side of the subject, facing the subject. The examiner used an imaginary coronal axis passing through the midline of the subject, to evaluate the postural position. Spinal regions were categorised according to their position in relation to the coronal axis. These regions were the following: cranium (head), cervical, thoracic and lumbar. Regions were identified as 1: ideal (no deviation from the coronal axis); and 2: non-ideal (deviating from the coronal axis) (Kapandji, 1974).

Spinal region: Sagittal axis

Equipment: A high stool.

Directions: The subject was positioned as for the *coronal* evaluation, but the examiner was positioned posterior to the subject, on a high stool. For this test the examiner used an imaginary sagittal axis passing through the midline of the subject, to evaluate postural position. The following regions were evaluated according to their position in relation to the

sagittal axis: cranium (head), cervical, thoracic and lumbar. Regions were categorised as 1: ideal (no deviation from the sagittal axis); and 2: non-ideal (deviating from axis) (Kapandji, 1974).

(d) *Upper limb region*

Upper limb region: Hand behind back ROM test

Equipment: Marker; tape measure.

Directions: The subject stood erect and relaxed, with his feet positioned at shoulder width, with the examiner standing posterior to the subject. The subject was instructed to rotate his left arm internally behind his back with a single movement, and to touch his back with his index finger. The subject aimed to achieve the highest possible position. The examiner carefully marked the achieved level on the spinous process. The subject repeated the same procedure with his right arm. The difference in height between the two marks were measured and recorded. Differences were categorised into 1: distance equal to or less than 1 cm (ideal); 2: 1–3 cm (non-ideal); and 3: >3cm (highly unsatisfactory). If differences in height occurred, the side with the smaller ROM was also noted (Kapandji, 1970b).

Upper limb region: Hand behind neck ROM test

Equipment: Marker; tape measure.

Directions: The subject was positioned the same as for the *hand behind back ROM test*. With a single movement the subject externally rotated his left arm behind his neck and achieved the lowest possible point with his index finger. This point was marked on the spinous process. The subject repeated this procedure with the right arm. Differences in height between the two marks were noted and measured. Measurements were categorised into 1: distance equal or distance less than 1 cm (ideal); 2: 1–3 cm (non-ideal); and 3: >3cm (highly unsatisfactory). The side with the smaller ROM was also noted (Kapandji, 1970b; Brukner & Khan, 2001).

Upper limb region: Shoulder coronal positional test

Equipment: High stool.

Directions: The subject stood erect, relaxed, with his feet at shoulder width. The examiner was seated on a high stool, and positioned laterally to the subject. The examiner used an imaginary coronal axis (line of gravity) passing through the midline of the subject to note the shoulder postural position of the subject. The shoulder postural position in relation to this axis was categorised as 1: anterior displacement of shoulder less than 2/3 (ideal); and 2: anterior displacement more than 2/3 (non-ideal) (Kapandji, 1970b; Brukner & Khan, 2001).

Upper limb region: Winging positional test

Equipment: High stool; marker.

Directions: The subject was positioned in a relaxed, standing position with his feet at shoulder width and the examiner seated on a high stool, posterior to the subject. Then, the examiner carefully marked the inferior medial margins of both scapulae as well as the spinous process of T9. The distances between the spinous process (T9) and the inferior medial margins were measured and categorised.

The categories were as follows:

- If distances left and right were equal, with no winging (ideal) on either side, then both left and right were categorised as 1.
- If a discrepancy of more than 1 cm occurred, if winging occurred on the larger measurement side, then the side was categorised as 2 (non-ideal). If no winging occurred on the contra-lateral side, it was categorised as a 1.
- If equal distances were measured (but larger than 1 cm), plus winging (non-ideal), then both sides were categorised as 2 (Kapandji, 1970b; Halbach & Tank, 1990; Brukner & Khan, 2001).

Upper limb region: Shoulder outline composition

Equipment: High stool.

Directions: The subject stood erect but relaxed, with the feet shoulder width apart and the examiner positioned to his lateral side. The examiner categorised the shoulder outline as 1: predominantly muscular with very few to no *visible* bony landmarks (ideal); and 2: less muscular with prominent bony landmarks *well visible* (non-ideal) (Halbach & Tank, 1990; Brukner & Khan, 2001).

Upper limb region: Throwing ROM test

Equipment: None.

Directions: The subject was positioned in an erect, relaxed position, with his feet at shoulder width apart, and the examiner positioned laterally on his left side. The subject then actively flexed his left shoulder to maximum ROM. The examiner next stabilised the trunk with the right hand, placed his left hand on the subject's elbow and flexed the shoulder passively to the end of its range with the left hand. The examiner then used an imaginary coronal axis passing through the midline (line of gravity) of the subject to note range. The ROM was categorised into 1: ROM touching or exceeding coronal midline (ideal); and 2: ROM unable to reach coronal midline (non-ideal) (Mullin, 1999).

(e) *Neurological assessment (neurodynamics)*

Neurological assessment: Straight leg raise (SLR)

Equipment: Plinth, long-arm goniometer.

Directions: The examiner positioned the subject supine on the plinth, with trunk and hips in a neutral position. The examiner then placed his one hand under the Achilles tendon of the subject and the other above the knee. He then lifted the leg perpendicular to the plinth. The limb was lifted as a solid lever moving at a fixed point in the hip joint, while the hand above the knee prevented any knee flexion. The examiner took the limb up to a symptom response or the end of range and noted this end of range (as in all tension testing). The examiner then used a standard long-arm goniometer – with the apex of the trochanter used as the midpoint – to measure the noted range of movement. Range was categorised as 1: greater than 90°

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

Neurological assessment: Upper limb tension test

Equipment: A plinth.

Directions: The subject was positioned supine on the plinth, in neutral supine, towards the left side of the plinth. The examiner then followed the following procedure:

1. He held the left hand of the subject in his right, while the subject's upper left arm rested on the examiner's thigh.
2. The examiner then used his left hand to depress the subject's left shoulder girdle. The examiner ensured maintenance of a neutral position of the shoulder girdle. The examiner then abducted the glenohumeral joint to 110° in the coronal plane.
3. With this abducted position maintained, the subject's forearm was supinated and the wrist and fingers extended by the examiner.
4. Next, the shoulder was rotated laterally.
5. From this position, the elbow was extended slowly.
6. With the above position maintained, the subject then added lateral flexion of the cervical spine to the left and then to the right.

The subjects were classified into three categories, with 1: 180°–0° (no tension) (slight symptom response is normal) (ideal); 2: 180°–10° (symptoms present) (non-ideal); and 3: 180° to more than 10°, (symptoms present) (highly unsatisfactory) (Halbach & Tank, 1990; Butler, 1991).

Neurological assessment: L3,4 nerve suppleness test (Prone knee bend)

Equipment: Plinth.

Directions: The subject was positioned prone on the plinth, facing the examiner. The subject's lower limb was passively flexed towards his gluteal area until either a symptom response or the end of range was achieved. This range was noted. Subjects were then

classified into three categories: 1: heel touching gluteus area with no tension (slight resistance from natural limiting factors is normal) (ideal); 2: heel touching gluteus area with strong resistance (non-ideal); and 3: heel not touching gluteus (highly unsatisfactory) (Gould III, 1990; Butler, 1991).

Neurological assessment: Slump test

Equipment: Plinth.

Directions: The subject sat well back on the plinth (knee crease at edge) with his legs over the side of the plinth. The following procedure was followed:

1. The subject linked both his hands in a relaxed position behind his back.
2. The subject was ordered to slump with his cervical spine in extension. The examiner now applied gentle overpressure to the thoracic and lumbar spine. This position was maintained.
3. The examiner then gave the order to flex the cervical spine and to place the chin to the chest, again with gentle overpressure by the examiner.
4. Now, with this position maintained, the subject was ordered to extend the knee, first the left, and then the right. The examiner noted angle and discomfort.
5. While holding the position in 4, dorsiflexion of the ankle and foot was carefully added. The range and discomfort were noted.
6. With the position in 5 held, the neck flexion was carefully released, and signs and symptoms noted.
7. The same test was repeated on the opposite side.
8. Finally, both knees were extended with the subject in the slump position, while gentle overpressure was applied by the examiner. Again, discomfort and range were noted.

Subjects were classified as follows: 1: full range, with dorsiflexion, asymptomatic (ideal); 2: full range, with dorsiflexion, and discomfort (non-ideal); and 3: limited range with tension (highly unsatisfactory) (Gould III, 1990; Brukner & Khan, 2001).

4.10 STATISTICAL ANALYSIS

A variety of statistical techniques was used to analyse the data. A purposive selection of non-equivalent experimental-control group design with multiple post-tests was used in this study.

The injury incidence rate (*injuries/1000 player hours*) was chosen to examine the influence of the prevention programme on the injury experience during the two rugby seasons. However, the injury records from the sports-medical clinics (distributions of severity of injury, type of injury, anatomical region affected, injured during match or training) was also described in order to provide a clearer, more in-depth understanding of the influence of the prevention programme on the injury experience of players during the two rugby seasons.

The overall injury incidence was expressed as the number of injuries per 1000 player-hours of rugby (15 players playing for 1 hour equals 15 player-hours of rugby). For the calculation of playing hours as well as injury incidence this study took into account each player's exposure to risk (measured as combined duration of all games played or training sessions attended). The coaches used an exposure form to measure the exposure (playing hours at risk). The coaches noted the total duration time of each match and training session on this form, as well as the participation time of each player. These times were then used to calculate the exposure time, as well as injury prevalence (expressed as *injuries/1000 player-hours*) of each group of players.

The overall injury incidence was determined by first adding each of the players' total number of match-play hours to his total number of training hours. This sum represented the total exposure time of each player. Secondly, to calculate the injury incidence of any group, the total exposure times of all the players in the specific group were added. The incidence was now expressed as *number of injuries/player-hours of rugby*. This was then converted to the amount of injuries per 1000 player hours of rugby and expressed as *injuries/1000 player-hours*. The same principles were used to calculate intrinsic and extrinsic injury incidences.

To calculate the severity, the definition of Garraway and Macleod (1995:1485) was used. It coded injuries according to the International Classification of Diseases. According to this, injuries were seen as i) transient: if the player missed fewer than 7 days from training or playing in matches, ii) mild: if 7 to 28 days missed, iii) moderate: if 29 to 84 days missed, iv) severe: if more than 84 days missed. Duration of injury/time off was calculated as the difference between the date of injury and the date of return to play. Only mild, moderate and severe injuries were included in the statistical analysis.

4.10.1 STATISTICAL METHODS OF DATA PROCESSING

Statistical software was used for all the data analysis. Data was processed by using the Statistica-7 for Windows program (StatSoft Inc., 2005). Descriptive statistics, repeated measures ANOVA, and effect sizes (practical significance) were used (Thomas & Nelson, 2001; Ellis & Steyn, 2003).

First, descriptive statistics were done on all groups involved in the study. This was done for all the anthropometric, physical and motor, and biomechanical and postural data at the first (T1), third (T3), fourth (T4) and final (T6) assessments (T1). Thereafter, injury incidence was analysed for practically significant differences between age groups. Statistically significant differences were not interpreted as the data were not randomised. Also, one should take into account that experimental and control groups were non-equivalent. The injury records from the sports-medical clinics (distributions of severity of injury, type of injury, anatomical region affected, injured during match or training) were described with the help of frequency tables.

The practically significant differences between means were determined using effect sizes (Steyn, 2000; Ellis & Steyn, 2003). Effect size is considered to provide an indication of the practical “meaningfulness” of differences. Effect size makes the difference independent of units and sample size, and also relates it to with the spread of the data (Steyn 2000; Ellis & Steyn, 2003). Effect size for injury incidence was calculated with the following formula:

$$d = (\bar{x}_1 - \bar{x}_2) / s_{\max}$$

where s_{\max} = maximum of s_1 and s_2 , the sample SDs (Steyn, 2000; Ellis & Steyn, 2003).

Cohen's guidelines are used for the interpretation of the effect size are (Steyn, 2000; Thomas & Nelson, 2001; Ellis & Steyn, 2003):

- (a) small effect: $d=0.2$
- (b) medium effect: $d=0.5$
- (c) large effect: $d=0.8$

Data with $d \geq 0.8$ are considered practically significant, since such data are the result of a difference having a large effect (Ellis & Steyn, 2003).

Repeated measures ANOVA was used to calculate how the different anthropometric, physical and motor and biomechanical and postural variables of players changed over successive testing occasions (two rugby seasons, T1 to T6). An analysis of the profiles of the different groups was used to examine the effects of the training programme, keeping in mind that the subject groups chosen for the study were not equivalent at the beginning of the study. Differences between testing occasions, and experimental and control groups were again analysed for practical significance (effect size for difference between means). Because the anthropometric, physical and motor and biomechanical and postural data were dependent, standard deviations (SDs) were not used in the calculation of effect size. Instead of the standard deviation, the square root of the mean square error (*MSE*) of the repeated measures ANOVA was used as the denominator. The *MSE* is a measure of the variance of data, while \sqrt{MSE} is a measure of the standard deviation in difference measurements. Therefore the

formula used for the effect sizes of the ANOVA was: $d = \frac{|\bar{x}_i - \bar{x}_j|}{\sqrt{MSE}}$ (Ellis & Steyn, 2003).

Once again, $d \geq 0.8$ was considered as practically significant for all cases, since it is the result of a difference having a large effect (Ellis & Steyn, 2003).

5

RESULTS AND DISCUSSION

- 5.1 Introduction
 - 5.2 Incidence of injury
 - 5.3 Injury records from the sports-medical clinics
 - 5.4 Results of intra-group comparisons between testing occasions
 - 5.5 Results of inter-group comparisons between experimental and control groups
 - 5.6 Identified deficiencies in the current prevention programme
 - 5.7 Summary of most important findings of the empirical study
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5.1 INTRODUCTION

The aims of the present study were to determine what effect an approved injury prevention programme has on the incidence of rugby injuries (intrinsic and extrinsic injuries) of selected groups of 15- and 16-year old schoolboys; as well as on their anthropometric, physical and motor, and biomechanical and postural variables over a period of two years. Originating from the above aims, a sub-aim was to use the different data from this study to provide modifications – if necessary – to the current prevention programme in order for it to be effectively applied at high school rugby level.

To achieve these aims, the following steps were followed:

First step: To determine the *injury incidence* (overall, intrinsic and extrinsic) of the groups of high school rugby players involved, over the selected two-year period.

Second step: To describe similarities and differences in *injury incidence* that might exist between the results of the first and second year over which the study was conducted, and to describe similarities and differences in *injury incidence* that existed between the corresponding experimental and control groups into which the subjects were divided.

Third step: To make use of the injury records from sports-medical clinics in order to describe the *severity of injury, type of injury, anatomical region affected*, and if it was sustained during *matches or training*. Then to use this information to identify shortcomings that might exist in the current injury prevention programme.

Fourth step: To describe the *anthropometric, physical and motor, and biomechanical and postural* variables of the different rugby-playing groups and study their development over the course of the two years.

Fifth step: To compare the changes in the *anthropometric, physical and motor and biomechanical and postural* variables between the selected groups, over the course of the study.

Sixth step: To analyse the results of the study, and in so doing end with a discussion of *deficiencies* in the current prevention programme. These deficiencies are then addressed in the final chapter under the heading '*specific recommendations*' in order for them to be more effectively applied at high-school rugby level.

Final step: To end with a *summary* of the most important findings. This summary of the most important results will have relevance to the aims of the study, with the intention that it will facilitate the discussion of the conclusions in the final chapter.

The results of this study are explained according to the format of the above steps. This also includes comparison of the results with available literature, and the interpretation of results.

5.2 INCIDENCE OF INJURY

Mean injury rates for the different groups are reflected in Table 5.1. Injuries were recorded per 1000 player-hours of rugby. Firstly it must be noted that according to the literature, when considering overall injury incidence of school players, A team players are normally expected to be injured more frequently than players in the lower teams (Nathan *et al.*, 1983; Roux, 1992). However, in the present study the experimental groups (A teams) were the ones receiving the intervention and were therefore expected to experience a reduction in overall injury incidence.

Yet, it could not be estimated beforehand if the prevention programme would sufficiently decrease the overall injury incidence experienced by the experimental groups to be below that experienced by the control groups. In actual fact, because overall injury incidence consists of the sum of the intrinsic and extrinsic injury incidence, the ability of the prevention programme to reduce overall injury incidence actually depends on its ability to reduce either the intrinsic or the extrinsic injury incidence, or both. Finally, as the groups used in this study were not chosen randomly (non-equivalent groups), the t-test could not be applied to determine the statistical significance to differences in injury incidences. Therefore, only effect sizes (practical significance of differences) were used to describe the differences which occurred (Steyn, 2000; Ellis & Steyn, 2003).

Upon studying Table 5.1 it can be seen that the overall injury incidence experienced by the 15-year old experimental group during the first season was 4.98 injuries/1000 player-hours. Few studies on schoolboy rugby were found in which injury incidence data could be converted to *injuries/1000 player-hours*, which makes comparison with similar school groups difficult. Nevertheless, by comparison the overall injury incidence in the 15-year old experimental group during the first season (4.98) is nearly similar to the mean of 4.81 (one injury per 208 boy-hours of rugby) reported by Nathan *et al.* (1983:133) for 15-year old schoolboy players of mixed grades (levels). This injury rate (4.98) was still considerably higher than the 4.50 reported for the 15-year old control group, even though the experimental group was the one receiving the intervention.

It can therefore be assumed that during the first season, the effect of the prevention programme on the overall injury incidence of the 15-year old experimental group was not enough to reduce it to below that experienced by the 15-year old control group. According to Table 5.1, a different scenario is visible for the 16-year olds during the first season. Table 5.1 shows that the 16-year old experimental group experienced an overall injury incidence of 2.76 injuries/1000 player-hours, which is lower than the mean value of 3.36 described by Nathan *et al.* (1983:133) for 16-year old players of mixed grades, as well as below the 3.08 experienced by the 16-year old control group. This could be due to the positive effect of the prevention programme on the overall injury incidence of the 16-year old experimental group experienced during the first season. It must be noted that none of the differences described so far was of high practical significance ($d \geq 0.8$).

Concerning the second season, the high overall injury incidence in the 15-year old experimental group declined significantly to 2.70, while the value in the control group increased to 5.24. This caused the overall incidence in the 15-year old experimental group during the second season to be highly significantly less ($d \geq 0.8$) than that achieved in the control group. Although not of high practical significance ($d = 0.38$), the increase in overall injury incidence among the 15-year old control group was expected, as overall injury incidence among schoolboys increases with age (Roux, 1992; Lee & Garraway, 1996; Noakes & Du Plessis, 1996), while the highly practically significant reduction ($d = 1.97$) in overall injury incidence visible among the 15-year old experimental group may possibly be attributed to the effect of the prevention programme during the second season.

Regarding the 16-year old players, data during the second season show that the 16-year old experimental as well as control groups experienced an increase in overall injury incidence from the first to the second season, with the incidence of the 16-year old experimental group surpassing that experienced by the 16-year old control group. Neither of these increases was highly practically significant. This tendency of a rise in overall injury incidence is normal for the 16-year old control group, as overall injury incidence in schoolboy players rises with age (Roux, 1992; Lee & Garraway, 1996; Noakes & Du Plessis, 1996), but was unexpected

for the 16-year old experimental group during the second season. This result for the 16-year old experimental group during the second season indicates that the prophylactic effect of the prevention programme during this season was not sufficient to prevent the overall injury incidence of this group from increasing to above that of the 16-year old control group. In order to find the most probable reason for this, as well as likely explanations for the rest of the above-mentioned trends in overall injury incidence, the overall injury incidence was divided into intrinsic injury incidence and extrinsic injury incidence.

Before these intrinsic and extrinsic injury incidences are explained, it must be mentioned that insufficient literature exists to describe the normal intrinsic and extrinsic injury incidences among schoolboy or even adult rugby players. This may be due to differences in injury definition or, in the case of intrinsic injuries, ineffective methods of injury recording. However, it has been determined that because of the increased intensity with which the game is played at A-team level, A-team players are at greater risk of sustaining extrinsic (related to trauma) injuries than players in the B teams (Roux, 1992; Noakes & Du Plessis, 1996). Essentially the same can be said for intrinsic injuries (injuries related to overuse). Because of increased pressure to perform at A-team level, as well as the fact that matches and training are more demanding, players in the A teams should be at increased risk of sustaining intrinsic injuries (Harvey, 1983; Micheli, 1983; Noakes & Du Plessis, 1996).

Table 5.1 lists the mean intrinsic and extrinsic injury incidence experienced by the different groups during each season, while the three-dimensional bars in Figure 5.1 represent a more visual image of the frequency with which intrinsic and extrinsic injuries occurred. At the time of commencement of this study, it was expected that the prevention programme would possibly not have a large effect on the extrinsic injury incidence of players in the experimental groups. This is firstly because there are always unpredictable elements present in the occurrence of these injuries, and secondly because A-team players are heavier, faster and play the game with more intensity so that when they collide the risk of injury tends to be greater (Davies & Gibson, 1978; Noakes & Du Plessis, 1996). Furthermore, the prevention programme did not focus on factors external to the individual, which are often associated with extrinsic injuries. However, it was expected that the prevention programme would

reduce intrinsic injuries (related to overuse) among the experimental groups, as these injuries are related to factors such as poor biomechanics and overuse, which can be prevented (Noakes & Du Plessis, 1996; McGinnis, 2005).

Table 5.1: Descriptive statistics of injury incidence during the two-year study and d-values (effect sizes) of the intra- and inter-group comparisons

	OVERALL INCIDENCE (injuries 1 000 player-hours)					INTRINSIC INCIDENCE (injuries 1 000 player-hours)					EXTRINSIC INCIDENCE (injuries 1 000 player-hours)				
	Season 1		Season 2		Intra-group difference (d-value)	Season 1		Season 2		Intra-group difference (d-value)	Season 1		Season 2		Intra-group difference (d-value)
	\bar{X}	sd	\bar{X}	sd		\bar{X}	sd	\bar{X}	sd		\bar{X}	sd	\bar{X}	sd	
15-year old experimental group (n=30)	4.98	1.16	2.70	0.51	1.97**	1.31	0.90	0.00	--	1.45**	3.67	0.20	2.70	0.51	1.90**
15-year old control group (n=30)	4.50	1.06	5.24	1.95	0.38	1.50	0.36	2.91	2.73	0.52	3.00	0.70	2.33	1.67	0.40
<i>Inter-group difference (d-value)</i>	0.41		1.30 ^{▼▼}			0.21		1.07 ^{▼▼}			0.96 ^{▼▼}		0.22		
16-year old experimental group (n=30)	2.76	0.33	3.62	2.55	0.34	0.28	0.27	0.00	--	1.04**	2.48	0.19	3.62	2.56	0.45
16-year old control group (n=30)	3.08	0.96	3.27	2.07	0.09	0.92	0.87	1.48	1.24	0.45	2.15	0.37	1.78	0.82	0.45
<i>Inter-group difference (d-value)</i>	0.33		0.14			0.74		1.19 ^{▼▼}			0.89 ^{▼▼}		0.72		

** = large practically significant *intra-group* difference between season 1 and season 2

▼▼ = large practically significant *inter-group* difference between experimental and control group of same age

-- = no injuries occurred, thus not completed due to lack of variation in data

\bar{X} = Mean

sd = Standard deviation

n = number of players in group

$d\text{-value} \geq 0.8$ = large practically significant effect

$0.5 \leq d\text{-value} < 0.8$ = medium practically significant effect

$0.2 \leq d\text{-value} < 0.5$ = small practically significant effect

Considering the intrinsic and extrinsic injury incidence reported during this study (Table 5.1), the results for the first season indicate that the 15-year old experimental group experienced highly significantly more ($d=0.96$) extrinsic injuries (3.67 injuries/1000 player-hours v. 3.00 injuries/1000 player-hours), but less ($d=0.21$) intrinsic injuries than the 15-year old control group (1.31 v. 1.50). This demonstrates the ability of the prevention programme to reduce the intrinsic injury incidence of the experimental group to less than would normally be expected of a 15-year old A team (explained in previous paragraph). The fact that the extrinsic injury incidence experienced by the 15-year old experimental group remained significantly more than that of the 15-year old control group is a possible indication that the prevention programme did not have a large effect on the extrinsic injury incidence of the experimental group. This outcome that the extrinsic injury incidence of the experimental group remained largely unaffected by the prevention programme, also serves as a possible reason why the overall injury incidence experienced by the 15-year old experimental group during the first season could not be reduced to below that experienced by the 15-year old control group.

Furthermore, still considering intrinsic and extrinsic injury incidences during the first season, experimental and control groups aged 16 years display the same trend as the 15-year olds (experimental group experienced a significantly ($d=0.89$) higher extrinsic incidence, but lower ($d=0.74$) intrinsic incidence than the control group). However, in the case of the 16-year olds, intrinsic injuries experienced by the experimental group accounted for only 10% ($n=1$) of overall injuries ($n=10$), whereas in the 15-year old experimental group a higher value of 26.32% ($n=5$) was seen (Figure 5.1). In this instance, the low percentage (10%) of intrinsic injuries sustained by the 16-year old experimental group during the first season may possibly explain why this experimental group also experienced a lower overall injury incidence compared to their corresponding control group; while in contrast the 15-year old experimental group did not. Seeing that both these 15 and 16-year old experimental groups followed identical prevention programmes, the higher percentage of intrinsic injuries among the younger group may be attributed to the fact that, on average, the 15-year olds in this study devoted more time to rugby than the 16-year olds during the first year (a 7-week

extended season). This may indicate that among schoolboy rugby players a longer season could have a negative influence on the percentage of intrinsic injuries sustained, even in the presence of the preventative strategies implemented in this study.

The intrinsic injury results for the second season indicate that the intrinsic injury incidences experienced by both the 15- and 16-year old experimental groups were strongly reduced ($d=1.45$ and $d=1.04$) to zero, while it increased in the two control groups. While this increase in intrinsic injury incidence experienced by the control groups may be due to an escalation in training load associated with aging, or a possible deterioration in their biomechanical and postural status (Noakes & Du Plessis, 1996; Neely, 1998; Bartlett, 1999; Watson, 2001), it is disconcerting to note that it accounted for as much as at least 45.45% of overall injuries during the second season (Figure 5.1). In contrast, the highly significant reduction among the experimental groups is heartening, as it may be due to the effect of the prevention programme. Furthermore, the fact that the programme had a more pronounced effect on the intrinsic injury incidence of the experimental groups during the second year indicates the possibility that the specific prevention programme only reached its full potential during the second year of intervention.

Similarly to the first season, the extrinsic injury incidence experienced by the two experimental groups during the second remained higher than those of the corresponding control groups. Although the differences were not highly practically significant ($d=0.22$ and $d=0.72$), this confirms the inability of the prevention programme to reduce the extrinsic injury incidence experienced by the experimental groups to below that of the control groups. *On the other hand, it is interesting that only the 16-year old experimental group experienced an increase in extrinsic injury incidence from the first to the second season. This increase also appears to be the reason why the overall injury incidence experienced by the 16-year old experimental group during the second season escalated to above that experienced by the control group.*

The increase in the 16-year old experimental group confirms earlier research that reports an increased likelihood of sustaining a trauma injury with aging in schoolboys, while the

decrease in the other three groups contradicts this (Noakes & Du Plessis, 1996). In the three groups that experienced a drop in extrinsic injury incidence from the first to second year, other factors such as decreases in mass, speed and strength could have influenced the risk of injury during the second season (Noakes & Du Plessis, 1996). However, analysis of data in Table 5.6 shows that this is not the case. The most likely explanations for these findings would seem that for some reason the level of competitiveness/demands of play experienced by the 15-year old experimental, 15-year old control and 16-year old control groups could have been less during the second season. This may have been true for the two control groups, but is not so for the 15-year old experimental group, where one off the teams was involved in the *finals of several leagues*. Therefore it is more likely that, during the second season, players in the 15-year old experimental group could have gained supplementary experience in protecting themselves in contact situations.

In summary, the injury patterns associated with overall injury incidence in this study suggest that, in practice, the ability of the prevention programme to control overall injury incidence actually depended on its effect on the intrinsic and extrinsic injury incidence. This occurred because the overall injury incidence of any group consists of the sum of the intrinsic and extrinsic injury incidences in the group. Most studies on rugby injuries do not discriminate between intrinsic and extrinsic injury incidences. However, when intrinsic injury incidence and extrinsic injury incidence were studied separately, interesting patterns emerged. Firstly, in the present study the majority of injuries reported in all the groups – except one – were extrinsic, which is normal for rugby players. This is an indication that changes in extrinsic injury incidence had the largest effect on overall injury incidence. However, it must be realised that in this study the prevention programme was not geared towards reducing extrinsic injury incidence, as there are too many unpredictable elements (associated with contact situations) present in the occurrence of these injuries. Therefore, it was not surprising that differences and changes in extrinsic incidences in this study could not be attributed to the effect of the prevention programme, and consequently the preventative effect of the programme on overall injury incidence was also irregular.

In the concluding chapter of this study, the latter aspect will be addressed through recommendations on how to reduce extrinsic injuries. Considering intrinsic injury incidence separately, there is strong evidence proving that the groups which followed the prevention programme always experienced the smaller risk of intrinsic injury. Furthermore, from the first to the second season a highly practically significant reduction was visible in the intrinsic injury incidences of the 15-year old ($d=1.45$) and 16-year old ($d=1.04$) experimental groups, while an insignificant escalation was founding in the two control groups. The most likely explanation for these finding is that the prevention programme had a positive effect on the intrinsic injuries of the two experimental groups during the first as well as the second season, and that this effect was possibly more pronounced during the second season.

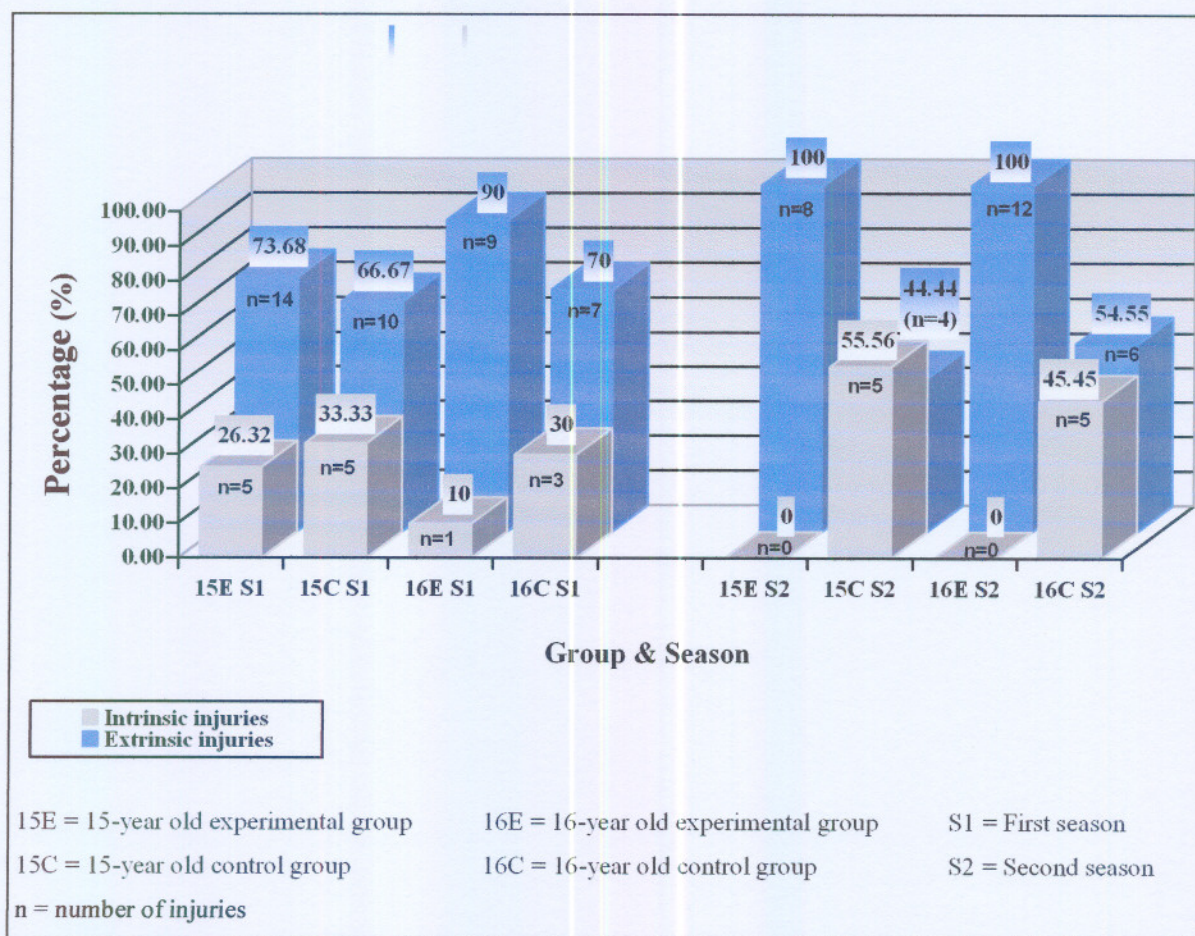


Figure 5.1: Frequencies of intrinsic and extrinsic injuries in the different experimental and control groups during the two rugby seasons

5.3 INJURY RECORDS FROM THE SPORTS-MEDICAL CLINICS

The players' injury report forms from sports-medical clinics were used to obtain a wide variety of injury data on each subject. Four variables (severity of injury, type of injury, anatomical region affected, and if injury had been sustained during matches/training) were selected for analysis. Data described in terms of distributions of injury may have limited application in risk assessment and management, as results produced in this way do not define risk levels (Fuller & Drawer, 2004). However, the data of this study will also be described in terms of percentage distributions for comparison with other studies, as well as to provide an understandable summary of the injury records from the sports-medical clinics.

5.3.1 SEVERITY OF INJURY

Table 5.2: Severity of injuries during two seasons of rugby

GROUP	SEASON 1				SEASON 2			
	n	MLD (%)	MOD (%)	SEV (%)	n	MLD (%)	MOD (%)	SEV (%)
15-year old experimental	19	84.21	5.26	10.53	8	62.50	25.00	12.50
16-year old experimental	10	90.00	10.00	0.00	12	22.22	77.78	0.00
Total experimental	29	68.52	27.78	3.70	20	70.00	25.00	5.00
15-year old control	15	46.67	53.33	0.00	9	75.00	25.00	0.00
16-year old control	10	49.00	51.00	0.00	11	72.73	27.27	0.00
Total control	25	60.00	37.50	2.50	20	50.00	50.00	0.00

MLD = Mild

SEV = Severe

MOD = Moderate

n = number of injuries

Table 5.2 reflects the percentages of mild, moderate and severe injuries during the first and second season. In this regard, the most common grade of injury reported by the two experimental groups during the first season was mild, at 84.21% (n=16) for the 15-year olds and 90% (n=9) for the 16-year olds, while the severe injuries fortunately remained low,

correlating with previous research (Clark *et al.*, 1990; Hattingh, 2003). The results for the first season of the two control groups differ slightly from the above, with more injuries being of a moderate nature (53.33% for 15-year olds and 51% for the 16-year olds); while severe injuries again remained low. On the other hand, results for the second season indicate that all groups reported mostly mild injuries; except for the 16-year old experimental group, which experienced predominantly moderate injuries (77.78%). This can possibly be attributed to the increase in extrinsic injuries (associated with trauma) experienced by the 16-year old experimental group during the second season (seen in Table 5.1). Analysis of severe injuries again shows a low percentage of severe injury among schoolboys, confirming other research (Nathan *et al.*, 1983; Clark *et al.*, 1990; Lee & Garraway, 1996).

In summary, when comparing the experimental and control groups during each of the two years, the results for severity of injury reveal that it is difficult to identify general trends which could be credited to the effect of the prevention programme. As the prevention programme significantly affected intrinsic injury incidence, a breakdown of intrinsic injuries may possibly reveal more interpretable results.

5.3.2 TYPE OF INJURY

Table 5.3 displays information regarding the type of injury sustained during the two years. Several observations regarding the type of injury can be made. When considering the type of injury during the first season, ligament/joint sprains accounted for most of the injuries among the 15-year old experimental group (31.58%), as well as 16-year old experimental group (50%). Ligament injuries have previously been shown to occur more in the contact phases, such as tackling and being tackled (extrinsic injuries) (Noakes & Du Plessis, 1996). Therefore the large percentage of ligament/joint sprains recorded among the experimental groups in this study can possibly be attributed to the higher extrinsic injury incidence experienced by these experimental groups.

The most common type of injury in the control groups during the first season was muscle/tendon strain, at 26.67% for the 15-year old control group, and 60% for the 16-year

old control group. Normally, muscle injuries occur more frequently in open play (running injuries) (Noakes & Du Plessis, 1996). Thus the predominant percentage of muscle injuries among the control groups could be due to the larger intrinsic injury incidence seen among the groups which did not follow the prevention programme during the first season. The results for the first season correlate well with other findings, which state that the type of injury which occurs most at school level are either ligament sprains or musculo-tendinous strains (Hattingh, 2003), but differed from the study of Nathan *et al.* (1983:134), who recorded concussions as the most common type of injury and Roux *et al.* (1987:310), who recorded fractures to be the most common. This phenomenon can possibly be due to changes and evolution visible in the game during the last decade (Hattingh, 2003).

Table 5.3: Distribution of type of injury sustained during the two years

Type of injury	SEASON 1 (% of total)				SEASON 2 (% of total)			
	Team				Team			
	15E (n=19)	15C (n=15)	16E (n=10)	16C (n=10)	15E (n=8)	15C (n=9)	16E (n=12)	16C (n=11)
Wounds	5.26%	0.00%	10.00%	0.00%	0.00%	0.00%	8.33%	0.00%
Deep bruising	15.79%	6.67%	0.00%	10.00%	25.00%	11.11%	8.33%	18.18%
Light bruising	0.00%	6.67%	0.00%	0.00%	0.00%	11.11%	8.33%	0.00%
Concussion	15.79%	20.00%	0.00%	0.00%	12.50%	0.00%	16.67%	0.00%
Muscle/Tendon strain	15.79%	26.67%	30.00%	60.00%	25.00%	44.44%	33.33%	18.18%
Ligament/Joint sprain	31.58%	20.00%	50.00%	10.00%	12.50%	0.00%	25.00%	9.09%
Joint dislocation	5.26%	0.00%	0.00%	0.00%	12.50%	0.00%	0.00%	0.00%
Fracture	5.26%	6.67%	0.00%	10.00%	12.50%	0.00%	0.00%	9.09%
Other	5.26%	13.33%	10.00%	10.00%	0.00%	33.33%	0.00%	45.45%

15E = 15-year old experimental group

15C = 16-year old control group

n = number of injuries

16E = 15-year old experimental group

16C = 16-year old control group

During the second season, the situation changed somewhat. The type of injury the 15-year old experimental group was most likely to sustain was either deep bruising (25%), or muscle/tendon strain (25%). However, in total, the more extrinsic types of injury (related to trauma) such as concussions, sprains, dislocations and fractures still dominated, while other injuries (predominantly of the overuse type) did not occur. This is indicative of the positive effect of the injury prevention programme on injuries of the overuse type. The 15-year old control group still reported a major percentage of muscle/tendon strain (44.44%), followed by a significant percentage (33.33%) of other injuries (overuse injuries like bursitis, medial tibial stress syndrome, and stress fractures), indicating that the percentage of these injuries escalated among the 15-year old group which had not followed the prevention programme. In the 16-year old experimental group, muscle/tendon strain (33.33%) represented most of the injuries during the second year, while no other injuries (overuse type) occurred. In contrast, within the 16-year old control group, other injuries (45.45%) (overuse injuries such as bursitis, medial tibial stress syndrome and stress fractures) were represented most, confirming an increase in overuse injuries with aging in schoolboy groups which did not follow the prevention programme.

In summary, ligament/joint sprains, as well as other injuries related to body contact, accounted for most injuries in the groups which reported predominantly extrinsic injuries, while muscle/tendon strain and overuse injuries were dominant in the groups which reported mostly intrinsic injuries. Therefore, the positive effect of the prevention programme on the intrinsic injury incidence is probably related to its effect on intrinsic injuries which occur due to overuse.

5.3.3 ANATOMICAL REGION AFFECTED

Injuries sustained in the general anatomical regions are depicted in Figure 5.2. In general, during the first season, the anatomical site most commonly injured among all the experimental and control groups were the lower limb at 57.91% for the 15-year old experimental group, 59.99% for the 15-year old control group, 70% for the 16-year old experimental group, and 50% for the 16-year old control group. This is in accordance with

the recent findings of Hattingh (2003:150, 154) for 15-year olds (55.42%), 18-year olds (56.67%), 19-year olds (72.72%%), and 20-year olds (66.65%), as well as a number of earlier research studies (Sparks, 1981; Roux *et al.*, 1987; Clark *et al.*, 1990; Upton *et al.*, 1996). However, it differed from research which found the head and neck to be more commonly injured (Nathan *et al.*, 1983; Davidson, 1987). This may be attributed to the way the modern game is played, as well as the strict implementation of the current rules in schoolboy rugby.

Alarminglly, the injuries of the lower limb area were succeeded by head injuries in the 15-year old experimental group (21.05%), as well as 15-year old control group (20%). However, upon further analysis (not shown in Figure 5.2) it became evident that severe concussion represented 66.67% of the above-mentioned head injuries in the 15-year old experimental group, while moderate concussion represented 100% of the head injuries present in the 15-year old control group. Luckily, no cervical spine injuries were present in either of these two groups. This is consistent with the finding that although head and neck injuries are fewer than in earlier years, concussions may still be common among schoolboys (Noakes & Du Plessis, 1996).

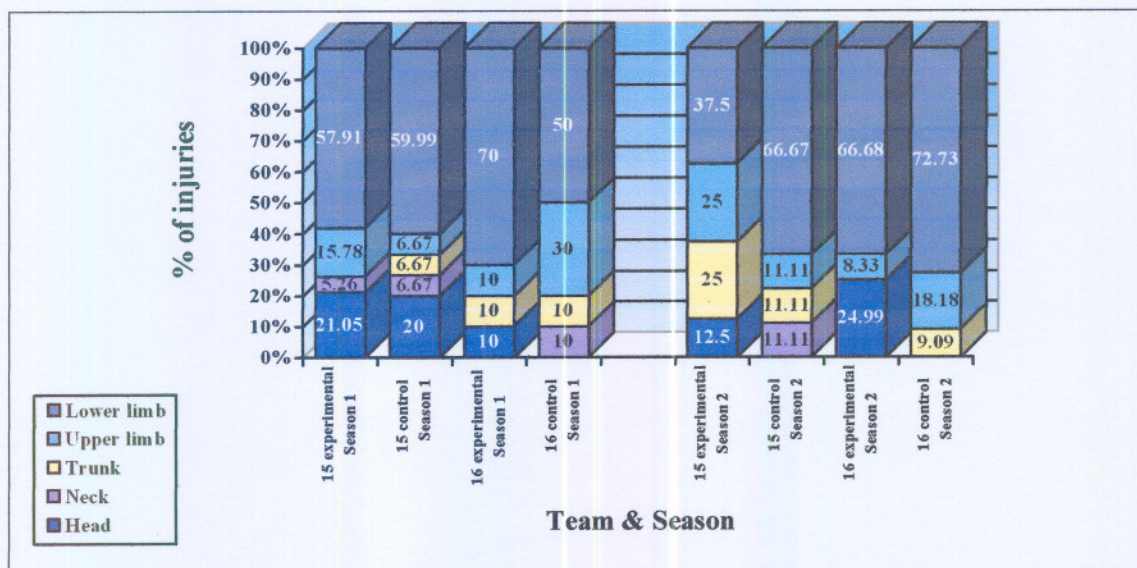


Figure 5.2: Anatomical distribution of injury in the experimental and control groups during the two years

During the second season, all the groups again sustained more injuries to the lower limb. However, the percentage of injuries allocated to the lower limb of the players in the two experimental groups decreased notably from the first to the second season, while in contrast this percentage in the two control groups increased considerably. As intrinsic injuries in rugby predominantly occur in the lower limb as a result of running, the difference in lower limb injuries was most probably a result of the decrease in intrinsic injury incidence among the experimental groups, and the increase among the control groups. This signifies that the intervention could possibly have had a preventative effect on lower limb injuries of intrinsic nature. However, other phases of play such as being tackled (extrinsic in nature) also cause injuries mainly to the lower limb. As the relationship between these phases of play and lower limb injuries were not analysed for the purpose of this study, it is also possible that a reduction in the occurrence of certain phases of play could have been responsible for the reduced percentage of injuries allocated to the lower limb.

In summary, concussions are still common among schoolboys, and the question can be asked if sufficient strategies exist to control this phenomenon. Furthermore, although injuries to the lower limb are most common, the specific intervention could possibly have had a preventative effect on lower limb injuries of intrinsic nature. Further analysis of the injury incidence during different phases of play is needed to substantiate this.

5.3.4 INJURIES SUSTAINED DURING MATCHES OR TRAINING

In Table 5.4 the percentage of injuries which occurred during matches and training is shown. Of all the injuries reported during the first season, the majority (more than 50%) of injuries occurred during matches. A similar trend was found by other researchers (Nathan *et al.*, 1983; Roux *et al.*, 1987; Roux, 1992). The most likely explanation for this is that matches are more competitive, thus increasing injury risk (Noakes & Du Plessis, 1996). In the 15- as well as 16-year olds, the percentages of injuries occurring to players during matches in the first season compares favourably to the 68-71% reported in the literature (Nathan *et al.*, 1983; Roux *et al.*, 1987; Roux, 1992). However, the percentage of injuries during first season matches in the 16-year old experimental group was lower than in the younger

experimental group. A possible explanation for this lower percentage of match-play injuries during the first season is that the 16-year olds were involved in less play-offs and finals than the 15-year olds, and consequently experienced less pressure to perform during their matches than the younger group (Noakes & Du Plessis, 1996).

Table 5.4: Distribution of injuries during matches and training

GROUP	INJURIES SEASON 1		INJURIES SEASON 2	
	MATCHES	TRAINING	MATCHES	TRAINING
15-year old experimental	73.68%	26.32%	75.00%	25.00%
15-year old control	66.67%	33.33%	44.44%	55.56%
16-year old experimental	70.00%	30.00%	75.00%	25.00%
16-year old control	70.00%	30.00%	63.64%	36.36%

Table 5.4 also gives an indication of the changes in the distribution of match-play and training (practice) injuries from the first to the second season. With the exception of the 15-year old control group, the majority of injuries reported during the second season occurred during matches, confirming the data of the first season. Although this seems to indicate that the 15-year old control group differed from the norm during the second season, a similar trend among B-team players (control group) of the same age has been documented by Roux *et al.* (1987:309). The authors did not supply a reason for their observation. However, in the case of the current study, it is most likely due to the 15-year old control group's medium practically significant increase ($d=0.52$; Table 5.1) in intrinsic injuries, which all occurred during training.

Besides this, changes from the first to the second season reveal a slight increase in the percentage of match-play injury episodes in the two experimental groups, confirming the belief that matches lead to increased levels of competitiveness with aging among schoolboy rugby players (Noakes & Du Plessis, 1996). By comparison, the increases in percentage of training injury episodes (decreased % during matches) in the two control groups are not

consistent with the above-mentioned trend. The first possible explanation for this is the substantial increases in intrinsic injuries (Table 5.1) – the majority of which occurred in training – experienced by the control groups. This is difficult to comment on as previous studies did not report intrinsic injury incidence, owing to different injury definitions.

This latter matter is complicated more by the possibility that previous research may have missed a large percentage of overuse injuries (intrinsic injuries) occurring during training, as a large number of these injuries will not be recorded in instances where injuries are recorded through purely medical channels (injuries treated at hospital, injury records of casualty departments), or are underreported in instances where injured players are not closely monitored through direct contact between the injured player and researcher (Van Mechelen *et al.*, 1992). The second explanation for the trend in the two control groups during the second year is a possible decrease in the level of competitiveness of match play, or less pressure to win matches during the second season, causing injuries to occur less frequently in matches. As previous research has not investigated this possibility in B teams (control groups), it cannot be compared to the literature.

In summary, the majority of injuries in each group occurred in matches. This is explained by the competitive nature of matches. In this study, changes in the incidence of intrinsic injury may have been responsible for changes in the percentage of injuries which occurred during training, as these injuries almost always occurred during training.

5.3.5 INTRINSIC INJURIES WITH A PREVIOUS HISTORY

The mean injury incidence was presented in Table 5.1. This table indicated that the prevention programme had a positive effect on the mean intrinsic injury incidence of the two experimental groups. Because of this positive effect, although not part of the initial aims of this chapter, it was decided to perform a supplementary analysis of intrinsic injuries. It was decided that since intrinsic injuries often have a chronic nature, a summary of the percentage of intrinsic injuries recorded as previous injuries (chronic injury history) would make it

possible to view intrinsic injuries in a different light. The percentage of intrinsic injuries which fitted this criterion (with previous history) is shown in Table 5.5.

Table 5.5: Percentage of intrinsic injuries recorded as previous injuries in the experimental and control groups of rugby players

INTRINSIC INJURIES WITH PREVIOUS HISTORY (as % of total number of intrinsic injuries)		
Group	Season 1	Season 2
15-year old experimental group	80%	0% (No intrinsic injuries)
15-year old control group	60%	40%
16-year old experimental group	100%	0% (No intrinsic injuries)
16-year old control group	33%	60%

In Table 5.5, the possible influence of previous injuries (injuries during the previous twelve months) upon the intrinsic injury incidence becomes visible. Among the 16-year old experimental group, a staggering 100% of intrinsic injuries during the first season were of a previous nature, compared to the 60% of the corresponding control group. The same pattern is visible in the 15-year old groups, during the first season. Thus, during the first season it is clear that the majority of intrinsic injuries experienced by all the experimental and control groups – with the exception of the 16-year old control group – were of previous nature. These results signify that, during the first season of intervention, intrinsic injuries of a previous nature remained a dilemma, even in the presence of the prevention programme. This could suggest that these injuries were not fully rehabilitated before the commencement of the study, or that the causes of these injuries were not removed completely during the first

season of the study. These findings cannot be compared to the literature, as no prior rugby research on intrinsic injuries of a previous nature could be found.

During the second season a different pattern emerges. It is evident that among both the experimental groups there were no intrinsic injuries of a previous nature visible (0%), while in contrast to this intrinsic injuries of a previous nature still amounted to a significant fraction in both the control groups. This could have been due to the rehabilitative effect of the prevention programme, as this programme is specifically aimed at reducing biomechanical shortcomings in the experimental groups. Therefore it can be concluded that during the second season the prevention programme possibly had a more significant effect on shortcomings due to previous injuries.

Thus, in summary, the sub-analysis of intrinsic injuries indicated that a high percentage of intrinsic injuries during the first season were due to re-injury. During the second season, this situation improved dramatically in the groups which followed the prevention programme. This might suggest that the programme restored certain impaired functions, and therefore had more of a rehabilitative effect than a preventative effect during the first season. Because of this, certain deficiencies were removed, and the programme could reach its preventative potential during the second year. Originating from this, it is advised that in order to achieve improved results during a rugby season, this prevention programme should be implemented earlier, during the previous off-season, instead of the first pre-season.

5.4 RESULTS OF INTRA-GROUP COMPARISONS BETWEEN TESTING OCCASIONS

Tables 5.6 to 5.8 display the results of the intra-group comparison of each experimental and control groups' anthropometric, physical and motor, and biomechanical and postural data over time. These tables make it possible to observe changes in anthropometric, physical and motor, and biomechanical and postural variables as they occurred over the two years within each experimental and control group. For a more visual description of the changes over time, these tables should be used in conjunction with Figures 5.3 to 5.5.

5.4.1 INTRA-GROUP COMPARISON OF ANTHROPOMETRIC RESULTS

A summary of the mean anthropometric components at different assessments is given in Table 5.6. Table 5.6 also indicates the moderately and highly significant anthropometric changes over time. Anthropometric testing reveals that in practice, all four groups changed highly significantly with regard to *stature*, revealing that the groups may have been in their growth spurt (also see Figure 5.3 (A)). Considering the *fat percentage*, it is notable that all the groups, except the 16-year old control group, decreased their fat percentage highly significantly from the start to the end of the first season (T1-T3), as well as from the start to the end of the total study period (T1-T6). The transformation in each individual skinfold is beyond the scope of this study. However, intra-group changes are shown in Table 5.6. Over the course of the season practically significant changes occurred in the upper arm girth, calf girth, humerus breadth and femur breadth of all the involved groups, confirming the growth period among these age groups. Note the significant gains in mesomorphy in all groups during the first season (T1-T3), second season (T4-T6) and total period (T1-T6), representing increasing musculoskeletal robustness relative to body length in the four groups.

At this final anthropometric assessment (T6), the mean stature and body weight of the different groups of this study correlated well with their counterparts in other schoolboy studies (Hattingh, 2003; De la Port, 2004; Spamer & Hattingh, 2004). However, the fat percentages recorded for all the groups in this study (between 8.52% and 11.76%) were lower than those of previous studies (Hattingh, 2003; Van Gent, 2003; De la Port, 2004; Spamer & Hattingh, 2004). The somatotype of the different groups at T6 can be described as predominantly muscular relative to body length (average mesomorphic value), with low to average relative fatness (endomorph) and low relative slenderness (ectomorph). This is consistent with the findings in the case of other schoolboy rugby players (Quarrie *et al.*, 1995; De la Port, 2004).

Table 5.6: Descriptive statistics and effect sizes (d-values) of anthropometric variables for intra-group comparisons between testing episodes in the 15-year olds (A) and 16-year olds (B)

Table 5.6(A): 15-year olds

INTRA-GROUP COMPARISONS WITHIN EACH EXPERIMENTAL AND CONTROL GROUP															
VARIABLES	MSE	15-YEAR OLD EXPERIMENTAL (n=30)							15-YEAR OLD CONTROL (n=30)						
		DESCRIPTIVE STATISTICS				EFFECT SIZE (d-value)			DESCRIPTIVE STATISTICS				EFFECT SIZE (d-value)		
		\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1- T3	d T4- T6	d T1- T6	\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1- T3	d T4- T6	d T1- T6
ANTHROPOMETRIC COMPONENTS															
Stature (cm)	0.09	172.95	174.44	175.99	177.02	5.0 ∇	3.4 ∇	13.6 ∇	169.66	171.16	172.63	173.64	5.0 ∇	3.4 ∇	13.3 ∇
Bodyweight (kg)	46	71.17	73.26	74.83	76.04	--	--	0.7	64.95	66.96	68.43	69.44	--	--	0.7
Triceps skinfold (mm)	0.18	9.07	8.43	8.54	8.14	1.5 ∇	0.9 ∇	0.7	9.87	9.22	9.40	8.99	1.5 ∇	1.0 ∇	0.7
Subscapular skinfold (mm)	2.68	9.67	8.30	8.40	8.17	0.8 ∇	--	0.9 ∇	10.22	9.32	9.42	9.22	0.5	--	0.6
Supraspinal skinfold (mm)	0.13	8.72	9.09	9.23	8.92	1.0 ∇	0.9 ∇	0.6	10.15	10.35	10.44	10.13	0.6	0.9 ∇	--
Midaxillary skinfold (mm)	0.15	7.68	8.78	8.80	8.47	2.8 ∇	0.9 ∇	2.0 ∇	8.38	8.88	8.95	8.66	1.3 ∇	0.8 ∇	0.7
Abdominal skinfold (mm)	0.3	11.83	11.28	11.51	11.11	1.0 ∇	0.7	1.3 ∇	12.97	12.47	12.57	12.18	0.9 ∇	0.7	1.4 ∇
Calf skinfold (mm)	0.18	10.87	11.06	12.06	11.56	--	1.2 ∇	1.6 ∇	11.32	11.60	12.59	12.09	0.7	1.3 ∇	1.8 ∇
Upperarm girth (cm)	0.03	31.08	32.33	32.78	33.58	7.2 ∇	4.5 ∇	14.3 ∇	30.30	32.33	32.00	32.80	7.2 ∇	4.6 ∇	14.4 ∇
Calf girth (cm)	0.03	36.09	36.50	36.60	36.95	2.3 ∇	2.0 ∇	4.9 ∇	34.98	35.43	35.53	35.88	2.6 ∇	2.0 ∇	5.2 ∇
Humerus breadth (cm)	0.001	7.32	7.68	7.78	7.98	11.6 ∇	6.3 ∇	21.1 ∇	7.22	7.63	7.73	7.93	13 ∇	6.4 ∇	22.5 ∇
Femur breadth (cm)	0.003	10.16	10.50	10.60	10.80	6.3 ∇	3.7 ∇	11.7 ∇	10.05	10.42	10.52	10.72	6.8 ∇	3.7 ∇	12.3 ∇
Fat percentage (%)	1.58	10.49	8.69	8.86	8.52	1.4 ∇	--	1.6 ∇	11.76	10.41	10.59	10.24	1.1 ∇	--	1.2 ∇
Endomorphy	0.672	2.65	2.40	2.40	2.35	--	--	--	3.10	2.73	2.74	2.69	--	--	0.5
Mesomorphy	0.01	5.59	6.13	6.15	6.91	5.4 ∇	7.6 ∇	13.2 ∇	5.48	6.12	6.15	6.93	6.4 ∇	7.8 ∇	14.5 ∇
Ectomorphy	0.008	2.28	2.20	2.24	2.20	0.9 ∇	/	0.8 ∇	2.62	2.56	2.58	2.52	0.7	0.7	1.2 ∇

Table 5.6(B): 16-year olds

INTRA-GROUP COMPARISONS WITHIN EACH EXPERIMENTAL AND CONTROL GROUP															
VARIABLES	MSE	16-YEAR OLD EXPERIMENTAL (n=30)							16-YEAR OLD CONTROL (n=30)						
		DESCRIPTIVE STATISTICS				EFFECT SIZE (d-value)			DESCRIPTIVE STATISTICS				EFFECT SIZE (d-value)		
		\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1- T3	d T4- T6	d T1- T6	\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1- T3	d T4- T6	d T1- T6
ANTHROPOMETRIC COMPONENTS															
Stature (cm)	0.09	176.94	178.18	179.01	179.52	4.1 [▼]	1.7 [▼]	8.6 [▼]	178.42	179.47	180.50	181.02	3.5 [▼]	1.7 [▼]	8.7 [▼]
Bodyweight (kg)	46	76.74	78.51	78.96	80.31	--	--	0.5	75.81	77.57	78.01	77.49	--	--	--
Triceps skinfold (mm)	0.18	9.28	8.87	8.95	8.55	1.0 [▼]	0.9 [▼]	1.7 [▼]	9.90	9.80	9.90	9.50	--	1.0 [▼]	1.0 [▼]
Subscapular skinfold (mm)	2.68	9.95	8.97	9.07	8.85	0.6	--	--	10.14	9.90	10.00	9.77	--	--	0.7
Supraspinal skinfold (mm)	0.13	7.98	6.90	7.20	6.90	3.0 [▼]	0.8 [▼]	3.0 [▼]	9.24	8.26	8.32	8.01	2.7 [▼]	0.9 [▼]	3.4 [▼]
Midaxillary skinfold (mm)	0.15	7.82	8.78	7.53	7.22	0.9 [▼]	0.8 [▼]	1.5 [▼]	8.34	8.88	8.08	7.78	0.7	0.8 [▼]	1.4 [▼]
Abdominal skinfold (mm)	0.3	12.67	12.17	12.27	11.90	0.9 [▼]	0.7	1.4 [▼]	12.08	11.58	11.68	11.26	0.9 [▼]	0.8 [▼]	1.5 [▼]
Calf skinfold (mm)	0.18	10.13	8.97	9.9	9.47	2.7 [▼]	1.2 [▼]	1.6 [▼]	9.97	9.37	10.37	9.87	1.4 [▼]	1.4 [▼]	--
Upperarm girth (cm)	0.03	32.70	33.95	34.40	35.20	7.2 [▼]	4.4 [▼]	14.2 [▼]	33.20	34.45	34.90	35.70	7.2 [▼]	4.5 [▼]	14.3 [▼]
Calf girth (cm)	0.03	37.66	38.11	38.21	38.56	2.6 [▼]	2.0 [▼]	5.2 [▼]	37.46	37.91	38.01	38.36	2.6 [▼]	2.0 [▼]	5.2 [▼]
Humerus breadth (cm)	0.001	7.52	7.92	8.02	8.22	12.6 [▼]	6.3 [▼]	21.1 [▼]	7.55	7.95	8.05	8.25	12.6 [▼]	6.3 [▼]	21.1 [▼]
Femur breadth (cm)	0.003	10.26	10.66	10.76	10.96	7.2 [▼]	3.7 [▼]	12.7 [▼]	10.42	10.82	10.92	11.12	7.2 [▼]	3.7 [▼]	12.7 [▼]
Fat percentage (%)	1.58	11.20	10.17	10.32	9.97	0.8 [▼]	--	1.0 [▼]	11.04	10.57	10.74	10.39	--	--	0.5
Endomorphy	0.672	2.59	2.26	2.30	2.22	--	--	0.5	2.78	2.58	2.59	2.55	--	--	--
Mesomorphy	0.01	5.81	6.51	6.63	7.31	7.1 [▼]	6.8 [▼]	15 [▼]	5.79	6.50	6.59	7.30	7.1 [▼]	7.1 [▼]	15.1 [▼]
Ectomorphy	0.008	2.04	1.94	2.01	2.00	1.0 [▼]	--	--	2.39	2.28	2.40	2.36	1.2 [▼]	0.5	--

MSE = Mean square error of ANOVA, a measurement of variance in data

$$d = \frac{|\bar{x}_i - \bar{x}_j|}{\sqrt{MSE}} = \text{effect size for difference between means; a measurement of practical significance}$$

▼ = Large practically significant *intra-group* difference between testing episodes

T1 = First testing episode of first season

T6 = Last testing episode of second season

T3 = Last testing episode of first season

\bar{X} = Mean value

T4 = First testing episode of second season

-- = Effect not of medium or large practical significance

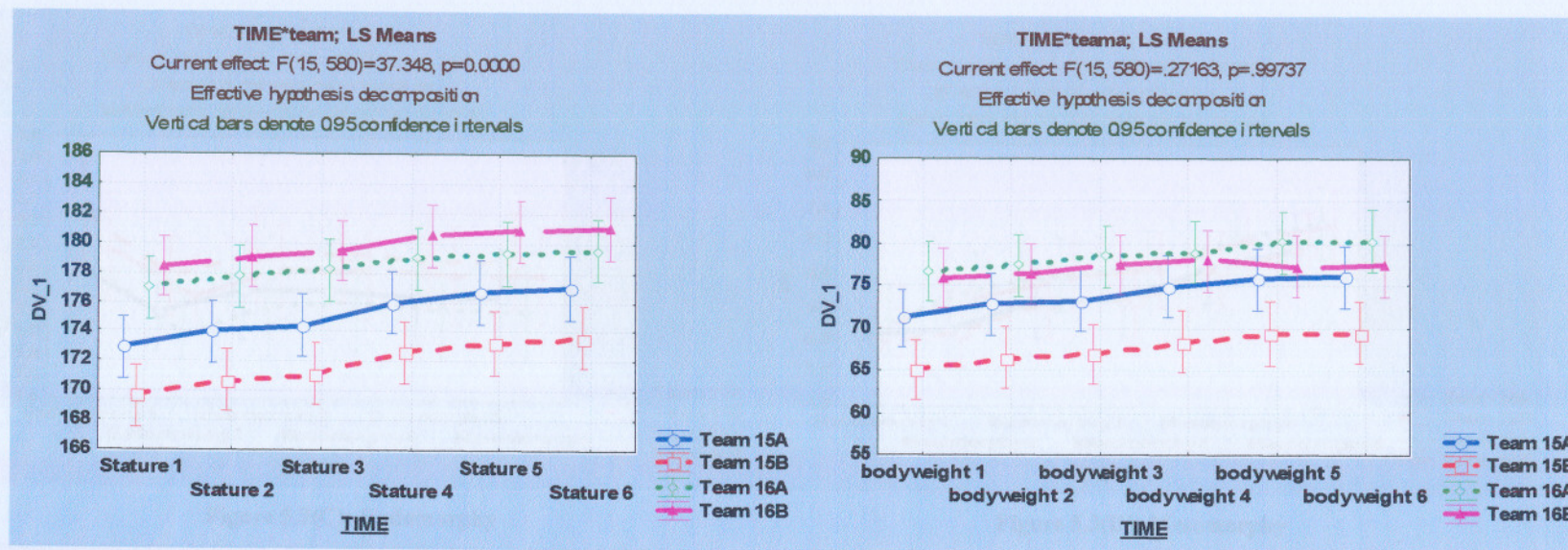


Figure 5.3(A): Stature

Figure 5.3(B): Body weight

Numbers 1 to 6 on the x-axis of graphs represent the six testing occasions (T1-T6)

Figure 5.3: Changes in the stature (A), body weight (B), endomorphy (C), mesomorphy (D), ectomorphy (E) and fat percentage (F) of each experimental and control group over time

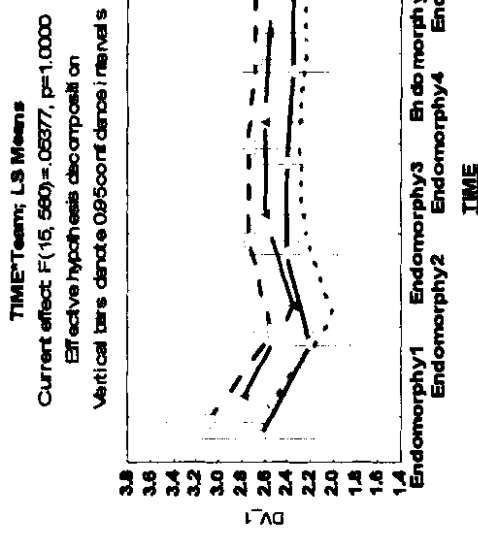


Figure 5.3(C): Endomorphy

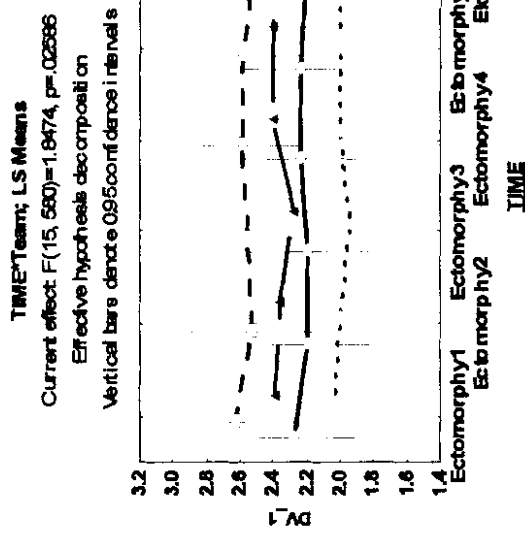


Figure 5.3(E): Ectomorphy

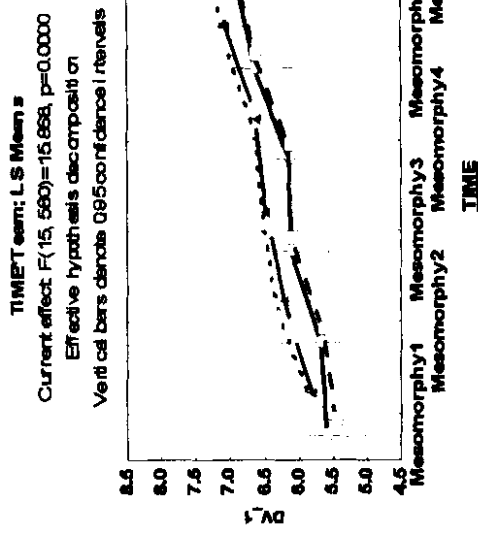


Figure 5.3(D): Mesomorphy

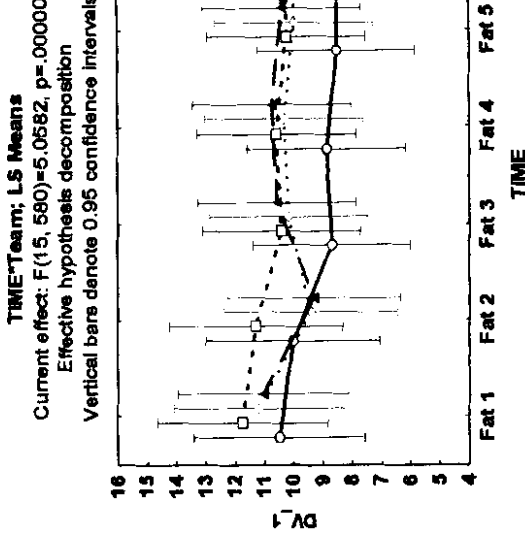


Figure 5.3(F): Fat percentage

In summary, the prevention programme was not specifically designed to change the anthropometric composition of subjects. The lack of contrasting trends between the anthropometric components of matching experimental and control groups confirms this. Most changes which did occur may be a result of the developmental changes in this age group. The natural increase in stature seen among the groups during the two years could render them less flexible, and more susceptible to injury (Micheli, 1983; Armstrong & McManus; 1996). A deterioration in fat percentage (Figure 5.3 (F)) is visible during the off-season (T3 to T4), signifying a possible slackening in physical activity levels during the off-season.

5.4.2 INTRA-GROUP COMPARISON OF PHYSICAL AND MOTOR RESULTS

Table 5.7 provides a summary of the physical and motor characteristics at four different physical assessments (T1, T3, T4, T6), in addition to the results of the intra-group comparison of each experimental and control groups' physical and motor data over time.

The *intra-group comparison* of physical and motor components (Table 5.7) reveals highly practically significant changes ($d \geq 0.8$) in the *vertical jump* (power) test over time (Figure 5.4(A)). As this occurred in both the experimental and control groups, this may be attributed to normal strength and power increases associated with advancing age in boys (Malina & Bouchard, 1991; Armstrong & McManus, 1996; Armstrong & Welsman, 1997), rather than the effect of the prevention programme. Similarly, the 7-stage abdominal *strength* test reveals that in practice, all the groups improved their abdominal strength highly significantly during the first season (T1-T3), second season (T4-T6), and total study period (T1-T6) (also see Figure 5.4(I)). Another strength test, the *grip strength* test, confirmed practically significant increases in the strength of all involved groups. The improvements in grip strength (left and right) were highly practically significant during the first season (T1-T3), and total study period (T1-T6) (Figure 5.4(J) shows the right grip strength). The results of the *pull-up* and *push-up* tests resembled the above-mentioned strength tests to a degree, with all experimental and control group improving significantly during the first season (T1-T3), second season (T4-T6) and total period (T1-T6) (Figures 5.4(G) and (H)).

These increases in strength, even among the groups not following the prevention programme, support results which reported increases in strength with advancing age in boys (Malina & Bouchard, 1991; Armstrong & McManus, 1996; Armstrong & Welsman, 1997). Lastly, it must be pointed out that, except for the grip strength (left and right), all groups involved in the study experienced strength and power loss during the off-season (area between T3 and T4 in the Figures), suggesting that the prevention programme could focus more on the retention of strength and power during the off-season phase.

For all the groups, the 10 m and 30 m tests for *speed* recorded strongly significant improvements when observing the first season (T1-T3), second season (T1-T6), and total period (T1-T6), correlating with recordings of strength and power, and confirming that the running speed of males improves more or less linearly from 5 to 17 years (Figure 5.4(B), and Figure 5.4(C)) (Malina & Bouchard, 1991). Yet again it is pointed out that, similar to strength and power, all groups involved in the study experienced speed loss during the off-season, suggesting that the prevention programme could focus more on the retention of running speed during the off-season phase.

The intra-group changes which occurred in the Illinois *agility* test, *speed endurance* test and bleep test for *aerobic endurance* replicated the highly significant trends which occurred in the speed tests, and also indicate that the prevention programme could focus additionally on the retention of agility, speed endurance and aerobic endurance during the off-season phase (Figures 5.4 (D)-(F)).

At the conclusion of the study (T6), the *10 m speed* of all the groups in this study was faster (15-year old experimental = 1.60 sec; 15-year old control = 1.64; 16-year old experimental = 1.59; 16-year old control = 1.61) than those in the studies of Van Gent (2003:139) (1.89 sec), and De la Port (2004:87) (1.90 sec). When looking at the *30 m speed*, the groups in this study were also faster than those in the studies of Hattingh (2003:91) (4.42 sec) and Van Gent (2003:139) (4.56 sec). All the players in the other studies were either of provincial or national calibre, and were therefore expected to be faster. However, they may have been tested earlier in the season.

Table 5.7: Descriptive statistics and effect sizes of physical and motor variables for intra-group comparisons between testing episodes in the 15-year olds (A) and 16-year olds (B)

Table 5.7(A): 15-year olds

INTRA-GROUP COMPARISONS WITHIN EACH EXPERIMENTAL AND CONTROL GROUP															
VARIABLES	MSE	15-YEAR OLD EXPERIMENTAL							15-YEAR OLD CONTROL						
		DESCRIPTIVE STATISTICS				EFFECT SIZE (d-value)			DESCRIPTIVE STATISTICS				EFFECT SIZE (d-value)		
		\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1- T3	d T4- T6	d T1- T6	\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1- T3	d T4- T6	d T1- T6
PHYSICAL AND MOTOR COMPONENTS															
Vertical jump (cm)	0.33	38.05	42.06	41.10	45.09	7.0 [▼]	6.9 [▼]	12.2 [▼]	36.53	40.69	39.41	43.08	7.2 [▼]	6.4 [▼]	11.4 [▼]
10 m Speed (sec)	0.002	1.99	1.80	1.90	1.60	4.2 [▼]	6.7 [▼]	8.6 [▼]	2.05	1.83	1.93	1.64	4.9 [▼]	6.4 [▼]	9.0 [▼]
30 m Speed (sec)	0.19	4.66	4.25	4.54	4.16	1.0 [▼]	0.9 [▼]	1.2 [▼]	4.78	4.37	4.67	4.24	0.9 [▼]	1.0 [▼]	1.3 [▼]
Illinois agility (sec)	0.30	15.99	14.36	15.17	13.87	3.0 [▼]	2.4 [▼]	3.9 [▼]	16.56	15.02	15.86	14.57	2.8 [▼]	2.4 [▼]	3.6 [▼]
Speed endurance (%)	0.0002	4.95	4.73	4.85	4.80	15.4 [▼]	3.3 [▼]	10.1 [▼]	5.13	4.92	5.04	4.99	15.4 [▼]	3.5 [▼]	10.4 [▼]
Bleep (level)	0.01	9.03	9.72	9.23	9.95	6.9 [▼]	7.2 [▼]	9.1 [▼]	8.93	9.68	9.19	9.88	7.5 [▼]	7.0 [▼]	9.5 [▼]
Pull-ups (n)	0.79	6.30	9.53	7.17	9.77	3.6 [▼]	2.9 [▼]	3.9 [▼]	6.87	10.17	7.70	10.90	3.7 [▼]	3.6 [▼]	4.5 [▼]
Push-ups (n)	5.5	34.33	38.70	36.20	42.07	1.9 [▼]	2.5 [▼]	3.3 [▼]	24.80	27.00	25.10	29.03	0.9 [▼]	1.7 [▼]	1.8 [▼]
7-stage abdominal strength test (n)	0.12	5.93	6.30	6.07	6.67	1.1 [▼]	1.7 [▼]	2.1 [▼]	5.53	6.33	5.67	6.53	2.3 [▼]	2.5 [▼]	2.9 [▼]
Grip strength left (kg)	2	48.17	52.18	54.33	54.23	2.8 [▼]	--	4.3 [▼]	44.52	48.63	50.67	50.53	2.9 [▼]	--	4.3 [▼]
Grip strength right (kg)	7	49.07	53.57	55.90	55.74	1.7 [▼]	--	2.5 [▼]	47.00	51.43	53.53	53.61	1.7 [▼]	--	2.5 [▼]

Table 5.7(B): 16-year olds

INTRA-GROUP COMPARISONS WITHIN EACH EXPERIMENTAL AND CONTROL GROUP															
VARIABLES	MSE	16-YEAR OLD EXPERIMENTAL							16-YEAR OLD CONTROL						
		DESCRIPTIVE STATISTICS				EFFECT SIZE (d-value)			DESCRIPTIVE STATISTICS				EFFECT SIZE (d-value)		
		\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1- T3	d T4- T6	d T1- T6	\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1- T3	d T4- T6	d T1- T6
PHYSICAL AND MOTOR COMPONENTS															
Vertical jump (cm)	0.33	37.77	41.73	40.41	44.18	6.9 [▼]	6.6 [▼]	11.2 [▼]	35.55	39.49	38.00	41.10	6.8 [▼]	6.4 [▼]	9.7 [▼]
10 m Speed (sec)	0.002	2.00	1.78	1.88	1.59	4.9 [▼]	6.5 [▼]	9.2 [▼]	2.01	1.79	1.89	1.61	4.9 [▼]	6.4 [▼]	9.0 [▼]
30 m Speed (sec)	0.19	4.58	4.17	4.46	4.04	0.9 [▼]	1.0 [▼]	1.3 [▼]	4.63	4.26	4.51	4.08	0.8 [▼]	1.0 [▼]	1.2 [▼]
Illinois agility (sec)	0.30	15.81	14.28	15.09	13.80	2.8 [▼]	2.4 [▼]	3.7 [▼]	16.23	14.28	15.63	14.42	2.6 [▼]	2.2 [▼]	3.3 [▼]
Speed endurance (%)	0.0002	4.99	4.77	4.8	4.85	15.4 [▼]	3.0 [▼]	10.0 [▼]	4.86	4.64	4.76	4.72	15.4 [▼]	2.8 [▼]	9.7 [▼]
Bleep (level)	0.01	9.80	10.66	10.15	10.93	8.6 [▼]	7.8 [▼]	11.3 [▼]	9.40	10.26	9.76	10.46	8.6 [▼]	7.0 [▼]	10.6 [▼]
Pull-ups (n)	0.79	8.57	12.63	9.47	12.27	4.6 [▼]	3.2 [▼]	4.2 [▼]	6.97	10.27	7.97	10.37	3.7 [▼]	2.7 [▼]	3.8 [▼]
Push-ups (n)	5.5	37.47	42.47	40.16	46.37	2.1 [▼]	2.6 [▼]	3.8 [▼]	33.50	37.07	34.50	39.87	1.5 [▼]	2.3 [▼]	2.7 [▼]
7-stage abdominal strength test (n)	0.12	6.33	6.60	6.37	6.77	0.8 [▼]	1.2 [▼]	1.3 [▼]	6.23	6.83	6.27	6.87	1.7 [▼]	1.7 [▼]	1.8 [▼]
Grip strength left (kg)	2	56.25	61.47	63.80	63.55	3.7 [▼]	--	5.2 [▼]	52.65	57.57	59.92	59.40	3.5 [▼]	--	4.8 [▼]
Grip strength right (kg)	7	59.47	64.97	67.38	67.07	2.1 [▼]	--	2.9 [▼]	56.10	61.32	63.50	63.27	2.0 [▼]	--	2.7 [▼]

MSE = Mean square error of ANOVA, a measurement of variance in data

$$d = \frac{|\bar{x}_i - \bar{x}_j|}{\sqrt{MSE}} = \text{effect size for difference between means; a measurement of practical significance}$$

-- = Effect not of medium or large practical significance

▼ = Large practically significant *intra-group* difference between testing episodes

Considering the *power* component (vertical jump) at T6, the groups in this study (between 41.10 cm and 45.09 cm) were outperformed by those in the study of Hattingh (2003:91) (46.46 cm), but not by those in the study of Van Gent (2003:139) (40.55 cm). On the other hand, the mean *abdominal strength* was stronger (between level 6.53 and 6.87) when compared to the study of Hattingh (2003:91) (level 4.72), and Van Gent (2003:139) (level 4.10). The number of *pull-ups* (between 9.77 and 10.9 for 15-year olds) was similar to those achieved by the 15-year olds in the Hattingh (2003:91) (10.48) study, while the number of *push-ups* (between 39.87 and 46.37) of all the groups – except for the 15-year old control group (29.03) – beat those in an earlier study (Hanekom, 2000). At T6 the players in the present study were more *agile* than those in the study of Hattingh (2003:91) (18.98 sec), Van Gent (2003:139) (18.01 sec) and De la Port (2004:87) (15.07 sec).

Values recorded for the *bleep test* at T6 indicate that the players in this study (level 9.88 to 10.93) have an *aerobic endurance* superior to those in the Hattingh (2003:91) study (level 9.23), while the *speed endurance* test points out that the speed endurance of these players is also better than that recorded in earlier studies (Hare, 1999; Hattingh, 2003; Van Gent, 2003).

In conclusion, intra-group comparisons calculated for each 15- and 16-year old experimental and control group established highly practically significant differences for the strength, running speed, agility, speed endurance and aerobic endurance tests of all groups. In general the improvements in these areas were as expected of schoolboys of this age. The significant increases in speed seen among all the groups increase their momentum when running (momentum = product of mass and velocity). Consequently, when these players collide, it will be with increased force, and their risk of extrinsic injury will increase (Noakes & Du Plessis, 1996). As similar trends occurred in the physical and motor variables of all experimental and control groups, the improvements in the experimental groups cannot be attributed to the effect of the prevention programme. Therefore, intra-comparisons – comparing changes in the experimental to those in the corresponding control group – are necessary (see heading 5.5, Table 5.10). Lastly, future prevention programmes should give more attention to the retention of physical and motor abilities during the off-season, while allowing for adequate rest and recovery.

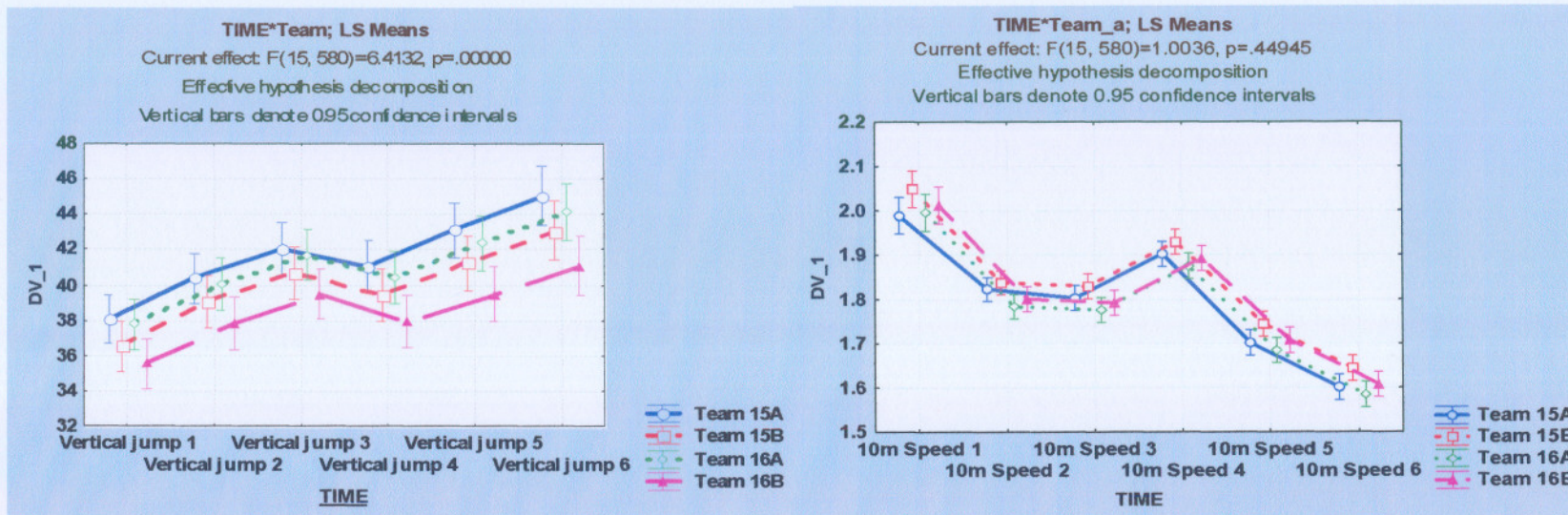


Figure 5.4(A): Vertical jump

Figure 5.4(B): 10 m speed

Numbers 1 to 6 on the x-axis of graphs represent the six testing occasions (T1-T6)

Figure 5.4: Changes in the vertical jump (A), 10 m speed (B), 30 m speed (C), Illinois agility (D), speed endurance (E), bleep test (F), pull-ups (G), push-ups (H), 7-stage abdominal strength (I) and right grip strength (J) of each experimental and control group over time

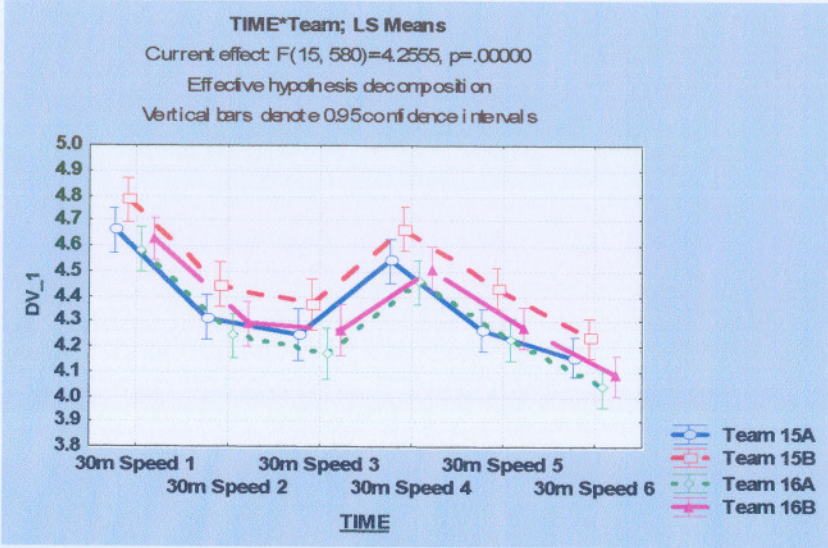


Figure 5.4(C): 30 m speed

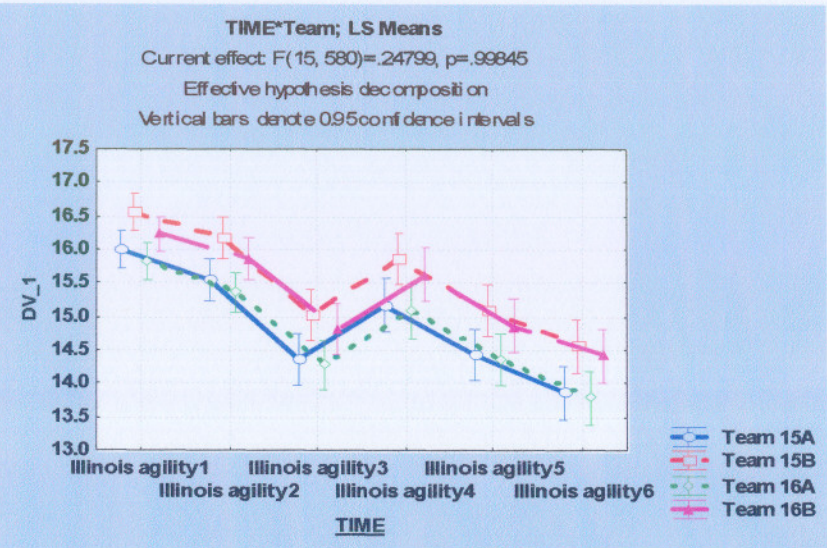


Figure 5.4(D): Illinois agility

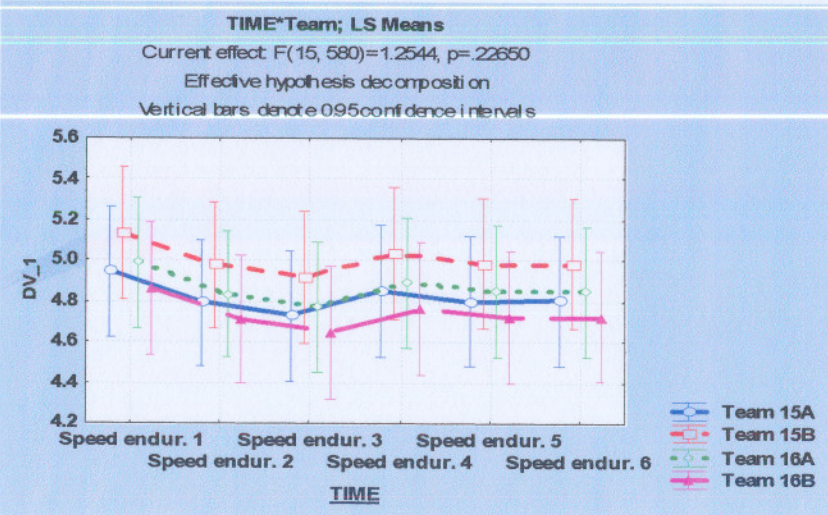


Figure 5.4(E): Speed endurance

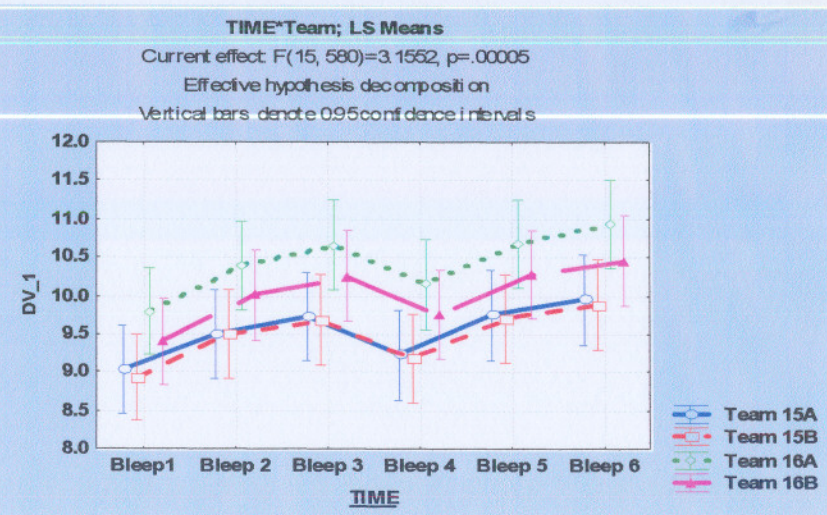


Figure 5.4(F): Bleep

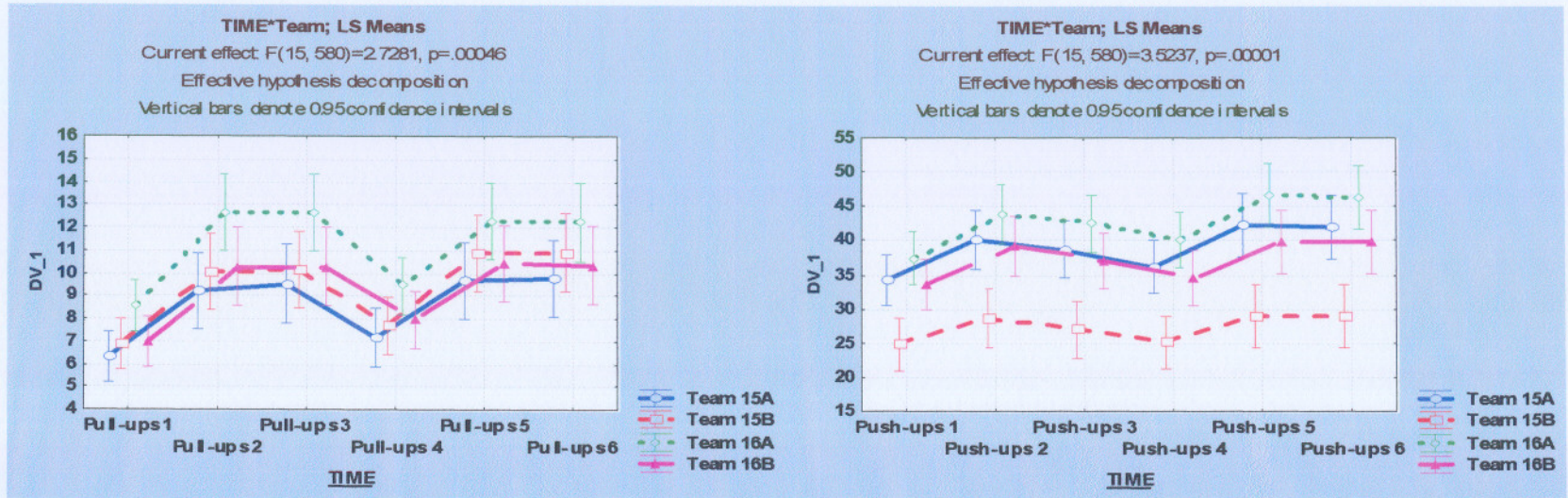


Figure 5.4(G): Pull-ups

Figure 5.4(H): Push-ups

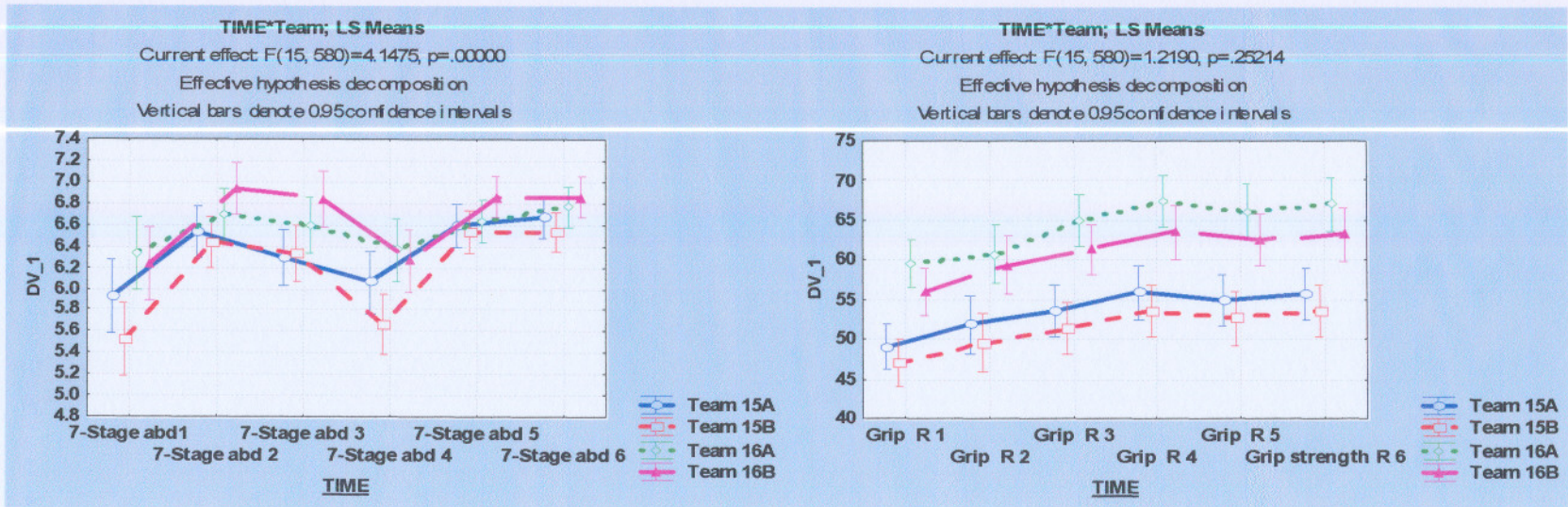


Figure 5.4(I): 7-stage abdominal strength

Figure 5.4(J): Right grip strength

5.4.3 INTRA-GROUP COMPARISON OF BIOMECHANICAL AND POSTURAL RESULTS

In Table 5.8, descriptive data is presented for the biomechanical and postural assessments at the beginning and end of each year (T1, T3, T4, T6). Data were collected under five main categories, namely lower limb, pelvic girdle, spinal region, upper limb and neurodynamics. Little research exists on the subject of biomechanics and posture in rugby. Pioneering research regarding the topic of biomechanics and posture in rugby has been done by Hattingh (2003) on adolescents. Therefore, this comparison will primarily refer to the study of Hattingh (2003). Before discussing the changes that occurred within each group, the biomechanical and postural status of the groups at the commencement of the study must be mentioned. This status will assist in outlining the weaknesses of the groups at the start of the study, thereby identifying areas which require the most improvement.

When analysing the first aspect of the *lower limb region*, namely lower limb dynamic mobility, it becomes apparent that among all the groups the modified Thomas (ITB, Quadriceps, and Iliopsoas mobility), gluteus maximus and hip external rotation tests recorded higher mean values just before the implementation of the prevention programme (T1), rendering these areas less mobile and dynamically loaded. This verified the research of Hattingh (2003:92). Furthermore, for all the groups, the second aspect of the lower limb (positional alignment of knee complex) evaluation reveals a high mean value for the patella tilt test. Although this finding concurs with the previous work of Hattingh (2003:92), the other tests in this area recorded values closer to the ideal (ideal = value of 1; non-ideal = value of 2), rendering these areas in a better positional status than those of the Hattingh (2003:92) study. Lastly, at the first assessment, data for the last lower limb aspect (foot and ankle region) show that the positional status in all groups was closer to the ideal (Hunt, 1990; McPoil & Brocato, 1990). However, the values recorded for the toe position of the groups indicate that this area was loaded.

In the *pelvic girdle region*, the mean values reveal that except for the bilateral pelvic position, all groups were more symmetric and stable than those in the study of Hattingh

(2003:93). As in the study by Hattingh (2003:93), the bilateral position of the pelvis was closer to non-ideal (value of 2), rendering this area susceptible to increased mechanical stress.

In the *spinal region*, the tests for dynamic mobility reveal low mean values (closer to ideal) (Kapandji, 1974) at T1, signifying that, at the start of the study, all the groups were more flexible in these areas than those of Hattingh (2003:93). Except for the lumbar position, the spinal tests for postural position at T1 show low mean values in the coronal axis, confirming the non-ideal bilateral pelvic position of all groups in this study. In the sagittal axis the thoracic area was measured as closer to non-ideal for both the 15-year old groups at T1. This is similar to earlier research and is mainly due to quadratic dominance (Hattingh, 2003).

In the category of the *upper limb*, the higher mean values of the shoulder and winging positional tests indicate poor regional positional stability in all experimental and control groups (Halbach & Tank, 1990). This correlates with earlier research and is a result of the developmental phase of the adolescent player (Hattingh, 2003).

Lastly, the *neurodynamic* category at T1 indicated high mean values (closer to non-ideal) for the straight leg raise test of the 15-year olds, confirming previous findings on 15-year old rugby players (Hattingh, 2003), and correlating with the rapid growth phase normally found in this age group (Butler, 1991). Furthermore, in the 16-year old control group, a mean value closer to non-ideal ($\bar{x} = 1.53$ left and right) was measured for the L3,4 prone knee bend test, indicating immobility in this area.

Now that the biomechanical and postural status at T1 has been described, attention will be paid to the changes in this status as they occurred over time within each experimental and control group. The d-values (effect sizes) in Table 5.8 represent the practical significance of intra-group changes in the biomechanical and postural status of each experimental and control group. Only highly practically significant ($d \geq 0.8$) and moderately practically significant ($d \geq 0.5$; medium effect) differences between testing episodes are shown in the table (Ellis & Steyn, 2003). Highly practically significant changes are printed in red.

Table 5.8: Descriptive statistics and intra-group comparisons of biomechanical and postural data of each experimental and control group, showing practically significant differences between testing episodes

INTRA-GROUP COMPARISONS WITHIN EACH EXPERIMENTAL AND CONTROL GROUP																													
Biomechanical and postural variables	MSE	15-year old experimental group (n=30)				15-year old control group (n=30)				16-year old experimental group (n=30)				16-year old control group (n=30)															
		Descriptive statistics				Effect sizes (d-values)			Descriptive statistics				Effect sizes (d-values)			Descriptive statistics				Effect sizes (d-values)									
		\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1- T3	d T4- T6	d T1- T6	\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1- T3	d T4- T6	d T1- T6	\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1- T3	d T4- T6	d T1- T6	\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1- T3	d T4- T6	d T1- T6
LOWER LIMB																													
<i>Lower limb dynamic mobility</i>																													
TA L	0.41	1.37	1.03	1.23	1.03	0.5	--	0.5	1.43	1.50	1.50	1.50	--	--	--	1.33	1.07	1.10	1.03	--	--	0.5	1.50	1.57	1.57	1.60	--	--	--
TA R	0.06	1.37	1.03	1.23	1.07	1.4	0.7	1.2	1.43	1.53	1.53	1.53	--	--	--	1.33	1.07	1.10	1.03	1.1	--	1.2	1.50	1.57	1.60	1.60	--	--	--
ITB L	0.05	1.47	1.00	1.27	1.03	2.1	1.0	1.9	1.53	1.63	1.67	1.67	--	--	--	1.53	1.17	1.27	1.07	1.6	0.9	2.1	1.67	1.70	1.73	1.73	--	--	--
ITB R	0.06	1.67	1.03	1.43	1.13	2.6	1.2	2.2	1.77	1.80	1.80	1.83	--	--	--	1.87	1.20	1.30	1.13	2.7	0.7	3.0	1.87	1.87	1.87	1.87	--	--	--
Quadriceps L	0.06	1.30	1.00	1.17	1.00	1.2	0.7	1.2	1.53	1.63	1.67	1.67	--	--	0.5	1.33	1.07	1.20	1.00	1.1	0.8	1.4	1.33	1.53	1.53	1.57	0.8	--	1.0
Quadriceps R	0.05	1.33	1.00	1.13	1.03	1.5	--	1.3	1.57	1.67	1.70	1.70	--	--	0.6	1.60	1.17	1.30	1.07	1.9	--	2.4	1.50	1.57	1.57	1.57	--	--	--
Iliopsoas L	0.06	1.50	1.07	1.33	1.10	1.8	0.7	1.6	1.50	1.57	1.57	1.57	--	--	--	1.73	1.20	1.23	1.07	2.2	0.7	2.7	1.70	1.73	1.73	1.80	--	--	--
Iliopsoas R	0.06	1.57	1.10	1.43	1.17	1.9	0.7	1.6	1.53	1.60	1.60	1.63	--	--	--	1.87	1.23	1.27	1.10	2.6	0.7	3.1	1.73	1.77	1.77	1.80	--	--	--
Gluteus maximus L	0.05	1.40	1.03	1.17	1.03	1.6	0.6	1.6	1.60	1.67	1.70	1.70	--	--	--	1.37	1.03	1.17	1.07	1.5	0.6	1.3	1.40	1.50	1.50	1.57	--	--	0.7
Gluteus maximus R	0.05	1.43	1.03	1.17	1.03	1.8	0.6	1.8	1.63	1.73	1.73	1.77	--	--	0.6	1.37	1.07	1.17	1.07	1.3	0.6	1.3	1.47	1.50	1.50	1.53	--	--	--
Adductor	0.01	1.03	1.00	1.03	1.00	--	--	--	1.00	1.07	1.07	1.07	0.7	--	0.7	1.07	1.07	1.07	1.07	--	--	--	1.10	1.13	1.13	1.13	--	--	--
Hip internal rotation L	/	1.00	1.00	1.00	1.00	--	--	--	1.00	1.00	1.00	1.00	--	--	--	1.03	1.03	1.03	1.03	--	--	--	1.00	1.00	1.00	1.00	--	--	--
Hip internal rotation R	/	1.00	1.00	1.00	1.00	--	--	--	1.00	1.00	1.00	1.00	--	--	--	1.03	1.03	1.03	1.03	--	--	--	1.00	1.00	1.00	1.00	--	--	--

Table 5.8 continues

Biomechanical and postural variables	MSE	15-year old experimental group (n=30)						15-year old control group (n=30)						16-year old experimental group (n=30)						16-year old control group (n=30)									
		Descriptive statistics				Effect sizes (d-values)			Descriptive statistics				Effect sizes (d-values)			Descriptive statistics				Effect sizes (d-values)			Descriptive statistics				Effect sizes (d-values)		
		\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1-T3	d T4-T6	d T1-T6	\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1-T3	d T4-T6	d T1-T6	\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1-T3	d T4-T6	d T1-T6	\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1-T3	d T4-T6	d T1-T6
Hip external rotation L	0.05	1.47	1.30	1.30	1.10	0.7	0.9	1.6	1.77	1.77	1.77	1.80	--	--	--	1.37	1.13	1.17	1.07	1.0	--	1.3	1.53	1.57	1.57	1.60	--	--	--
Hip external rotation R	0.04	1.47	1.33	1.30	1.10	0.7	1.0	1.8	1.77	1.77	1.80	1.80	--	--	--	1.37	1.13	1.17	1.07	1.2	0.5	1.3	1.53	1.57	1.57	1.60	--	--	--
<i>Lower limb positional alignment</i>																													
<i>Knee complex</i>																													
Q-angle L	/	1.10	1.10	1.10	1.10	--	--	--	1.07	1.07	1.07	1.07	--	--	--	1.13	1.13	1.13	1.13	--	--	--	1.27	1.27	1.27	1.27	--	--	--
Q-angle R	/	1.10	1.10	1.10	1.10	--	--	--	1.07	1.07	1.07	1.07	--	--	--	1.13	1.13	1.13	1.13	--	--	--	1.27	1.27	1.27	1.27	--	--	--
Patella squint L	/	1.10	1.10	1.10	1.10	--	--	--	1.13	1.13	1.13	1.13	--	--	--	1.13	1.13	1.13	1.13	--	--	--	1.27	1.27	1.27	1.27	--	--	--
Patella squint R	/	1.10	1.10	1.10	1.10	--	--	--	1.13	1.13	1.13	1.13	--	--	--	1.13	1.13	1.13	1.13	--	--	--	1.27	1.27	1.27	1.27	--	--	--
Patella tilt L	/	1.33	1.33	1.33	1.33	--	--	--	1.50	1.50	1.50	1.50	--	--	--	1.47	1.47	1.47	1.47	--	--	--	1.63	1.63	1.63	1.63	--	--	--
Patella tilt R	/	1.30	1.30	1.30	1.30	--	--	--	1.50	1.50	1.50	1.50	--	--	--	1.47	1.47	1.47	1.47	--	--	--	1.63	1.63	1.63	1.63	--	--	--
VMO-L comparison L	0.01	1.07	1.03	1.07	1.07	--	--	--	1.17	1.13	1.13	1.10	--	--	0.7	1.03	1.00	1.00	1.00	--	--	--	1.13	1.10	1.10	1.07	--	--	0.6
VMO-L comparison R	0.01	1.07	1.03	1.07	1.07	--	--	--	1.17	1.13	1.13	1.07	--	0.6	1.0	1.03	1.00	1.00	1.00	--	--	--	1.13	1.10	1.10	1.07	--	--	0.6
<i>Foot and Ankle region</i>																													
Longitudinal arch status L	/	1.73	1.73	1.73	1.73	--	--	--	1.80	1.80	1.80	1.80	--	--	--	1.47	1.47	1.47	1.47	--	--	--	1.63	1.63	1.63	1.63	--	--	--
Longitudinal arch status R	/	1.73	1.73	1.73	1.73	--	--	--	1.80	1.80	1.80	1.80	--	--	--	1.47	1.47	1.47	1.47	--	--	--	1.63	1.63	1.63	1.63	--	--	--
Forefoot positional L	/	1.13	1.13	1.13	1.13	--	--	--	1.20	1.20	1.20	1.20	--	--	--	1.30	1.30	1.30	1.30	--	--	--	1.33	1.33	1.33	1.33	--	--	--
Forefoot positional R	/	1.13	1.13	1.13	1.13	--	--	--	1.20	1.20	1.20	1.20	--	--	--	1.30	1.30	1.30	1.30	--	--	--	1.33	1.33	1.33	1.33	--	--	--
Rear foot standing L	/	1.80	1.80	1.80	1.80	--	--	--	1.93	1.93	1.93	1.93	--	--	--	1.70	1.70	1.70	1.70	--	--	--	1.87	1.87	1.87	1.87	--	--	--

Table 5.8 continues

Biomechanical and postural variables	MSE	15-year old experimental group (n=30)						15-year old control group (n=30)						16-year old experimental group (n=30)						16-year old control group (n=30)									
		Descriptive statistics				Effect sizes (d-values)			Descriptive statistics				Effect sizes (d-values)			Descriptive statistics				Effect sizes (d-values)			Descriptive statistics				Effect sizes (d-values)		
		\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1-T3	d T4-T6	d T1-T6	\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1-T3	d T4-T6	d T1-T6	\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1-T3	d T4-T6	d T1-T6	\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1-T3	d T4-T6	d T1-T6
Rear foot standing R	/	1.80	1.80	1.80	1.80	--	--	--	1.93	1.93	1.93	1.93	--	--	--	1.70	1.70	1.70	1.70	--	--	--	1.87	1.87	1.87	1.87	--	--	--
Rear foot lying L	/	1.80	1.80	1.80	1.80	--	--	--	1.93	1.93	1.93	1.93	--	--	--	1.70	1.70	1.70	1.70	--	--	--	1.87	1.87	1.87	1.87	--	--	--
Rear foot lying R	/	1.80	1.80	1.80	1.80	--	--	--	1.93	1.93	1.93	1.93	--	--	--	1.70	1.70	1.70	1.70	--	--	--	1.87	1.87	1.87	1.87	--	--	--
Transverse arch area comparison L	/	1.33	1.33	1.33	1.33	--	--	--	1.27	1.27	1.27	1.27	--	--	--	1.30	1.30	1.30	1.30	--	--	--	1.40	1.40	1.40	1.40	--	--	--
Transverse arch area comparison R	/	1.33	1.33	1.33	1.33	--	--	--	1.27	1.27	1.27	1.27	--	--	--	1.30	1.30	1.30	1.30	--	--	--	1.40	1.40	1.40	1.40	--	--	--
Foot mobility L	/	1.67	1.67	1.67	1.67	--	--	--	1.63	1.63	1.63	1.63	--	--	--	1.63	1.63	1.63	1.63	--	--	--	1.67	1.67	1.67	1.67	--	--	--
Foot mobility R	/	1.67	1.67	1.67	1.67	--	--	--	1.63	1.63	1.63	1.63	--	--	--	1.63	1.63	1.63	1.63	--	--	--	1.67	1.67	1.67	1.67	--	--	--
Toe position L	/	1.77	1.77	1.77	1.77	--	--	--	1.87	1.87	1.87	1.87	--	--	--	1.87	1.87	1.87	1.87	--	--	--	1.90	1.90	1.90	1.90	--	--	--
Toe position R	/	1.77	1.77	1.77	1.77	--	--	--	1.87	1.87	1.87	1.87	--	--	--	1.87	1.87	1.87	1.87	--	--	--	1.90	1.90	1.90	1.90	--	--	--
PELVIC GIRDLE REGION																													
Leg length discrepancy	0.05	1.47	1.20	1.20	1.13	1.2	--	1.5	1.27	1.33	1.33	1.37	--	--	--	1.47	1.13	1.17	1.10	1.5	--	1.6	1.27	1.30	1.30	1.30	--	--	--
ASIS	0.05	1.43	1.17	1.17	1.10	1.2	--	1.5	1.43	1.30	1.30	1.33	--	--	--	1.47	1.17	1.20	1.10	1.3	--	1.6	1.27	1.30	1.30	1.30	--	--	--
PSIS	0.05	1.43	1.17	1.17	1.10	1.2	--	1.5	1.43	1.30	1.30	1.33	--	--	--	1.47	1.17	1.20	1.10	1.3	--	1.6	1.27	1.30	1.30	1.30	--	--	--
Pelvic rami position	0.05	1.43	1.17	1.17	1.10	1.2	--	1.5	1.43	1.30	1.30	1.33	--	--	--	1.47	1.17	1.20	1.10	1.3	--	1.6	1.27	1.30	1.30	1.30	--	--	--
Sacroiliac cleft	/	1.00	1.00	1.00	1.00	--	--	--	1.00	1.00	1.00	1.00	--	--	--	1.00	1.00	1.00	1.00	/	--	/	1.00	1.00	1.00	1.00	--	--	--
Bilateral pelvic position	0.06	1.87	1.43	1.60	1.23	1.8	1.5	2.6	1.90	1.90	1.90	1.90	--	--	--	1.87	1.23	1.27	1.10	2.6	0.7	3.1	1.77	1.77	1.77	1.80	--	--	--

Table 5.8 continues

Biomechanical and postural variables	MSE	15-year old experimental group (n=30)				15-year old control group (n=30)				16-year old experimental group (n=30)				16-year old control group (n=30)															
		Descriptive statistics				Effect sizes (d-values)			Descriptive statistics				Effect sizes (d-values)			Descriptive statistics				Effect sizes (d-values)									
		\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1-T3	d T4-T6	d T1-T6	\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1-T3	d T4-T6	d T1-T6	\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1-T3	d T4-T6	d T1-T6	\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1-T3	d T4-T6	d T1-T6
SPINAL REGION																													
<i>Spinal dynamic mobility</i>																													
TLF L	0.04	1.43	1.07	1.17	1.13	0.5	--	1.5	1.47	1.43	1.45	1.43	--	--	--	1.40	1.20	1.23	1.10	1.0	0.7	1.5	1.27	1.27	1.27	1.27	--	--	--
TLF R	0.04	1.43	1.07	1.17	1.13	0.5	--	1.5	1.43	1.43	1.43	1.43	--	--	--	1.40	1.20	1.23	1.10	1.0	0.7	1.5	1.27	1.27	1.27	1.27	--	--	--
Sacral rhythm L	/	1.00	1.00	1.00	1.00	--	--	--	1.00	1.00	1.00	1.00	--	--	--	1.00	1.00	1.00	1.00	--	--	--	1.00	1.00	1.00	1.00	--	--	--
Sacral rhythm R	/	1.00	1.00	1.00	1.00	--	--	--	1.00	1.00	1.00	1.00	--	--	--	1.00	1.00	1.00	1.00	--	--	--	1.00	1.00	1.00	1.00	--	--	--
Functional extension	0.01	1.07	1.00	1.03	1.00	0.7	--	0.7	1.07	1.07	1.07	1.07	--	--	--	1.10	1.07	1.07	1.03	--	--	0.7	1.07	1.03	1.03	1.03	--	--	--
Functional flexion	0.03	1.27	1.07	1.13	1.07	1.2	--	1.2	1.37	1.40	1.37	1.37	--	--	--	1.20	1.10	1.23	1.07	0.6	--	1.2	1.23	1.23	1.23	1.23	--	--	--
Rotation L	0.01	1.07	1.00	1.07	1.00	0.7	--	0.7	1.03	1.03	1.03	1.03	--	--	--	1.10	1.03	1.03	1.03	0.7	--	0.7	1.07	1.07	1.07	1.07	--	--	--
Rotation R	0.006	1.07	1.00	1.07	1.00	0.9	0.9	0.9	1.03	1.03	1.03	1.03	--	--	--	1.10	1.07	1.07	1.07	--	--	--	1.07	1.07	1.07	1.07	--	--	--
Side flexion L	0.007	1.07	1.03	1.07	1.00	0.5	0.8	0.8	1.03	1.03	1.03	1.00	--	--	--	1.10	1.03	1.03	1.03	0.8	--	0.8	1.13	1.13	1.13	1.13	--	--	--
Side flexion R	0.007	1.07	1.03	1.07	1.00	0.5	0.8	0.8	1.03	1.03	1.03	1.00	--	--	--	1.10	1.03	1.03	1.03	0.8	--	0.8	1.13	1.13	1.13	1.13	--	--	--
<i>Spinal positional alignment</i>																													
<i>Coronal axis</i>																													
Head position	0.004	1.03	1.03	1.03	1.03	--	--	--	1.07	1.07	1.07	1.10	--	0.5	0.5	1.00	1.00	1.00	1.00	--	--	--	1.00	1.00	1.00	1.07	--	1.1	1.1
Cervical position	/	1.00	1.00	1.00	1.00	--	--	--	1.00	1.00	1.00	1.00	--	--	--	1.00	1.00	1.00	1.00	--	--	--	1.00	1.00	1.00	1.00	--	--	--
Thoracic position	0.03	1.33	1.13	1.27	1.23	1.2	--	0.6	1.20	1.20	1.20	1.23	--	--	--	1.23	1.13	1.13	1.13	0.6	--	0.6	1.27	1.27	1.27	1.30	--	--	--
Lumbar position	0.08	1.83	1.50	1.67	1.23	1.2	1.5	2.1	1.83	1.80	1.80	1.80	--	--	--	1.87	1.23	1.27	1.03	2.2	0.8	2.9	1.80	1.80	1.80	1.83	--	--	--
<i>Sagittal axis</i>																													
Head position	/	1.00	1.00	1.00	1.00	--	--	--	1.00	1.00	1.00	1.00	--	--	--	1.00	1.00	1.00	1.00	--	--	--	1.00	1.00	1.00	1.00	--	--	--
Cervical position	/	1.00	1.00	1.00	1.00	--	--	--	1.00	1.00	1.00	1.00	--	--	--	1.00	1.00	1.00	1.00	--	--	--	1.00	1.00	1.00	1.00	--	--	--

Table 5.8 continues

Biomechanical and postural variables	MSE	15-year old experimental group (n=30)						15-year old control group (n=30)						16-year old experimental group (n=30)						16-year old control group (n=30)									
		Descriptive statistics				Effect sizes (d-values)			Descriptive statistics				Effect sizes (d-values)			Descriptive statistics				Effect sizes (d-values)			Descriptive statistics				Effect sizes (d-values)		
		\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1-T3	d T4-T6	d T1-T6	\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1-T3	d T4-T6	d T1-T6	\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1-T3	d T4-T6	d T1-T6	\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1-T3	d T4-T6	d T1-T6
Thoracic position	/	1.50	1.50	1.50	1.50	--	--	--	1.53	1.53	1.53	1.53	--	--	--	1.37	1.37	1.37	1.37	--	--	--	1.47	1.47	1.47	1.47	--	--	--
Lumbar position	/	1.10	1.10	1.10	1.10	--	--	--	1.07	1.07	1.07	1.07	--	--	--	1.00	1.00	1.00	1.00	--	--	--	1.00	1.00	1.00	1.00	--	--	--
UPPER LIMB																													
Hand behind back ROM L	0.02	1.13	1.03	1.03	1.03	0.7	--	0.7	1.03	1.03	1.03	1.03	--	--	--	1.23	1.10	1.10	1.03	0.9	0.5	1.4	1.30	1.30	1.30	1.30	--	--	--
Hand behind back ROM R	0.02	1.13	1.03	1.03	1.07	0.7	--	0.5	1.03	1.03	1.03	1.03	--	--	--	1.27	1.10	1.10	1.03	1.2	0.5	1.6	1.30	1.30	1.30	1.30	--	--	--
Hand behind neck ROM L	0.001	1.00	1.00	1.00	1.00	--	--	--	1.00	1.00	1.00	1.00	--	--	--	1.03	1.00	1.00	1.00	0.9	--	0.9	1.10	1.10	1.10	1.10	--	--	--
Hand behind neck ROM R	0.001	1.00	1.00	1.00	1.00	--	--	--	1.00	1.00	1.00	1.00	--	--	--	1.03	1.00	1.00	1.00	0.9	--	0.9	1.10	1.10	1.10	1.10	--	--	--
Shoulder positional test L	0.05	1.63	1.50	1.47	1.27	0.6	0.9	1.6	1.67	1.67	1.63	1.70	--	--	--	1.60	1.43	1.43	1.33	0.7	0.6	1.2	1.70	1.70	1.67	1.67	--	--	--
Shoulder positional test R	0.05	1.63	1.50	1.47	1.27	0.6	0.9	1.6	1.67	1.67	1.63	1.70	--	--	--	1.60	1.43	1.43	1.30	0.7	0.6	1.2	1.70	1.70	1.67	1.67	--	--	--
Winging positional test L	0.04	1.63	1.63	1.53	1.43	--	0.5	1.0	1.73	1.73	1.70	1.67	--	--	--	1.60	1.43	1.43	1.27	0.8	0.8	1.7	1.83	1.83	1.80	1.77	--	--	--
Winging positional test R	0.04	1.63	1.63	1.53	1.37	--	0.8	1.3	1.73	1.73	1.70	1.70	--	--	--	1.60	1.43	1.43	1.30	0.8	0.7	1.5	1.83	1.83	1.80	1.77	--	--	--
Shoulder outline composition L	0.04	1.37	1.07	1.20	1.00	1.5	1.0	1.8	1.37	1.37	1.33	1.27	--	--	0.5	1.30	1.10	1.07	1.03	1.0	--	1.3	1.40	1.37	1.37	1.30	--	--	0.5
Shoulder outline composition R	0.04	1.37	1.07	1.20	1.00	1.5	1.0	1.8	1.37	1.37	1.33	1.27	--	--	0.5	1.30	1.10	1.07	1.03	1.0	--	1.3	1.40	1.37	1.37	1.30	--	--	0.5
Throwing position L	0.008	1.07	1.07	1.10	1.10	--	--	--	1.13	1.13	1.13	1.13	--	--	--	1.10	1.03	1.03	1.03	0.8	--	0.8	1.00	1.00	1.00	1.00	--	--	--
Throwing position R	0.008	1.07	1.07	1.10	1.10	--	--	--	1.13	1.13	1.13	1.13	--	--	--	1.10	1.03	1.03	1.03	0.8	--	0.8	1.00	1.00	1.00	1.00	--	--	--

Table 5.8 continues

Biomechanical and postural variables	MSE	15-year old experimental group (n=30)						15-year old control group (n=30)						16-year old experimental group (n=30)						16-year old control group (n=30)									
		Descriptive statistics				Effect sizes (d-values)			Descriptive statistics				Effect sizes (d-values)			Descriptive statistics				Effect sizes (d-values)									
		\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1-T3	d T4-T6	d T1-T6	\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1-T3	d T4-T6	d T1-T6	\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1-T3	d T4-T6	d T1-T6	\bar{X} T1	\bar{X} T3	\bar{X} T4	\bar{X} T6	d T1-T3	d T4-T6	d T1-T6
NEURODYNAMICS																													
Straight leg raise L	0.05	1.53	1.07	1.23	1.07	2.1	0.7	2.1	1.73	1.70	1.70	1.67	--	--	--	1.47	1.20	1.23	1.10	1.2	0.6	1.6	1.47	1.43	1.43	1.40	--	--	--
Straight leg raise R	0.05	1.57	1.07	1.23	1.07	2.2	0.7	2.2	1.73	1.70	1.70	1.63	--	--	--	1.50	1.30	1.33	1.10	0.9	1.0	1.8	1.47	1.43	1.43	1.43	--	--	--
Upper limb tension L	0.001	1.03	1.00	1.00	1.00	0.9	--	0.9	1.07	1.07	1.07	1.07	--	--	--	1.00	1.00	1.00	1.00	--	--	--	1.03	1.03	1.03	1.03	--	--	--
Upper limb tension R	0.001	1.03	1.00	1.00	1.00	0.9	--	0.9	1.07	1.07	1.07	1.07	--	--	--	1.00	1.00	1.00	1.00	--	--	--	1.03	1.03	1.03	1.03	--	--	--
L3,4 prone knee bend L	0.04	1.43	1.00	1.30	1.13	2.2	0.8	1.5	1.40	1.47	1.43	1.40	--	--	--	1.37	1.07	1.07	1.03	1.5	--	1.7	1.53	1.53	1.53	1.53	--	--	--
L3,4 prone knee bend R	0.04	1.47	1.00	1.27	1.13	2.3	0.7	1.7	1.40	1.47	1.47	1.43	--	--	--	1.37	1.10	1.10	1.03	1.3	--	1.7	1.53	1.53	1.53	1.53	--	--	--
Slump L	/	1.00	1.00	1.00	1.00	--	--	--	1.00	1.00	1.00	1.00	--	--	--	1.00	1.00	1.00	1.00	--	--	--	1.00	1.00	1.00	1.00	--	--	--
Slump R	/	1.00	1.00	1.00	1.00	--	--	--	1.00	1.00	1.00	1.00	--	--	--	1.00	1.00	1.00	1.00	--	--	--	1.00	1.00	1.00	1.00	--	--	--

Note: All biomechanical and postural values in the experimental groups either improved or stayed the same, but they were not always of medium (possible) or large (definite) practical significance, and are therefore not shown in the table.

Values printed in red = a practically significant ($d \geq 0.8$) intra-group difference between testing episodes (large effect)

d-value = effect size for difference between means; a measurement of practical significance

MSE = Mean square error as measurement of variance of data
 T1-T3 = d-value comparing the first and third testing episodes
 T4-T6 = d-value comparing the fourth and sixth testing episodes
 T1-T6 = d-value comparing the first and sixth testing episodes

/ = MSE could not be completed due to lack of variation in data
 -- = Difference was not of medium ($d \geq 0.5$) or large ($d \geq 0.8$) practical significance
 L = Left
 R = Right

Figures 5.5 (A) to (T) give a graphic image of the biomechanical and postural changes over time, as well as the difference between groups (only figures of highly practically significant effects included). Only one side of the body (left or right) was included in this graphic display, even though practically significant effects often occurred on both sides of the body. For clarity, results under this heading (5.4.3) will first be discussed for the first season, then the second season, and lastly for the whole study period (two seasons together).

As seen in table 5.8, results comparing the beginning to the end of *the first season* (T1-T3) reveal several highly practically significant improvements in the *lower limb dynamic mobility* of the *15-year old* experimental players. This was achieved for the right TA ($d=1.4$), left and right ITB ($d=2.1$ and 2.6), left and right quadriceps ($d=1.2$ and 1.5), left and right iliopsoas ($d=1.8$ and 1.9), and left and right gluteus maximus ($d=1.6$ and 1.8) tests (also see Figures 5.5 (A) to (E)). In contrast to this, no significant improvements occurred in the 15-year old control group. Therefore, the positive changes in the lower limb dynamic mobility of the 15-year old experimental group during the first season can be attributed to the effect of the prevention programme.

Upon studying the changes in lower limb dynamic mobility of the *16-year old* groups during the first season, a similar trend is visible. The 16-year old experimental group showed highly practically significant improvements in the same areas as the 15-year old experimental group. In addition, the 16-year old experimental group also improved highly significantly in the hip external rotation test (left and right) ($d=1.0$ and 1.2). In contrast, the 16-year old control group did not improve moderately or highly practically significantly in the dynamic mobility of the lower limb area, but actually deteriorated highly significantly in the mobility of the left quadriceps ($d=0.8$) (Figure 5.5 (C)). Resembling the 15-year olds, the changes in the lower limb dynamic mobility of the 16-year old experimental group during the first season can be attributed to the positive effect of the prevention programme.

No deviations were observed in the positional alignment of the lower limb (*foot and ankle*, and *knee* region) during the first season.

When studying the changes in the *pelvic region* during the first season (T1-T3) it becomes clear that both the 15 and 16-year old experimental groups experienced a strong practically significant improvement in the positional tests (symmetry) of leg length (d=1.2 and 1.5), ASIS (d=1.2 and d=1.3), PSIS (d=1.2 and d=1.3), and pelvic rami (d=1.2 and d=1.3), as well as the bilateral pelvic position test (d=1.8 and d=2.6). These improvements were not recorded in the corresponding control groups. This again indicates the ability of the prevention programme to improve core stability as well as dynamic mobility in the pelvic region during the first season, thus leading to a more symmetrical and stable postural position.

Considering the *spinal region* during the first season (T1-T3), it can be seen that the *dynamic spinal mobility* of both the 15- and 16-year old experimental groups improved either highly or moderately significantly in the left TLF (d=0.5 and 1.0), right TLF (d=0.5 and 1.0), functional flexion (d=1.2 and 0.6), left side flexion d=0.5 and 0.8), and right side flexion tests (d=0.5 and 0.8). The corresponding control groups did not show improvement in any of these areas during the first season, which again indicates the ability of the prevention programme to improve dynamic spinal mobility in the discussed areas. When considering the *spinal region positional tests*, it can be seen that the lumbar position in the coronal axis improved highly significantly among the two experimental groups (d-value for 15-year olds = 1.2 and 16-year olds = 2.2), while it did not improve in the control groups. This may be attributed to the ability of the prevention programme to improve the lumbar position/bilateral pelvic tilt during the first season. A similar improvement was achieved for the thoracic position of the 15-year old experimental group (d=1.2) and 16-year old experimental group (d=0.6) during the first season.

During the first season (T1-T3), the *upper limb region* of the 15-year old experimental group improved highly practically significantly with regard to the shoulder outline composition (left and right) (d=1.5 and 1.5). In contrast these improvements were not shared by the 15-year old control group during the first season. Furthermore, highly practically significant improvements were also recorded for the left and right hand behind back (d=0.9 and 1.2), left and right hand behind neck (d=0.9 and d=0.9), winging (left and right) (d=0.8 and 0.8),

shoulder outline composition (left and right) ($d=1.0$ and 1.0) and throwing position (left and right) ($d=0.8$ and 0.8) tests of the 16-year old experimental group. The 16-year old control group did not change significantly in the upper limb region during the same period of time. The above results of the first season demonstrate the ability of the prevention programme to increase the muscularity (shoulder outline composition) of the shoulder in both the experimental groups, the flexibility of the shoulder capsule, as well as regional shoulder stability in the older experimental group.

When analysing the area of *neurodynamics* in Table 5.8 it becomes clear that, in practice, both the experimental groups improved highly significantly in the straight leg raise, and L3,4 prone knee bend (nerve suppleness) tests over the course of the first season (T1-T3). No significant changes occurred in the corresponding control groups, confirming that the prevention programme was effective in improving the straight leg raise, and L3,4 prone knee bend tests. Furthermore, the 15-year old experimental group also improved highly significantly in the left ($d=0.9$) and right upper limb tension test ($d=0.9$) during this period.

Before discussing the second season (T4-T6), it must be noted that a transitional period exists between the first and second year (T3-T4). This period starts as soon as the final matches end and ends when the next pre-season begins. During this period, the players followed the post-season transition and off-season phases of the prevention programme (see Chapter 4, section 4.8.2.1). The aims of these phases were first to provide a mental and physical rest period, and then to maintain a general physical fitness base until the more intensive pre-season training. Furthermore, recovery from injury and limitations and weaknesses from the previous season were addressed. However, this period included the long December holiday, and the possibility of biomechanical and postural deterioration among the less disciplined. In practice, Figures 5.5 (A)-(T) reveal noteworthy trends during this period (T3-T4). During the period it seems that both the experimental groups lost some of the positive effects gained through following the intervention programme. For the 15-year old experimental group, highly practically significant deterioration occurred in the TA (right) (Figure 5.5(A)), ITB (left and right) (Figure 5.5(B)), iliopsoas (left and right) (Figure 5.5(D)), right spinal rotation, thoracic position (coronal axis) (Figure 5.5(M)), and L3,4 prone knee bend (left and right)

(Figure 5.5(T)). This was probably a result of detraining. This trend is not confirmed by the results among the 15-year old control group. A possible reason for this observation is that, in the period between T4 and T6, the frequency or intensity of the prevention programme was inadequate in some regions.

Furthermore, it is worth noting that in practice, the amount of winging improved moderately in the 15-year old experimental group. As this did not occur in the control group, this positive effect may be attributed to the prevention programme. Related results for the 16-year old experimental group during this period (T3-T4) do not show highly practically significant changes. However, the quadriceps (left and right) as well as gluteus maximus (left) did deteriorate moderately in the 16-year old experimental group. Although this trend was not confirmed in the control group, a decrease in dynamic mobility occurred at the right TA of the 16-year old control group, indicating the possibility of increased TA immobility among 16-year olds who did not follow the prevention programme during this period. In light of the changes which occurred between T3 and T4, it can be said that the off-season may play an important role in the deterioration of some of the biomechanical and postural variables among adolescent rugby players, particularly in highly conditioned groups (experimental group).

The intra-group comparison for the *second season* (T4-T6) once more indicates several moderately and highly practically significant biomechanical and postural improvements in the two experimental groups, which are not seen in the control groups. For the 15-year old experimental group, highly significant improvements occurred in the left and right ITB ($d=1.0$ and $d=1.2$), left and right hip external rotation ($d=0.9$ and $d=1.0$), bilateral pelvic position ($d=1.5$), right spinal rotation ($d=0.9$), left and right side flexion ($d=0.8$ and $d=0.8$), lumbar position in the coronal axis ($d=1.5$), left and right shoulder position ($d=0.9$ and $d=0.9$), right winging ($d=0.8$), left and right shoulder outline composition ($d=1.0$ and $d=1.0$) and left L3,4 prone knee bend test ($d=0.8$). The highly significant improvements in the 16-year old experimental group during the second season occurred in the following areas: left ITB ($d=0.9$), left quadriceps ($d=0.8$), lumbar position in coronal axis ($d=0.8$), left winging ($d=0.8$) and right straight leg raise ($d=1.0$). The number of highly practically significant

improvements which occurred in both the experimental groups during the second season were fewer than the number during the first season, pointing to a plateau in the effectiveness of the prevention programme during the second year.

This was particularly true for tests of dynamic mobility and pelvic symmetry. These phenomena during the second year may be credited to a loss of flexibility which occurs with aging during this rapid growth period (Armstrong & McManus, 1996), or adaptation to the difficulty level of the prevention programme. Furthermore, as players started the second year with a biomechanical and postural status closer to the ideal than at the beginning of the study, it is likely that it was more difficult to improve on this close to ideal profile. This shows that in practice, the volume, intensity or type of exercises applied in the prevention programme need to be changed during the second year among similar groups. Compared to the first year, the more pronounced improvements in the shoulder and winging positional tests among the 15-year old experimental group during the second year may be partly due to the natural improvement in regional stability, associated with aging schoolboys (Hattingh, 2003). Lastly, moderately and highly practically significant deterioration was recorded in the head position (coronal axis) of the 15-year old control group ($d=0.5$) and 16-year old control group ($d=1.1$) during the second season.

Finally, in order to note how the groups changed over the *whole two-season period*, the biomechanical and postural status of groups at the completion of the study is compared to their status at the commencement of the study (T1-T6). The results reveal high practically significant improvements in the *lower limb dynamic mobility* of the 15-year old experimental group in the right TA ($d=1.2$), left and right ITB ($d=1.9$ and $d=2.2$), left and right quadriceps ($d=1.2$ and $d=1.3$), left and right iliopsoas ($d=1.6$ and $d=1.6$), left and right gluteus maximus ($d=1.6$ and $d=1.8$) and the left and right hip external rotation ($d=1.6$ and $d=1.8$) tests. Unlike the 15-year old experimental group, the 15-year old control group did not show any improvement, but rather a moderately practically significant deterioration in the left and right quadriceps ($d=0.5$ and $d=0.6$), adductor ($d=0.7$) and right gluteus maximus tests ($d=0.6$). The 16-year old groups experienced similar results, with the 16-year old experimental group experiencing highly practically significant improvements in the same tests as the 15-year old

experimental group (also see Figures 5.5 (A)-(F)), and the control group deteriorating with regard to the left quadriceps ($d=1.0$) and left gluteus maximus ($d=0.7$) tests. This proves the effectiveness of the prevention programme not only in preventing quadriceps, adductor and gluteus maximus immobility, but also in improving dynamic mobility in the TA (right), ITB (left and right), quadriceps (left and right), iliopsoas (left and right), gluteus maximus (left and right) and hip external rotation (left and right) over a period of two rugby seasons.

Considering changes in *lower limb positional alignment* from the first to the last testing occasion, it is clear that no changes of moderate or high practical significance occurred in either of the two experimental groups with regard to the knee complex, or foot and ankle region. This highlights the inability of the preventative exercises significantly to alter the positional alignment of the knee complex and the foot and ankle region. The most probable reason for this is that the biomechanical and postural position of these areas is often a result of other structures (e.g. shape of bones) (Brukner & Khan, 2001) which are not easily affected by exercise. On the other hand, the VMO-L test (left and right side) improved in the two control groups, and not in the experimental groups. The apparent reason for the lack of improvement in the two experimental groups is that the experimental groups were already a great deal closer to ideal (closer to a value of 1) before the implementation of the exercise programme.

Biomechanical and postural variables in the *pelvic region* reveal that, in practice, the prevention programme was highly effective in improving the pelvic symmetry ($d=1.5$ and $d=1.6$ in the leg length, ASIS, PSIS and pelvic rami position tests of 15 and 16-year olds respectively) and bilateral pelvic position (less lordosis) ($d=2.6$ and $d=3.1$) among the two experimental groups over the two year period. No significant changes occurred in the two control groups.

In the *spinal dynamic and positional* testing (T1-T6), the prevention programme was highly practically effective in improving the TLF (left and right) ($d=1.5$ and $d=1.5$), functional flexion ($d=1.2$ and $d=1.2$), side flexion (left and right) ($d=0.8$ and $d=0.8$), and lumbar position (coronal axis) ($d=2.1$ and $d=2.9$), among both the 15- and 16-year old experimental

groups, as well as right rotation ($d=0.9$) among the 15-year old experimental group. Not only did the 15- and 16-year old control groups not show significant improvements over the same two year period, but instead they deteriorated with regard to their head position in the coronal axis ($d=0.5$ and $d=1.1$).

Upper limb testing (T1-T6) revealed highly significant improvements in the left and right shoulder positional ($d=1.6$ and $d=1.6$), left and right winging positional ($d=1.0$ and 1.3), and left and right shoulder outline composition ($d=1.8$ and $d=1.8$) tests of the 15-year old experimental group, versus the moderate improvement in the left and right shoulder outline composition ($d=0.5$ and $d=0.5$) of the 15-year old control group. In practice, these differences indicate a highly positive effect of the prevention programme on the shoulder position (left and right), winging (left and right), as well as a possible effect on the shoulder outline (left and right) over a period of two years. The moderately significant improvement in the shoulder outline composition (left and right) tests of the 15-year old control group may be attributed to the natural growth process (Hattingh, 2003), and therefore the large effect of the prevention programme on shoulder outline (left and right) of the 15-year old experimental group over the two year period should be seen as less than highly significant.

The results of the *16-year old* experimental and control groups were approximately the same as that of the 15-year olds, the only difference being additional improvements in the left and right hand behind back ROM ($d=1.4$ and $d=1.6$), left and right hand behind neck ROM ($d=0.9$ and $d=0.9$), and left and right throwing position tests ($d=0.8$ and $d=0.8$) of the 16-year old experimental group. The trend in the 16-year olds confirms the highly positive effect of the prevention programme on the shoulder position (left and right), and winging (left and right), as well as the possible effect on the shoulder outline (left and right) over the two year study. Additionally, over the two year period, the results of the 16-year olds also highlight the ability of the programme to improve hand behind back ROM (left and right), hand behind neck ROM (left and right), and throwing position (left and right) to close to ideal.

Neurodynamically, both the 15 and 16-year old experimental groups improved highly significantly in the straight leg raise (left and right) and L3,4 prone knee bend (left and right)

tests over the time of two rugby years, while the two control groups did not change significantly in any of the neurological tests. In addition, highly significant improvements were also seen in the left and right upper limb tension test ($d=0.9$ and $d=0.9$) of the 15-year old experimental group. Thus, over a period of two years, the prevention programme effectively improved the neurodynamics of the 15- and 16-year old experimental groups, as tested in the straight leg raise (left and right) and L3,4 prone knee bend (left and right), and left and right upper limb tension (only 15-year olds) tests.

In summary, after studying the results of the intra-group comparison in Table 5.8, it is clear that *before the implementation of the prevention programme (T1)*, the characteristics of the groups revealed certain mean biomechanical and postural weaknesses (values closer to non-ideal, closer to a value of 2), rendering these areas less mobile, dynamically loaded, with inadequate core stability and therefore susceptible to intrinsic injury. The biomechanical and postural status at this stage (T1) was typical of the developmental phase of the adolescent player. *At the end of the first season of intervention*, it was clear that, with the exception of hip external rotation and winging in the 15-year olds experimental group, and the shoulder position of both experimental groups, the experimental groups improved highly significantly in all the dynamic mobility and positional tests which caused concern (weaknesses, closer to non-ideal) at T1. Furthermore, additional improvements also occurred in dynamic mobility, and positional tests which were already closer to ideal at T1.

Even though the experimental teams followed an off-season exercise programme, some highly practically significant deterioration occurred after the end of the first season. This occurred in a few tests in the 15-year old experimental group. During the second season, when the difficulty of the prevention programme was stepped up, these areas improved once more. Similar to the first season, the intra-group comparison for the *second season (T4-T6)* indicated several highly practically significant improvements in dynamic mobility and positional tests in the two experimental groups, which were not seen in the control groups. In total, the improvements in the two experimental groups were of such a nature that all the tests which caused concern (weaknesses) at T1 – except for patella tilt, toe position and thoracic

position in the sagittal axis – had improved to an acceptable status (closer to ideal) by T6. This status of the experimental groups at T6 was not shared by the control groups.

To sum up, these changes within each group, when considered for *the total period of two rugby seasons*, proved that the prevention programme provided the experimental groups with a more balanced (closer to ideal) dynamic mobility, core stability and regional position. This happened to such a degree that at T6 the two experimental groups in this study also outperformed the 15-year old rugby players in the Hattingh (2003:92-93) study in all areas except the left and right forefoot position (15- and 16-year olds), and the thoracic position in the sagittal axis (15-year olds). Furthermore, the effectiveness of the prevention programme in preventing specific biomechanical and postural deterioration over a period of two rugby seasons was also noted. Lastly, the inability of the preventative exercises significantly to alter the positional alignment of the knee complex and the foot and ankle region was documented.

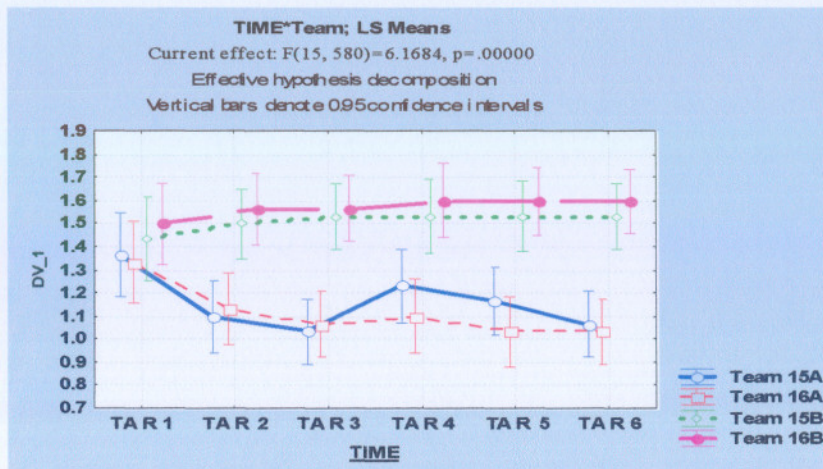


Figure 5.5(A): Right TA

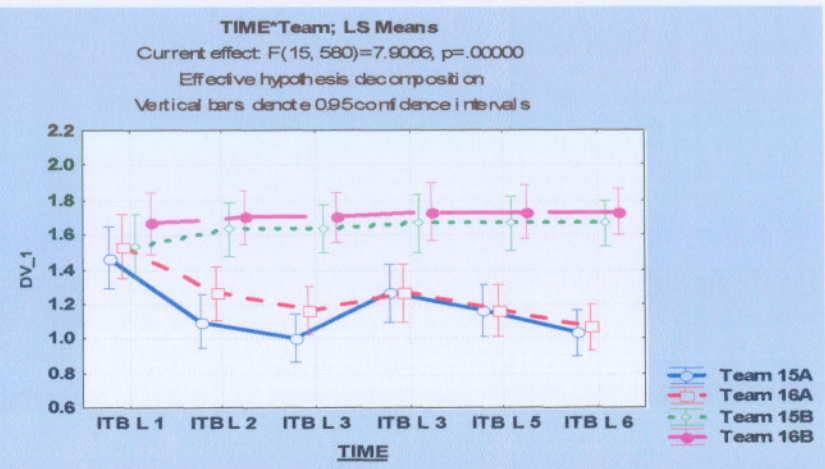


Figure 5.5(B): Left ITB

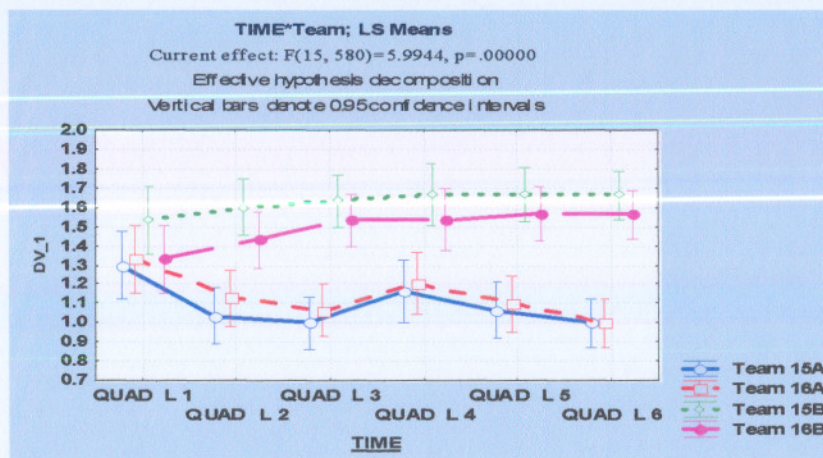


Figure 5.5(C): Left Quadriceps

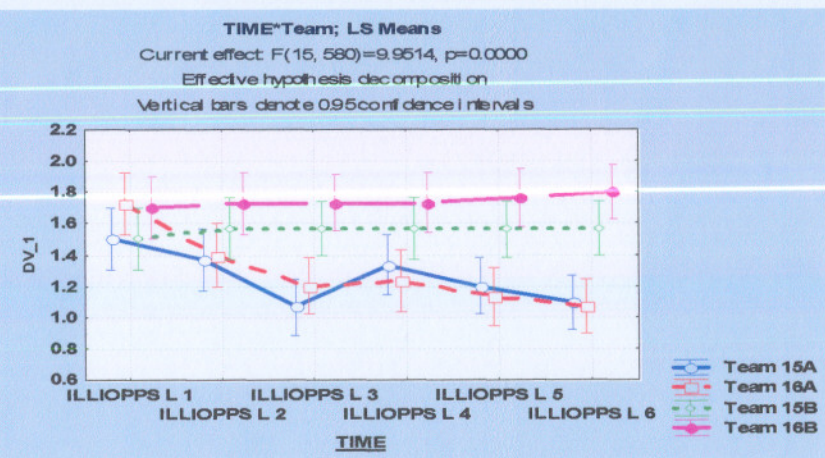


Figure 5.5(D): Left Iliopsoas

Numbers 1 to 6 on the x-axis of graphs represent the six testing occasions (T1-T6)

Figure 5.5(A-T): Changes in the biomechanical and postural tests of the experimental and control groups over time

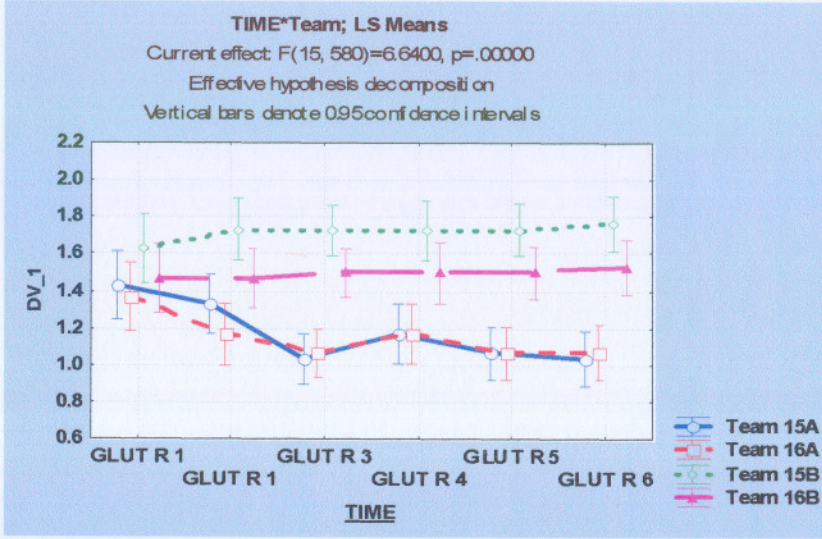


Figure 5.5(E): Right gluteus maximus

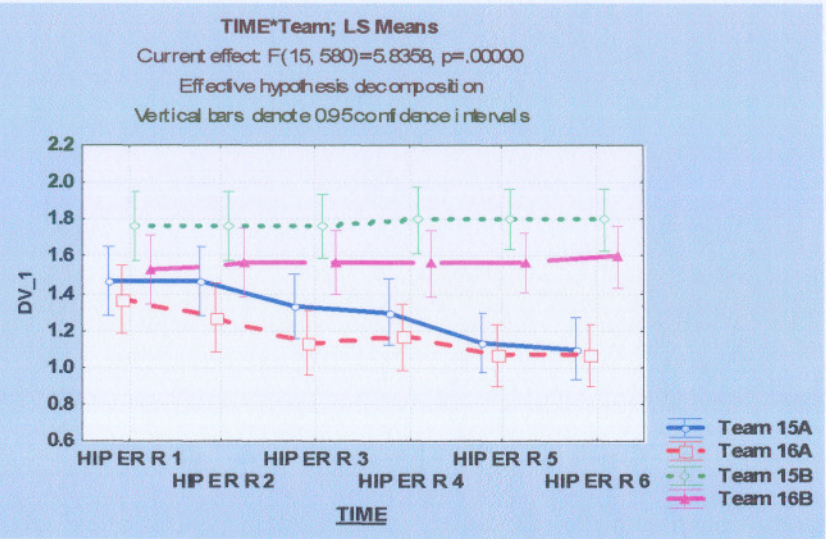


Figure 5.5(F): Right Hip External Rotation

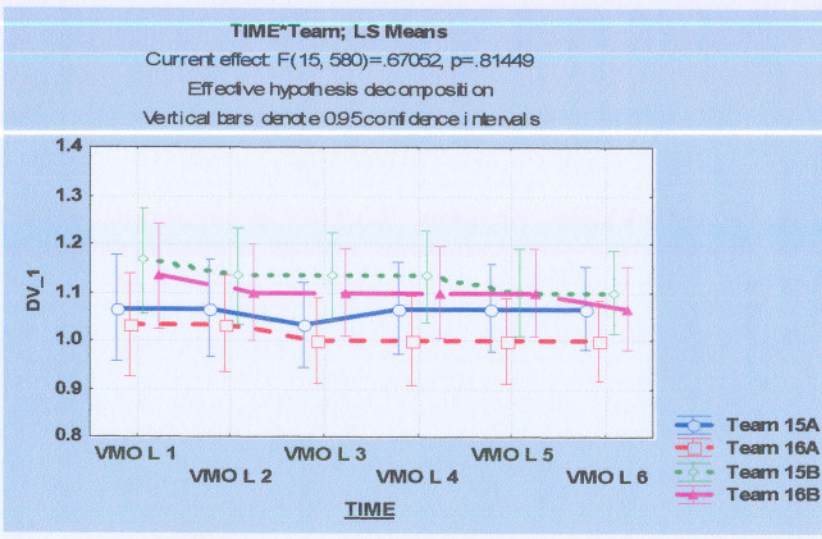


Figure 5.5(G): Left VMO-L

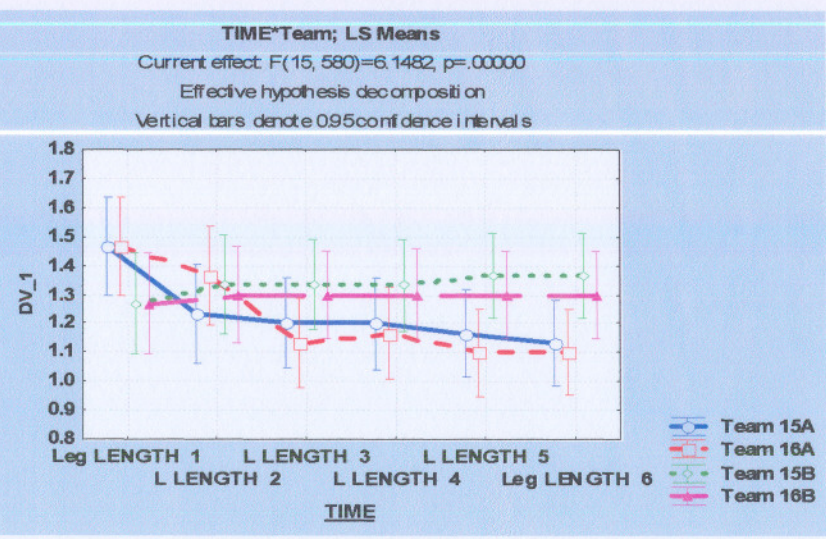


Figure 5.5(H): Leg Length

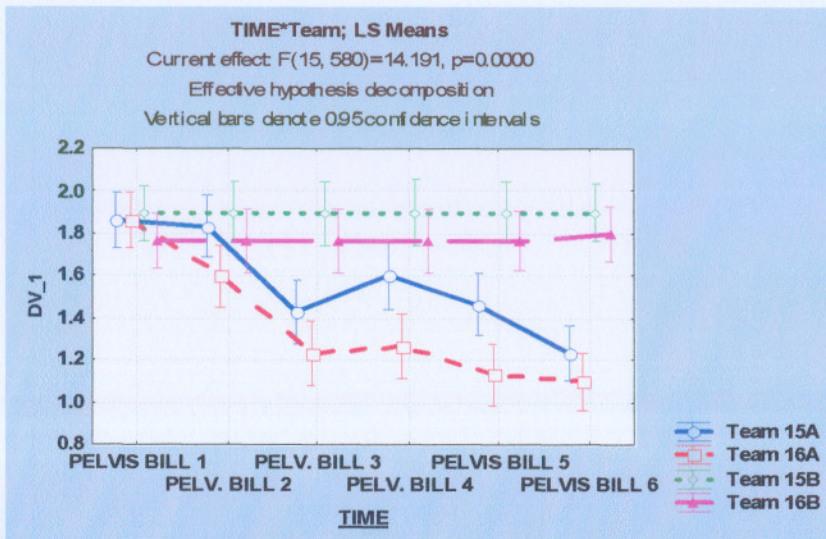


Figure 5.5(I): Bilateral pelvis position

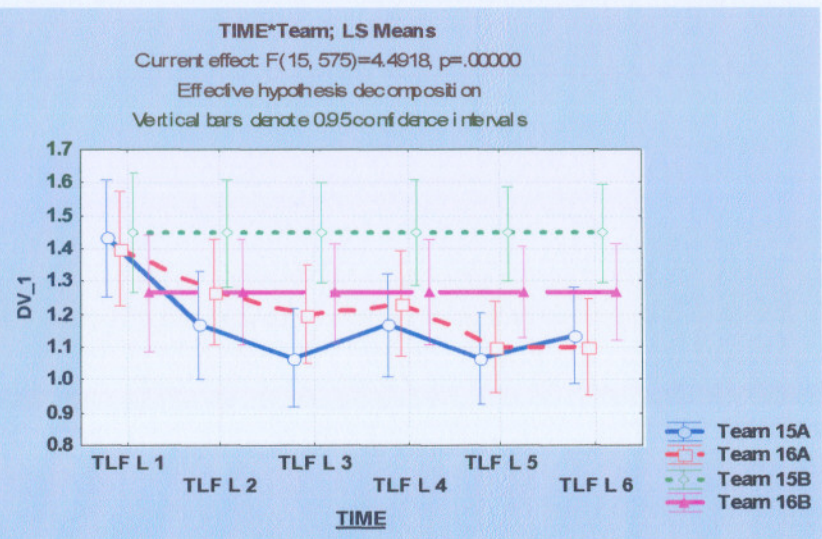


Figure 5.5(J): Left TLF

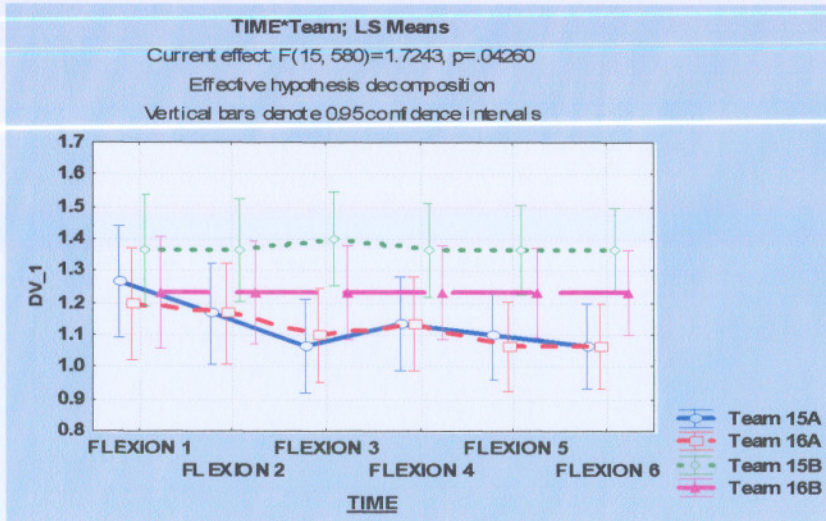


Figure 5.5(K): Flexion

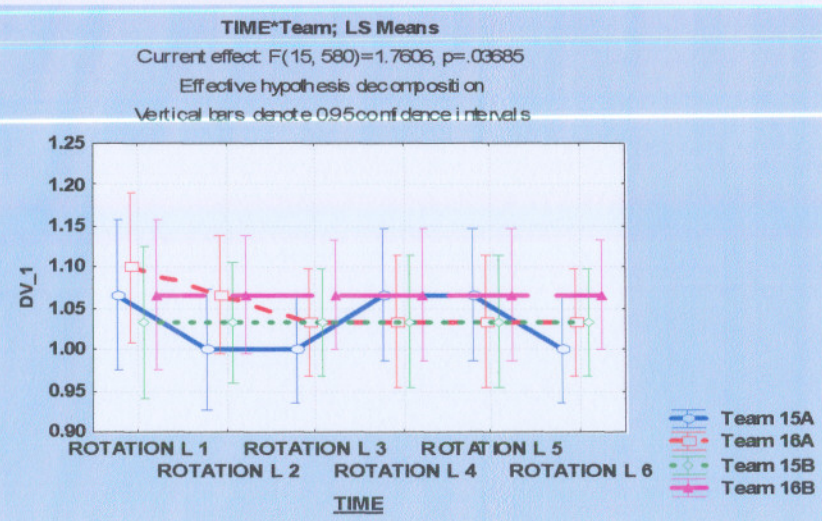


Figure 5.5(L): Left Rotation

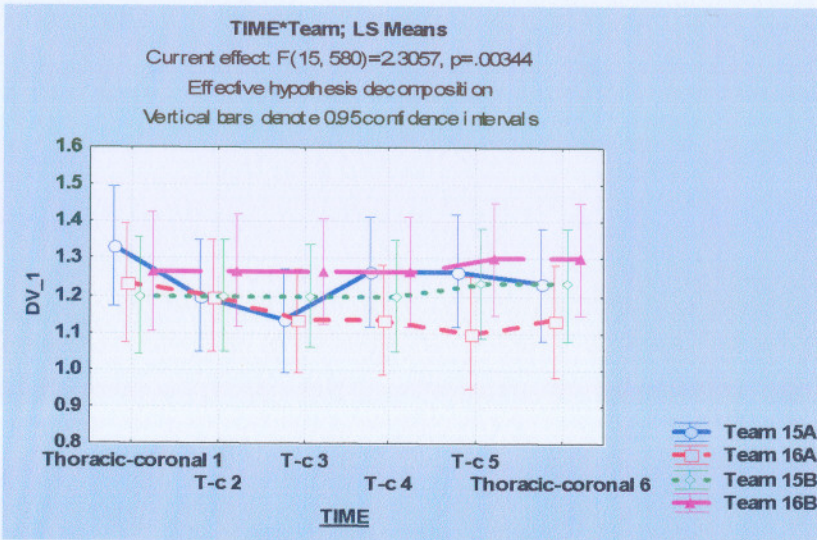


Figure 5.5(M): Thoracic position – coronal axis

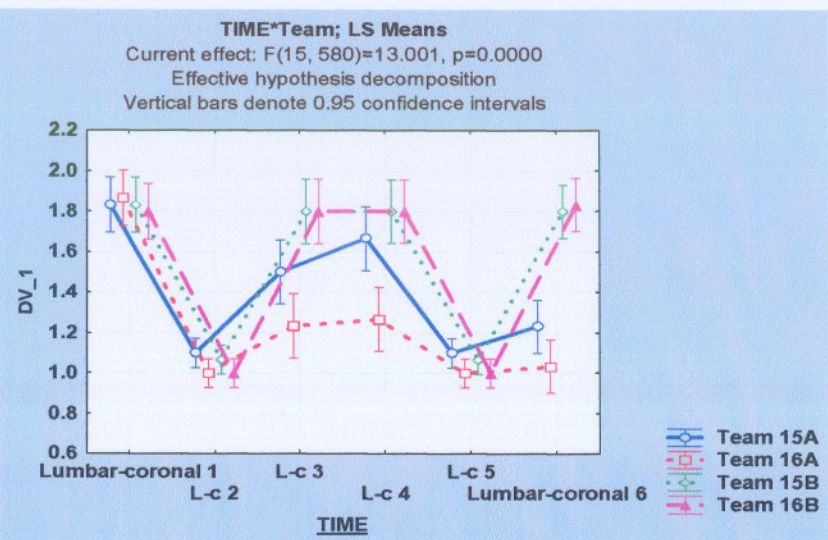


Figure 5.5(N): Lumbar position – coronal axis

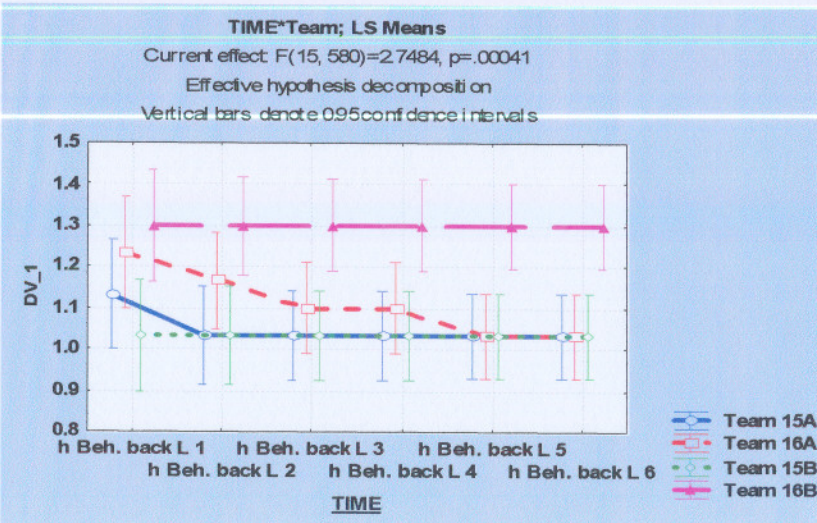


Figure 5.5(O): Left hand behind back

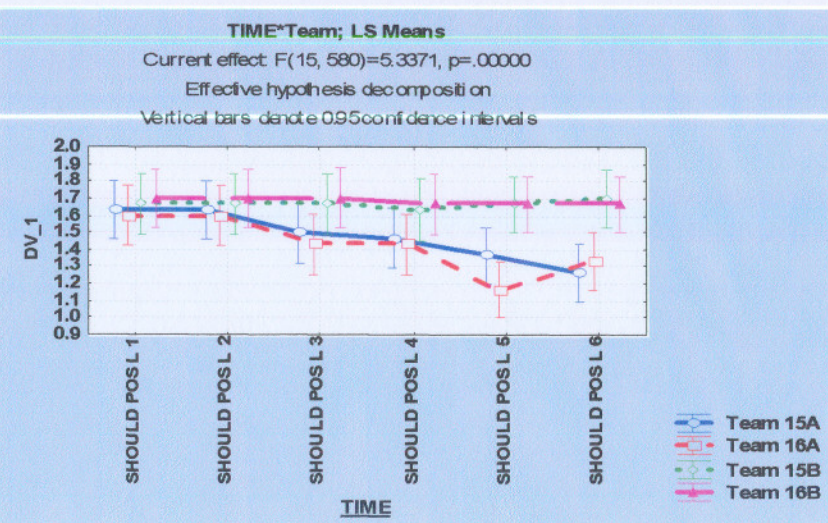


Figure 5.5(P): Left shoulder position

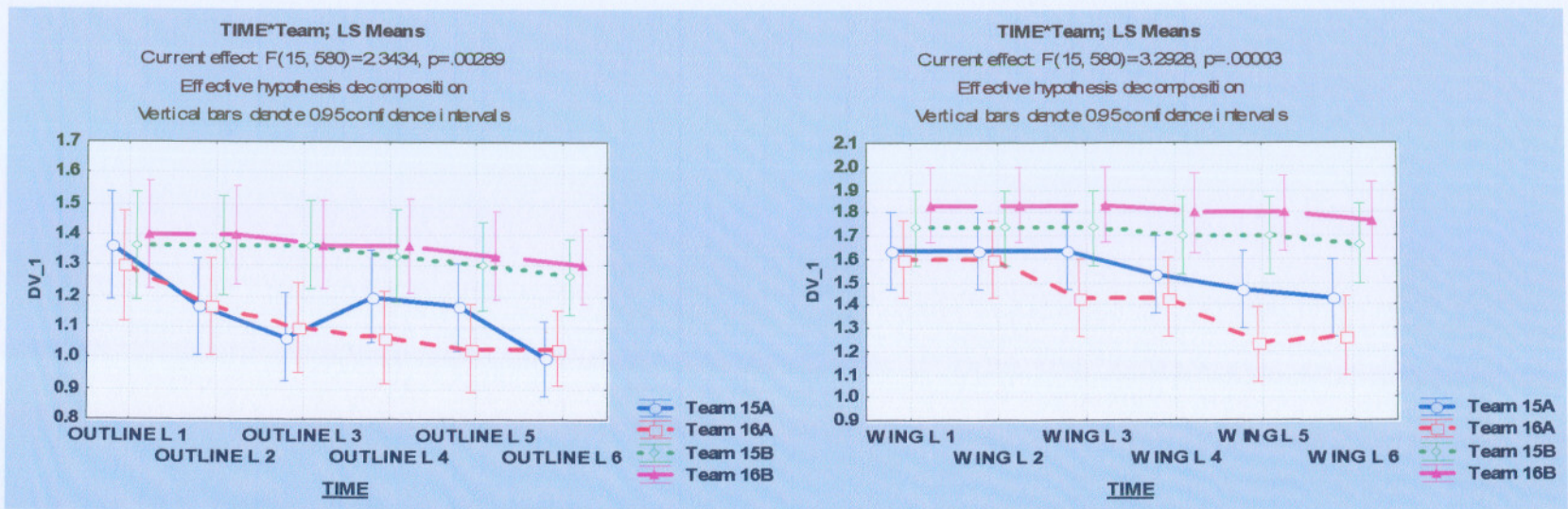


Figure 5.5(Q): Left shoulder outline

Figure 5.5(R): Left winging

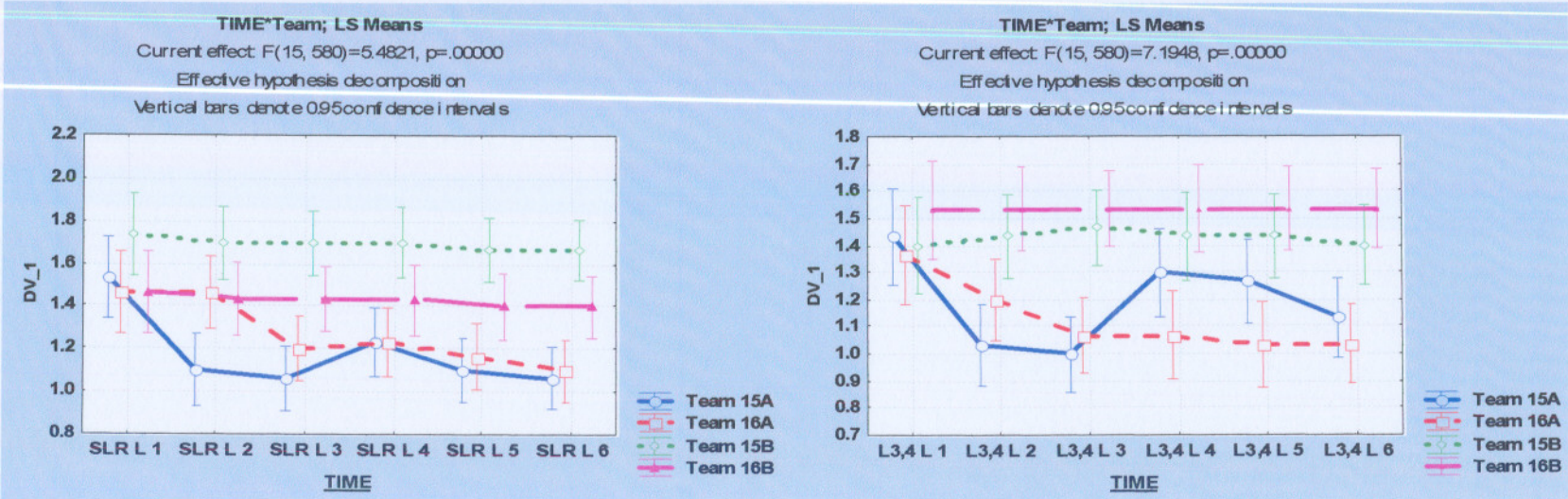


Figure 5.5(S): Left SLR

Figure 5.5(T): Left L3,4

5.5 RESULTS OF INTER-GROUP COMPARISONS BETWEEN EXPERIMENTAL AND CONTROL GROUPS

The intra-group comparisons regarding each group's anthropometric, physical and motor, and biomechanical and postural results were discussed in section 5.4. The repeated measures ANOVA indicated that within each individual group, moderately and highly significant anthropometric, physical and motor, and biomechanical and postural changes occurred over the course of time. As analogous trends often occurred in both the corresponding experimental and control group, improvements in the experimental group could not always be credited to the effect of the prevention programme. Furthermore, even in instances where contrasting trends were seen in matching experimental and control groups, it was difficult to say if these were large enough to cause a practically significant difference between the relevant experimental group and the corresponding control group. Hence, an *inter-group comparison* was required to compare the anthropometric, physical and motor, and biomechanical and postural changes in each experimental group to the changes in the matching control group.

The changes which developed during the first season, the second season and over the total period within each experimental group were compared to those which developed in the matching control group during the same period of time. For each variable, the changes which occurred in a specific group were calculated by subtracting the mean values recorded at different testing episodes from each other: (*change/difference* in specific group = $\bar{x}_{\text{earlier test episode}} - \bar{x}_{\text{later test episode}}$). During the calculation of practical significance (see section 4.10.1), the difference (change) which was calculated in the control group was subtracted from the one which was calculated in the experimental group ($\text{difference}_{\text{experimental group}} - \text{difference}_{\text{control group}}$). Note that only medium to highly practically significant differences are given in all tables which portray inter-group comparisons (Table 5.9 to Table 5.11). The mean values of each variable at the specific testing episodes have already been revealed in Tables 5.6–5.8.

5.5.1 INTER-GROUP COMPARISON OF ANTHROPOMETRIC RESULTS

In section 5.4.1 it was mentioned that roughly parallel trends were recorded for the anthropometric components of matching experimental and control groups. However, Table 5.9 depicts the true number of highly and moderately significant anthropometric differences between groups when the anthropometric changes in the experimental groups are compared to the changes in the control groups. Upon comparing the changes in matching experimental and control groups, moderately or highly practically significant *inter-group differences* were apparent in the stature, triceps skinfold, supscapular skinfold, supraspinal skinfold, midaxillary skinfold, calf skinfold, humerus breadth, femur breadth, fat percentage, and mesomorphy.

When studying these changes it is noticeable that the moderately significant difference in stature ($d=0.6$) only occurred during the first season of the 16-year olds, while no significant effects occurred in the body weight. Furthermore, for the purpose of this study, the differences which occurred in the individual skinfolds, breadths and girths were not considered as important as their effect on the fat percentage and somatotype (endomorph, mesomorphy and ectomorphy). Firstly, upon looking at the fat percentage it is clear that compared to the 16-year old control group, the 16-year old experimental group experienced a moderately practically significant reduction in fat percentage over the first season ($d=0.5$) and the total period ($d=0.5$). Secondly, the individual changes in stature, triceps skinfold, subscapular skinfold and supraspinal skinfold were not large enough to have a significant effect on the endomorphy component. Thirdly, the lack of significant differences in stature and body weight is responsible for the fact that no significantly different trends occurred in the ectomorphy component. Fourthly, the highly significant effect seen in the mesomorphy component of the 15-year olds during the first season ($d=1.1$), and over the total period ($d=1.3$), is most likely a consequence of the increase in humerus and femur breadth during the first season and the total period. Therefore, in comparison to the control group, the improved mesomorphy of the 15-year old experimental group cannot be attributed to the prevention programme, but rather to natural bone growth.

Table 5.9: Inter-group comparison of changes in anthropometric components between experimental and control groups

INTER-GROUP COMPARISON BETWEEN EXPERIMENTAL AND CONTROL GROUP							
VARIABLES	MSE OF ANOVA	15-YEAR OLD EXPERIMENTAL AND CONTROL GROUP			16-YEAR OLD EXPERIMENTAL AND CONTROL GROUP		
		d-value	d-value	d-value	d-value	d-value	d-value
		1 st season	2 nd season	whole period	1 st season	2 nd season	whole period
Anthropometric variables							
Stature (cm)	0.09	--	--	--	0.6	--	--
Body weight (kg)	46	--	--	--	--	--	--
Triceps skinfold (mm)	0.18	--	--	--	0.7	--	0.8 [▼]
Subscapular skinfold (mm)	2.68	--	--	--	0.5	--	0.5
Supraspinal skinfold (mm)	0.13	0.5	--	--	--	--	--
Midaxillary skinfold (mm)	0.15	1.5 [▼]	--	1.3 [▼]	--	--	--
Abdominal skinfold (mm)	0.3	--	--	--	--	--	--
Calf skinfold (mm)	0.18	--	--	--	1.3 [▼]	--	1.3 [▼]
Upper arm girth (cm)	0.03	--	--	--	--	--	--
Calf girth (cm)	0.03	--	--	--	--	--	--
Humerus breadth (cm)	0.001	1.4 [▼]	--	1.4 [▼]	--	--	--
Femur breadth (cm)	0.003	0.5	--	0.5	--	--	--
Fat percentage (‰)	1.58	--	--	--	0.5	--	0.5
Endomorphy	0.672	--	--	--	--	--	--
Mesomorphy	0.01	1.1 [▼]	--	1.3 [▼]	--	--	--
Ectomorphy	0.008	--	--	--	--	--	--

$$d = \frac{|\bar{x}_i - \bar{x}_j|}{\sqrt{MSE}} = \text{effect size for difference between means: a measurement of practical significance.}$$

MSE = Mean square error of ANOVA, a measurement of variance in data

d-value = intra-group comparison, comparing the changes over time in the experimental group to the changes in the matching control group

1st season = first year of intervention, changes from T1 to T3

2nd season = second year of intervention, changes from T4 to T6

whole period = The whole intervention period, from T1 to T6

▼ = practically significant ($d \geq 0.8$) inter-group difference between testing episodes (large effect)

-- = Difference was not of medium ($d \geq 0.5$) or large ($d \geq 0.8$) practical significance

In summary, the inter-group comparison of changes in these groups confirm that the prevention programme did not have a significant effect on the anthropometric variables of the two experimental groups, and that changes which occurred may be due to other factors, such as the natural growth phase of boys.

5.5.2 INTER-GROUP COMPARISON OF PHYSICAL AND MOTOR RESULTS

In contrast to the inter-group comparison of physical and motor components, the moderately and highly significant *intra*-group effects which can be seen in Table 5.10 may be attributed to the effect of the prevention programme (study in conjunction with Figures 5.4(A)-(J)).

When *power* (explosiveness) is considered it can be seen that the prevention programme had a highly significant effect on the vertical jump tests of the 15-year olds during the first season ($d=0.8$) and the whole period ($d=0.8$), as well as the second season ($d=1.2$) and the whole period ($d=1.5$) in the case of the 16-year olds. In the categories of *speed* and *agility*, the prevention programme did not have the desired effect.

Regarding *aerobic endurance*, *speed endurance* (running) and local *muscle endurance* (pull-ups, push-ups), it is obvious that the prevention programme only affected the aerobic endurance (bleep test) and local muscle endurance tests (pull-ups, push-ups). Significant improvements in the bleep test occurred in the first season of the 15-year olds ($d=0.6$), the second season of the 16-year olds ($d=0.8$) and the whole period of the 16-year olds ($d=0.7$). These improvements in aerobic endurance may possibly have contributed to significantly improved recovery from fast, high-intensity activities, and to significantly less physiological stress among the experimental groups (Williford *et al.*, 1994; Jones & Knapik, 1999).

Significant effects were also visible for the pull-up test of the 15-year olds (d -value second season=0.7, whole period=0.6) and 16-year olds (d -value first season=0.9, second season=0.5), as well as push-up test of the 15-year olds (d -value first season=0.9, second season=0.8; whole period=1.5) and 16-year olds (d -value first season=0.6, whole period=1.1).

Finally, when comparing *strength* increases between the matching experimental and control groups, moderately or highly significant effects (negative effects) were found in the abdominal strength (7-stage abdominal strength test) of both age groups during the first season, second season and final period. Upon studying Figure 5.4(I) it becomes clear that this is a negative effect, signifying that the two control groups improved more than their experimental counterparts. Thus the prevention programme was not successful enough in improving the specific muscles used during the 7-stage abdominal strength test. A likely reason for this may be that the 7-stage abdominal strength test involves mostly the upper abdominals, whilst the prevention paid more attention to the lower abdominals and core stabilisers. Thus it is advised that future rugby tests, specifically those aimed at injury prevention, should include tests for the lower abdominals and individual core stabilisers.

In summary, moderate or highly significant improvements were found in the vertical jump, bleep, pull-ups and push-ups tests. Although most of the remaining physical and motor variables may actually also have improved more in the experimental groups than in the matching control groups, the effect of the prevention programme was not always enough to cause differences of moderate or high practical significance. Furthermore, it must be remembered that from the beginning of the study (T1) up to the end of the first (T3) and second year (T6), the experimental groups predominantly recorded significantly better values in the physical and motor tests than the control groups (see mean values in Table 5.7). This result was recorded in the vertical jump (15- and 16-year olds); 10 m speed (15- and 16-year olds); 30 m speed (15- and 16-year olds); Illinois agility (15- and 16-year olds); speed endurance (15-year olds); bleep (15- and 16-year olds); pull-up (16-year olds); push-up (15- and 16-year olds); and left and right grip strength (15- and 16-year olds) tests. This means that throughout the competitive seasons – as a result of their highly significantly better speed, power and thus momentum – the experimental groups may have been at an increased risk for extrinsic injury (Noakes & Du Plessis, 1996). To sum up, in practice it can be said that the prevention programme had a moderately or highly significantly positive effect on the vertical jump, bleep (only 16-year olds), pull-up (only 15-year olds) and push-up tests of the experimental groups over the total two-year period. Lastly, future injury prevention

programmes should also concentrate more on improving results in the 7-stage abdominal strength test, while including additional tests for lower abdominal strength, and each of the core stabilising muscles.

Table 5.10: Inter-group comparison of changes in physical and motor components between experimental and control groups

INTER-GROUP COMPARISON BETWEEN EXPERIMENTAL AND CONTROL GROUP							
VARIABLES	MSE OF ANOVA	15-YEAR OLD EXPERIMENTAL AND CONTROL GROUP			16-YEAR OLD EXPERIMENTAL AND CONTROL GROUP		
		d-value	d-value	d-value	d-value	d-value	d-value
		1 st season	2 nd season	whole period	1 st season	2 nd season	whole period
Physical-and motor variables							
Vertical jump (cm)	0.33	0.8 [▼]	0.5	0.8 [▼]	/	1.2 [▼]	1.5 [▼]
10 m speed (sec)	0.002	--	--	--	--	--	--
30 m speed (sec)	0.19	--	--	--	--	--	--
Illinois agility (sec)	0.30	--	--	--	--	--	--
Speed endurance (%)	0.0002	--	--	--	--	--	--
Bleep (level)	0.01	0.6	--	--	--	0.8 [▼]	0.7
Pull-ups (n)	0.79	--	0.7	0.6	0.9 [▼]	0.5	--
Push-ups (n)	5.5	0.9 [▼]	0.8 [▼]	1.5 [▼]	0.6	--	1.1 [▼]
7-stage abdominal strength test (n)	0.12	1.3 [▼]	0.8 [▼]	0.8 [▼]	1.0 [▼]	0.6	0.6
Grip strength left (kg)	2	--	--	--	--	--	--
Grip strength right (kg)	7	--	--	--	--	--	--

MSE = Mean square error of ANOVA, a measurement of variance in data

d-value = intra-group comparison, comparing the changes over time in the experimental group to the changes in the matching control group

1st season = first year of intervention, changes from T1 to T3

2nd season = second year of intervention, changes from T4 to T6

whole period = The whole intervention period, from T1 to T6

▼ = practically significant ($d \geq 0.8$) inter-group difference between testing episodes (large effect)

-- = Difference was not of medium ($d \geq 0.5$) or large ($d \geq 0.8$) practical significance

5.5.3 INTER-GROUP COMPARISON OF BIOMECHANICAL AND POSTURAL RESULTS

The results of the inter-group comparison for the biomechanical and postural variables are given in Table 5.11. Only tests which improved with medium ($d \geq 0.5$) and high ($d \geq 0.8$) practical significance are shown in the table. When considering the *lower limb dynamic mobility*, the results reveal that in practice, moderately and highly significant differences occurred during the first season (T1 to T3), second season (T4 to T6) and the whole study period (T1 to T6). These effect sizes ranged from 0.5 to 3.4. Generally, this occurred in the TA, modified Thomas (ITB, quadriceps, iliopsoas), gluteus maximus and hip external rotation tests. When observing the TA test during the second season (T4 to T6) the differences between matching experimental and control groups were of low practical significance ($d \geq 0.2$) and are therefore not shown in the table.

Interestingly, when comparing the matching experimental and control groups during the off-season (see Figures 5.5(A)-(F)), the deterioration in lower limb dynamic mobility during the *off-season* (period between T3 and T4) was neither moderately nor highly significant. Consequently it can be said that in practice, the effect of the prevention programme on lower limb dynamic mobility during the off-season was large enough for the experimental groups to maintain their mobility in comparison to the control groups. Still considering lower limb dynamic mobility, regions which *did not improve* with a moderately or highly practically significant amount over the whole 2-year period of intervention were the adduction (15- and 16-year olds), and left as well as right hip internal rotation (15- and 16-year olds). However, the adduction and hip internal rotation tests recorded almost ideal values at the start of the study and were therefore difficult to improve much further.

Except for the VMO-L (left and right) comparison test among the 15-year olds, no moderately or highly significant effects were recorded for the tests of *lower limb positional alignment*. The most probable reason for this being that – unlike the VMO-L comparison test – the position of the knee complex and foot and ankle regions are often a result of structural deformities (Brukner & Khan, 2001), which are not easily corrected through exercise.

Table 5.11: Inter-group comparison of changes in biomechanical and postural components between matching experimental and control groups

INTER-GROUP COMPARISON BETWEEN EXPERIMENTAL AND CONTROL GROUP							
VARIABLES	MSE OF ANOVA	15-YEAR OLD EXPERIMENTAL AND CONTROL GROUP			16-YEAR OLD EXPERIMENTAL AND CONTROL GROUP		
		d-value 1 st season	d-value 2 nd season	d-value whole period	d-value 1 st season	d-value 2 nd season	d-value whole period
LOWER LIMB							
<i>Lower limb dynamic mobility</i>							
TA L	0.41	0.6	--	0.6	0.5	--	0.6
TA R	0.06	1.8	0.7	1.6	1.4	--	1.6
ITB L	0.05	2.5	1.0	2.5	1.8	0.9	2.4
ITB R	0.06	2.7	1.4	2.4	2.7	0.7	3.0
Quadriceps L	0.06	1.6	0.7	1.8	1.9	1.0	2.3
Quadriceps R	0.05	1.9	0.5	1.9	2.2	1.0	2.7
Iliopsoas L	0.06	2.0	1.0	1.9	2.3	1.0	3.1
Iliopsoas R	0.06	2.2	1.2	2.0	2.7	0.8	3.4
Gluteus maximus L	0.05	1.9	0.6	2.1	1.9	0.8	2.1
Gluteus maximus R	0.05	2.2	0.8	2.4	1.9	0.6	1.6
Hip external rotation L	0.05	0.8	1.0	1.8	1.2	0.6	1.6
Hip external rotation R	0.04	0.7	1.0	2.0	1.3	0.7	1.8
<i>Lower limb positional alignment</i>							
<i>Knee complex</i>							
VMO-L comparison L	0.01	--	--	0.7	--	--	--
VMO-L comparison R	0.01	--	0.7	1.0	--	--	--
<i>Foot and Ankle region</i>							
No variables with significant variance							
PELVIC GIRDLE REGION							
Leg length discrepancy	0.05	1.5	0.5	1.9	1.6	--	1.8
ASI	0.05	1.5	0.5	1.9	1.5	0.5	1.8
PSIS	0.05	1.5	0.5	1.9	1.5	0.5	1.8
Pelvic rami position	0.05	1.5	0.5	1.9	1.5	0.5	1.8
Bilateral pelvic position	0.06	1.8	1.5	2.6	2.6	0.8	3.3

Table 5.11 continues

VARIABLES	MSE OF ANOVA	15-YEAR OLD EXPERIMENTAL AND CONTROL GROUP			16-YEAR OLD EXPERIMENTAL AND CONTROL GROUP		
		d-value 1 st season	d-value 2 nd season	d-value whole period	d-value 1 st season	d-value 2 nd season	d-value whole period
SPINAL REGION							
<i>Spinal dynamic mobility</i>							
TLF L	0.04	1.6	--	1.3	1.0	0.7	1.5
TLF R	0.04	1.8	--	1.5	1.0	0.7	1.5
Functional extension	0.01	0.7	--	0.7	--	--	--
Functional flexion	0.03	1.4	--	1.2	0.6	--	0.8
Rotation L	0.01	0.7	0.7	0.7	0.7	--	0.7
Rotation R	0.01	0.9	0.9	0.9	/	--	--
Side flexion L	0.007	0.5	0.5	0.5	0.8	--	0.8
Side flexion R	0.007	0.5	0.5	0.5	0.8	--	0.8
<i>Spinal positional alignment</i>							
<i>Coronal axis</i>							
Head position	0.004	--	0.5	0.5	--	1.1	1.1
Thoracic position	0.03	1.2	--	0.8	0.6	--	0.8
Lumbar position	0.08	1.1	1.5	2.0	2.2	0.9	3.0
<i>Sagittal axis</i>							
No variables with significant variance							
UPPER LIMB							
Hand behind back ROM L	0.02	0.7	--	0.7	0.9	0.5	1.4
Hand behind back ROM R	0.02	0.7	--	0.5	1.2	0.5	1.6
Hand behind neck ROM L	0.001	--	--	--	0.9	--	0.9
Hand behind neck ROM R	0.001	--	--	--	0.9	--	0.9
Shoulder positional test L	0.05	0.6	1.2	1.8	0.8	0.6	1.0
Shoulder positional test R	0.05	0.6	1.2	1.8	0.8	0.6	1.2
Winging positional test L	0.04	--	--	0.7	0.8	0.7	1.3
Winging positional test R	0.04	--	0.8	1.2	0.8	0.5	1.2
Shoulder outline composition L	0.04	1.5	0.7	1.3	0.8	--	0.8
Shoulder outline composition R	0.04	1.5	0.7	1.3	0.8	--	0.8
Throwing position L	0.008	--	--	--	0.8	--	0.8
Throwing position R	0.008	--	--	--	0.8	--	0.8

Table 5.11 continues

VARIABLES	MSE OF ANOVA	15-YEAR OLD EXPERIMENTAL AND CONTROL GROUP			16-YEAR OLD EXPERIMENTAL AND CONTROL GROUP		
		d-value 1 st season	d-value 2 nd season	d-value whole period	d-value 1 st season	d-value 2 nd season	d-value whole period
NEURODYNAMICS							
Straight leg raise L	0.05	1.9 [▼]	0.6	1.8 [▼]	1.0 [▼]	0.5	1.3 [▼]
Straight leg raise R	0.05	2.1 [▼]	0.5	1.8 [▼]	0.8 [▼]	1.0 [▼]	1.6 [▼]
Upper limb tension L	0.001	0.9 [▼]	--	0.9 [▼]	--	--	--
Upper limb tension R	0.001	0.9 [▼]	--	0.9 [▼]	--	--	--
L3,4 prone knee bend L	0.04	2.5 [▼]	0.7	1.5 [▼]	1.5 [▼]	--	1.7 [▼]
L3,4 prone knee bend R	0.04	2.7 [▼]	0.5	1.8 [▼]	1.3 [▼]	--	1.7 [▼]

MSE = Mean square error of ANOVA, a measurement of variance in data

d-value = intra-group comparison, comparing the changes over time in the experimental group to the changes in the matching control group

1st season = first year of intervention, changes from T1 to T3

2nd season = second year of intervention, changes from T4 to T6

whole period = The whole intervention period, from T1 to T6

-- = Difference was not of medium ($d \geq 0.5$) or large ($d \geq 0.8$) practical significance

The results of the *pelvic girdle region* indicate that differences between experimental and control groups reached moderately and highly practically significant differences for the leg length, ASIS, PSIS, rami positional and bilateral pelvic positional tests of the 15-year olds and 16-year olds over the course of the first season, second season and the total study period, indicating that the prevention programme was effective in improving the amount of pelvic symmetry and pelvic tilt in the experimental groups during the first season, second season and total study period. During the off-season, no significant deterioration was observed with regard to the pelvic girdle region, and consequently the status of the experimental groups were closer to ideal at the start of the second season. This close to ideal position at the start of the second season (e.g. Figure 5.5(H)) is also the most apparent reason why the two experimental groups improved less significantly with regard to their pelvic girdle region during the second season. Concerning the sacroiliac cleft test during the first, second and total period, it can be seen that no highly significant differences occurred. However, this test remained at ideal throughout the study, and could therefore not improve any further.

In the *spinal region*, regarding the dynamic mobility of the spine, the results of medium or large practical significance are those seen in the left and right TLF, functional extension, functional flexion, left and right rotation, and left and right side flexion tests. In the division of the spinal positional alignment, medium or large effect sizes were observed in the head positional (coronal axis), thoracic positional (coronal axis) and lumbar positional (coronal axis) tests. In general, these data indicate that several moderately or highly significant effects occurred during the first season, second season and total period. In practice, the results reveal that both the 15- and 16-year old groups experienced their largest number of highly significant improvements during the first season (T1 to T3), and total period of two years (T1 to T6). Most importantly, given the *total period of two years*, it can be said that the prevention programme managed to improve the left and right TLF, functional flexion, left rotation, left and right side flexion, head positional alignment (coronal axis), thoracic positional alignment (coronal axis) and lumbar positional alignment (coronal axis) of both the experimental groups either moderately or highly significantly.

The reasons why the 16-year olds did not record effects of medium or high practical significance in the functional extension or right rotation tests over the total period is that the 16-year old control group also improved in functional extension, while the experimental group did not improve enough on right rotation. The remaining tests of *dynamic spinal mobility* and *spinal positional alignment* did not record d-values of medium or high effect. A probable explanation for this is that – except for the thoracic position in the sagittal axis – these other tests already recorded values closer to ideal during the first testing episode (T1) (Table 5.8) and were consequently more difficult to improve. The result for the thoracic position in the sagittal axis is probably due to quadratic dominance (Hattingh, 2003).

Comparison of transformations which occurred in the status of the *upper limb* (Table 5.11) reveals that the 15- and 16-year old groups shared moderately and highly significant effects in certain tests. Generally this occurred in the hand behind back ROM (left and right), shoulder positional test (left and right), winging positional test (left and right) and shoulder outline composition test (left and right).

Concerning the important *total period of two years*, Table 5.11 demonstrates that in practice both the 15- and 16-year old experimental groups improved highly significantly ($d \geq 0.8$) with regard to the hand behind back ROM (left and right) shoulder positional test (left and right), winging positional (right) and shoulder outline composition (left and right), when compared to the control groups. This confirms the positive effect of the prevention programme on the hand behind back ROM (left and right), shoulder positional (left and right), winging positional (right) and shoulder outline composition test (left and right) of both the experimental groups, especially when the whole two-year period is considered. Furthermore, both the age groups also shared highly significant improvements in the shoulder outline composition test (left and right) during the *first season*.

When the remaining *upper limb* changes in the experimental and control groups are compared (changes that are not shared by both age groups), it is clear that large effect sizes ($d \geq 0.8$) are visible in the left ($d=0.9$) and right ($d=1.2$) hand behind back ROM of the 16-year olds (first season), left ($d=0.9$) and right ($d=0.9$) hand behind neck ROM of the 16-year olds (first season, and total period), left ($d=1.2$) and right ($d=1.2$) shoulder positional of the 15-year olds (second season) and 16-year olds (first season) ($d=0.8$), left winging of 16-year olds (first season) ($d=0.8$), right winging of the 15-year olds (second season) ($d=0.8$) and 16-year olds (first season) ($d=0.8$) and left and right throwing position tests of the 16-year olds (first season and total period) ($d=0.8$).

In addition, during closer examination of the experimental groups (Table 5.8), it becomes clear that – except for the winging positional (left and right) test of the 15-year olds (T3, T4) – all upper limb tests remained closer to ideal (closer to a value of 1 than to a value of 2) after the implementation of the prevention programme (T3, T4, T6), and were therefore more difficult to improve during the second season, suggesting that the prevention programme was not largely effective in improving winging (left and right) of the 15-year old experimental group during the first season. Lastly, compared to the 15-year old control group, the 15-year old experimental group recorded a highly significant decline ($d=0.8$) in left and right shoulder outline composition (not shown in the tables, but visible in Figure 5.5(Q)) during the off-season, but improved ($d=0.7$) again during the following season.

Results of the last one of the five biomechanical and postural regions, that is *neurodynamics*, indicate that over the course of the study the upper limb tension (left and right) and slump tests always revealed a tendency towards very low (close to ideal) values, and consequently did not need to improve much. In contrast, the status of the straight leg raise and L3,4 prone knee bend tests warranted improvement. In actual practice, the results in Table 5.11 indicate that the prevention programme improved the straight leg raise (left and right) and L3,4 prone knee bend tests of the 15- and 16-year olds highly significantly over the first season as well as the total study period. Finally, in comparison to the control group, the 15-year old experimental group also achieved highly practically significant improvements in the upper limb tension test (left and right) during the first season and total study period.

In summary, the biomechanical and postural changes which developed during the first season, second season and the total period within each experimental group were compared to those which developed in the matching control group during the same period of time. Several moderately and highly practically significant effects were visible. Therefore, in practice, it can be said that the prevention programme caused the following improvements: moderately or highly significant improvement in the TA, modified Thomas (ITB, quadriceps, iliopsoas), gluteus maximus and hip external rotation tests during the first season (T1 to T3), second season (T4 to T6) and whole study period (T1 to T6) of both age groups, and moderately and highly significant improvements in leg length discrepancy, ASIS, PSIS, pelvic rami positional and bilateral pelvic positional tests of the 15-year olds and 16-year olds over the course of the first season, second season and the total period of intervention; moderately and highly significant improvements in the TLF, functional flexion, left rotation and side flexion tests of both age groups over the two-year period together with either moderately or highly measurable improvements in the TLF, functional extension, functional flexion, side flexion and rotation tests during the other periods; highly significant improvements in the spinal lumbar positional (coronal axis) test during the first season, second season and the total period of both groups; scattered improvements of moderate and high practical significance in the head position (coronal axis) and thoracic position (coronal axis); moderately or highly practically significant improvements in the hand behind back

ROM, shoulder positional, winging positional, and shoulder outline composition tests of both the 15 and 16-year old experimental groups over the total two year period, with scattered improvements in the remaining upper limb tests during other periods; medium or highly practically improved straight leg raise and L3,4 prone knee bend tests of the 15-year olds and 16-year olds during the first season, second season and the total period; highly practically significant improvements in the upper limb tension tests of the 15-year old group of players during the first season and the total study period.

A probable explanation for the lack of moderately and highly significant improvement in the other biomechanical and postural variables during specific periods is that these variables already recorded values closer to ideal at the periods in question, and were subsequently more difficult to improve, except for the right spinal rotation test of the 16-year olds, and thoracic positional test in the sagittal axis of both the 15- and 16-year olds, which warrants additional improvement.

All in all, positive changes in the experimental groups outweighed those of the control groups. It can therefore be assumed that by the end of the study, the prevention programme had provided the experimental groups with a more balanced (closer to ideal) dynamic mobility, core stability and postural symmetry. This is important as the ability to obtain a more ideal biomechanical and postural status may be important in reducing intrinsic injuries. The possible shortcomings of the prevention programme will be discussed in more detail in the next section (5.6).

5.6 IDENTIFIED DEFICIENCIES IN THE CURRENT PREVENTION PROGRAMME

The purpose of this chapter was to describe the intrinsic, extrinsic and overall incidence of injury as experienced by the different experimental and control groups during two full school rugby seasons, and to determine what effect an approved injury prevention programme had on these rugby injury incidences, as well as on the anthropometric, physical and motor, and biomechanical and postural variables over a period of two years. Originating from this,

specific deficiencies were identified. Identifying these deficiencies makes it possible to recommend effective modifications to the prevention programme (see Chapter 6, section 6.3.1), in so doing realising the sub-aim of this study. Deficiencies which had a direct bearing on the hypotheses were the following:

- *Extrinsic injury incidence* remained largely unaffected by the prevention programme;
- the inability of the prevention programme to significantly alter the *anthropometric composition* of subjects;
- deterioration in the *fat percentage* during the off-season;
- in the categories of *speed, agility, speed endurance* (running) and *strength* (7-stage abdominal strength, grip strength) the prevention programme did not have the desired effect;
- *running speed, strength, agility, speed endurance, aerobic endurance* and *power loss* during the off-season;
- deterioration in the *biomechanical and postural status* occurred during the off-season;
- the inability of the preventative exercises significantly to alter the positional alignment of the *knee complex, and foot and ankle region*;
- unsatisfactory improvements during the first year of intervention in the *right rotation* test (*spinal*) (16-year olds), and left and right *winging* tests (15-year olds) when comparing experimental to control groups,
- insufficient improvements during the second year of intervention in the *right rotation (spinal)* test (16-year olds), *thoracic position* test in the coronal axis (15 and 16-year olds), *thoracic position* test in the sagittal axis (15 and 16-year olds) and *left winging* test (15-year olds) when comparing experimental to control groups;
- insufficient improvements over the **total period** of intervention (whole 2 years) in the *right rotation (spinal)* test (16-year olds), and *thoracic position* test in the coronal axis (15- and 16-year olds) when comparing experimental to control groups;

- finally, not enough maintenance in the *right TA, left and right ITB, left and right iliopsoas, right spinal rotation, thoracic position in the coronal axis and left and right L3,4 prone knee bend* tests of the 15-year olds during the off-season.

The information from these identified deficiencies can now be used to recommend modifications to the prevention programme, in order for it to be more effectively applied at high school rugby level. Recommended modifications to the prevention programme are discussed in Chapter 6, section 6.3.1.

5.7 SUMMARY OF MOST IMPORTANT FINDINGS OF THE EMPIRICAL STUDY

5.7.1 INJURY INCIDENCE

In summary, it is noted that in practice the ability of the prevention programme to control overall injury incidence actually depends on the programme's effect on the intrinsic as well as the extrinsic injury incidence (overall injury incidence = intrinsic injury incidence + extrinsic injury incidence). The prevention programme was not geared towards reducing extrinsic injury incidence, as there are too many unpredictable elements (associated with contact situations) present in the occurrence of these injuries. Consequently, differences and changes in extrinsic injury incidence in this study could not be attributed to the effect of the prevention programme, and as a result injury trends related to overall injury incidence were inconsistent when comparing the experimental groups to the matching control groups.

Considering intrinsic injury incidence separately, it can be seen that from the first to the second season a highly practically significant reduction was visible in the intrinsic injury incidences of the 15-year old ($d=1.45$) as well as 16-year old ($d=1.04$) experimental groups, while an insignificant escalation was found in the two control groups. This provides evidence that the groups which followed the prevention programme always experienced the smaller risk of intrinsic injury. The most likely explanation for these finding is that the prevention programme had a positive effect on the intrinsic injuries of the two experimental

groups during the first as well as the second season, and that this effect was possibly more pronounced during the second season.

5.7.2 ANALYSIS OF SPORTS-MEDICAL INJURY RECORDS

When comparing the injury records (section 5.3) of the experimental and control groups during each of the two years, the results reveal different general trends. In summary, ligament/joint sprains as well as other injuries related to body contact accounted for most injuries in the groups which reported predominantly extrinsic injuries, while muscle/tendon strain and overuse injuries were dominant in the groups which reported mostly intrinsic injuries. Therefore, the positive effect of the prevention programme on the intrinsic injury incidence of the experimental groups is probably related to its effect on intrinsic injuries which occur due to overuse. This is indicative of the positive effect of the injury prevention programme on injuries of the overuse type (such as bursitis, medial tibial stress syndrome, and stress fractures).

Injuries to the lower limb are most common among the groups in this study. The relationship between different phases of play and lower limb injuries were not analysed for the purpose of this study. Therefore it is difficult to say if it was the prevention programme or rather a reduction in the occurrence of certain phases of play which was responsible for decreases in percentage of injuries allocated to the lower limb. Furthermore, although injuries to the lower limb are most common, concussions still occur frequently among schoolboys, and the question can be asked if sufficient strategies exist to control this phenomenon.

The majority of injuries in each group occurred during matches. This is explained by the competitive nature of matches. In this study, changes in intrinsic injury incidence may have been responsible for changes visible in the percentage of injuries which occurred during practice, as intrinsic injuries almost always occurred during practice.

A sub-analysis of intrinsic injuries revealed that a high percentage of intrinsic injuries during the first season were due to re-injury. During the second season, this situation improved

dramatically in the groups which followed the prevention programme. This might suggest that the programme restored certain impaired functions during the first season, and therefore had more of a rehabilitative effect than a preventative effect. Because of this rehabilitative effect during the first season, deficiencies were removed, and the programme could reach its preventative potential during the second year. Originating from this, it is advised that teams who wish to implement this programme do so early on – during the previous off-season, instead of the current pre-season.

5.7.3 ANTHROPOMETRIC VARIABLES

The lack of contrasting trends between the anthropometric components of matching experimental and control groups confirms that the prevention programme was not specifically designed to change the anthropometric composition of subjects. Most changes which did occur may be due to other factors, such as the natural growth phase of boys. The natural increase in stature seen among the boys during the total period of two years could render them less flexible, and more susceptible to injury (Micheli, 1983; Armstrong & McManus; 1996). A deterioration is visible in the fat percentage (Figure 5.3 (F)) during the off-season (T3 to T4), which could signify a slackening in physical activity levels.

5.7.4 PHYSICAL AND MOTOR VARIABLES

Firstly, intra-group comparisons were calculated for each 15- and 16-year old experimental and control group. Intra-group comparisons established highly practically significant changes in the strength, running speed, agility, speed endurance and aerobic endurance tests of all groups. In general the improvements in these areas were as expected of schoolboys of this age. As similar trends occurred in the physical and motor variables of all experimental and control groups – the improvements in the experimental groups could not be attributed to the effect of the prevention programme. Therefore, inter-group comparisons – comparing changes in the experimental to those in the control group – were needed (Table 5.6).

During the inter-group comparisons, moderate or highly practically significant improvements were recorded in the vertical jump, bleep (only 16-year olds), pull-ups (only 15-year olds), and push-up tests of the experimental groups over the total two-year period.

Lastly, as a result of their highly significantly better speed, power and momentum, the experimental groups may have been at an increased risk of extrinsic injury throughout the season (Noakes & Du Plessis, 1996). Future prevention programmes should give more attention to the retention of physical and motor abilities during the off-season, while allowing for adequate rest and recovery, and should focus on improving results in the 7-stage abdominal strength test, while also including tests for lower abdominal strength and the core stabilisers.

At the final testing episode (T6), the 10 m speed, 30 m speed, Illinois agility, aerobic endurance, speed endurance, number of push-ups (except in the 15-year old control group), 7-stage abdominal strength, and left and right grip strength outperformed those in earlier studies.

Considering the power component (vertical jump) at the conclusion (T6) of the study, the groups in this study were outperformed by those in the study of Hattingh (2003:91), but not by those in the study of Van Gent (2003:139). The number of pull-ups was similar to those achieved in the Hattingh (2003:91) study.

5.7.5 BIOMECHANICAL AND POSTURAL VARIABLES

The biomechanical and postural results in Table 5.8 made it clear that the characteristics of all the groups revealed certain mean biomechanical and postural values closer to non-ideal (a value of 2) *before the implementation of the prevention programme* (T1), rendering these areas less mobile, dynamically loaded, with inadequate core stability, and therefore susceptible to intrinsic injury. The biomechanical and postural status at this stage (T1) was typical of the developmental phase of the adolescent player.

The *intra-group* comparison *at the end of the first season of intervention* revealed that only the two experimental groups improved highly significantly in all the dynamic mobility, and positional tests which were a cause of concern (closer to non-ideal) at T1, with the exception of hip external rotation as well as winging in the 15-year old experimental group, and the thoracic position (sagittal axis) as well as shoulder position in both experimental groups. Furthermore, additional *intra-group* improvements also occurred in dynamic mobility and positional tests which were already close to ideal at T1. Even though the experimental teams followed an off-season exercise programme, some highly significant deterioration occurred after the end of the first season (from T3 to T4). This occurred in a few tests in the 15-year old experimental group (Figures 5.5 A, B, D, M, T). During the second season, when the difficulty of the prevention programme was stepped up, these areas improved once more.

Similar to the first season, the *intra-group* comparison for the *second season* (T4-T6) indicated several highly practically significant improvements in dynamic mobility and positional tests in the two experimental groups, which were not visible in the control groups.

These changes within each group, when considered for *the total period of two rugby seasons*, proved that the prevention programme provided the experimental groups with a more balanced (closer to ideal) dynamic mobility, core stability and regional position.

The above-mentioned *intra-group* comparisons revealed several improvements in the biomechanical and postural status of the experimental groups. However, biomechanical and postural changes – although not necessarily practically significant – also occurred within the two control groups. Therefore further statistical techniques (*inter-group comparisons*) were applied to confirm that the improvements which developed in the experimental groups were practically significant when compared to the changes in the matching control groups over the same periods of time.

In short, the *inter-group comparison* revealed numerous moderately and highly practically significant effects. Thus, according to the *inter-group comparison*, it can be said that in practice the prevention programme caused the following improvements:

- moderately or highly significant improvement in the TA, modified Thomas (ITB, quadriceps, iliopsoas), gluteus maximus and hip external rotation tests during the first season (T1 to T3), second season (T4 to T6) and whole study period (T1 to T6) of both age groups;
- moderately and highly significant improvements in the leg length discrepancy, ASIS, PSIS, pelvic rami positional and bilateral pelvic positional tests of the 15-year olds and 16-year olds over the course of the first season, second season and during the total period of intervention;
- moderately and highly significant improvements in the TLF, functional flexion, left rotation and side flexion tests of both age groups over the total 2-year period, together with either moderately or highly measurable improvements in the TLF, functional extension, functional flexion, side flexion and rotation tests during the other periods;
- highly significant improvements in the spinal lumbar positional test during the first season, second season and total period of both groups;
- scattered improvements of moderate and high practical significance in the head position (coronal axis) and thoracic position (coronal axis); moderately or highly practically significant improvements in the hand behind back ROM, shoulder positional, winging positional and shoulder outline composition tests of both the 15 and 16-year old experimental groups over the total two year period, with scattered improvements in the remaining upper limb tests during other periods;
- medium or highly practically significant improved straight leg raise and L3,4 prone knee bend tests of the 15-year olds and 16-year olds during the first season, second season and total period; and
- highly practically significant improvements in the upper limb tension tests of the 15-year old group of players during the first season and total study period.

A probable explanation for the lack of moderately and highly significant improvement in the other biomechanical and postural variables during specific periods is that these variables already recorded values closer to ideal during the periods in question, and were subsequently

more difficult to improve, except for the right spinal rotation test of the 16-year olds, which warrants additional improvement.

All-in-all, positive changes in the experimental groups outweighed those of the control groups. Furthermore, the effectiveness of the prevention programme in preventing specific biomechanical and postural deterioration over a period of two rugby seasons was noted. It can therefore be assumed that the prevention programme provided the experimental groups with a more balanced (closer to ideal) dynamic mobility, core stability and postural symmetry. This is important as the ability to obtain a more ideal biomechanical and postural status may be important in reducing intrinsic injuries. In fact, over the course of the study the two experimental groups improved to such an extent that by the end of the intervention (T6) their biomechanical and postural status was superior to the comparable age group in the Hattingh (2003:92-93) study, except for the tests of left and right forefoot position (15 and 16-year olds) and thoracic position in the sagittal axis (15-year olds).

Lastly, the inability of the preventative exercises to significantly alter the positional alignment of the knee complex and foot and ankle region was documented. The possible shortcomings of the prevention programme were discussed in section 5.6.

6

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

- 6.1 Summary
 - 6.2 Conclusions
 - 6.3 Recommendations
 - 6.4 Limitations
-

6.1 SUMMARY

From the literature it is evident that modern rugby has evolved into a sport which places specific demands upon players. Firstly, increases in the number of tackles, rucks per player and average weight per player are all developments characteristic of the modern-day game (Wilson, 2000; Quarie *et al.*, 2001). Furthermore, the nature of the game has changed from that of a contact sport to a collision sport, where the body has to absorb more impact (Wilson, 2000; Holtzhausen, 2001). Secondly, players nowadays are subjected to an increased training load as a result of longer seasons and more time spent improving fitness, strength and speed through very specific and advanced training programmes (Noakes & Du Plessis, 1996; Wilson, 2000; Holtzhausen, 2001; Hattingh, 2003). One of the results of these changes in modern rugby is an increase in the number of rugby injuries (overall, intrinsic and extrinsic). This tendency of an unacceptable rise in injury epidemiology is already visible at South African youth level (Roux, 1992; Lee & Garraway, 1996; Jakoet, 2002; Hattingh 2003).

The schoolboy rugby players most at risk of injury are fifteen to nineteen year old A team players (CHIRPP, 1995; Noakes & Du Plessis, 1996) and adolescent players who are experiencing or who have just completed their growth spurt (Caine *et al.*, 1989; Stanitski,

1989). The players are particularly at risk during the early season period, and just after the mid-season recess period of the season (Sparks, 1981; Williams, 1984; Noakes & Du Plessis, 1996). Seeing that rugby injuries are present from a young age, it makes sense to combat rugby injuries from an early age – before the risk of injury becomes an even bigger problem (Noakes & Du Plessis, 1996).

In spite of the rise in injury epidemiology, most South African schools do not maintain adequate intervention programmes (Noakes & Du Plessis, 1996; Upton *et al.*, 1996). Many school coaches, advocates of talent development and selectors, however, do put a high priority on the development of bigger, stronger, faster and more skilful players who can excel at their sport (Quarrie *et al.*, 1996; Hare, 1999; Hanekom, 2000). One dilemma concerning this is that athletes often become injured as they become stronger and faster, and develop poor biomechanics (joint symmetry, dynamic muscle mobility and core stability) and posture in the process. Poor biomechanics and posture render the athlete prone to overuse-type injuries (Brukner & Khan, 2001; Sahrmann, 2002; Bell-Jenje & Bourne, 2003; Hattingh, 2003). Topical research by Hattingh (2003:185) revealed major shortcomings in elite senior school rugby players in certain biomechanical and postural areas. Many other researchers agree that schoolboy rugby programmes can be improved, as they do not place enough emphasis on the prevention of injuries (Nathan *et al.*, 1983; Lee & Garraway, 1996; Upton *et al.*, 1996; Quarrie *et al.*, 1996).

Some examples of successful injury prevention strategies, though, can be found in senior rugby. The New Zealand Rugby Union, for example, has managed to reduce their injury rate by approximately 47% through the implementation of a total prevention programme, the so-called ACC (Accident Compensation Cooperation) Sport Smart 2000 programme. Ten components addressed and researched in the programme were the following (Quarrie *et al.*, 2001):

- (i) Screening
- (ii) Warm-up/cool-down
- (iii) Physical condition

- (iv) Technique
- (v) Fair play
- (vi) Protective equipment
- (vii) Hydration and nutrition
- (viii) Injury surveillance
- (ix) Environmental factors
- (x) Injury management

From the literature it is evident that modern rugby has evolved into a sport which demands specific anthropometric (Olds, 2001; Swart, 2002), physical and motor (Nicholas, 1997; Van Gent, 2003) and biomechanical and postural characteristics (Hattingh, 2003) from players. Keeping in mind the modern anthropometric, physical and motor and biomechanical and postural demands of the game, it is apparent that it is necessary to prevent rugby injuries. Although several senior rugby teams already have injury prevention strategies in place, many South African schools are still lacking in this regard.

Accordingly, a question of interest which arises out of the literature is whether an approved injury prevention programme has an effect on the rugby injuries (overall, intrinsic and extrinsic injuries) of schoolboys. A second question is what the effect of an approved injury prevention programme can be on selected anthropometric, physical and motor and biomechanical and postural (symmetry, dynamic mobility and positional core stability) variables. Answers to these questions will provide more data on schoolboy rugby injuries, specific norms and characteristics of various schoolboy player groups, and their risk of injury. Furthermore, the results will supply useful advice to players, teachers/coaches, medical teams and management on how to prevent, reduce and manage injuries.

Following from the above-mentioned questions, the aims of this study were to determine:

1. the effect of an approved injury prevention programme on the incidence of rugby injuries (overall, intrinsic and extrinsic injuries) of 15- and 16-year old schoolboys over a two-year period;

2. the effect of this injury prevention programme on selected anthropometric, physical and motor, and biomechanical and postural variables of all the groups involved in this study, over the selected period of two years.

Originating from these aims, a sub-aim of this study was then to propose modifications – if necessary – to the prevention programme that was used in this study in order for it to be used effectively by high school rugby coaches.

To achieve these aims, two groups of high-school, male rugby players (N=120) were chosen and studied over a period of two years, namely the year 2004 elite A-team players (15- and 16-year-olds) and the 2004 elite B-team players (15- and 16-year-olds). Data concerning the previous injury history of all players was acquired through a current and previous injury questionnaire (Annexure A.2). The occurrence of injuries was documented through *free* sports-medical clinics, held weekly. At these clinics the injured players completed a coded injury report form (Annexure A.3), were screened by the medical team, and referred for rehabilitation if necessary. At the end of each season, the relevant data needed for the study were extracted from the injury report forms and analysed. Biomechanical and postural data collected were noted on a coded biomechanical and postural assessment form (Annexure A.4), while a rugby data sheet (Annexure A.5) was used to record anthropometric plus physical and motor data.

The tests and protocols which were used in this study were chosen on basis of the literature, and their usefulness has been proven in previous rugby studies (Hare, 1997; Hare, 1999; Hanekom, 2000; Hanekom, 2003; Hattingh, 2003; Spamer & Winsley, 2003; Van Gent, 2003; Plotz, 2004). Anthropometric, physical and motor, as well as biomechanical and postural testing were completed six times over a two-year period. This lasted from February 2004 to August 2005 (a period of two school rugby seasons). During each of the two years there were three testing occasions where all players were tested: pre-season (T1), during the mid-season break (T2) and at the end of season (T3). The results of the tests were used to monitor changes in each player's profile during various stages of the training programme, and to modify the prevention programme of the experimental groups accordingly.

All players in the experimental group received periodised prevention programmes in accordance with the guidelines described by Hattingh (2003:182-184). However, a post-season transition phase (Twist, 1997) (Chapter 4, Figure 4.2) was added to the periods described by Hattingh (2003:182-184). For the prescription of specific exercises, the present study chiefly used the exercises suggested by Hattingh (2003:210-276). However, in order to improve the effect of this programme, exercises were combined with a few protocols recommended in various other publications (Turnbull *et al.*, 1995; Noakes & Du Plessis, 1996; Twist, 1997; Hazeldine & McNab, 1999; Prentice, 1999; Arnheim & Prentice, 2000; Brown *et al.*, 2000; O'Sullivan, 2000; Brukner & Khan, 2001; Mottram & Comerford, 2001; Schweltnus & Derman, 2001b; Sahrmann, 2002; Luger & Pook, 2004).

Each of the two years consisted of the same seven phases, namely:

- 1: Pre-season programme (3-week preparation programme)
- 2: Start-of-season programme. *Level 1* (6-week maintenance programme)
- 3: Start-of-season programme. *Level 2* (advanced maintenance programme)
- 4: Mid-season programme (1-week conditioning programme)
- 5: Mid-season programme. *Level 3* (most advanced conditioning programme)
- 6: Post-season transition programme (3 weeks active rest, recovery and corrective biomechanical/postural exercise)
- 7: Off-season programme (low-key programme)

The results of this longitudinal prevention programme were analysed in detail in Chapter 5. In this chapter the conclusions of the study will be provided (paragraph 6.2), based on the results and their discussion as provided in Chapter 5. Firstly, the specific key conclusions will be presented under the headings *Hypothesis 1* and *Hypothesis 2*, as stated in Chapter 1. Secondly, to meet the specific requirements of the sub-aim of this study, the *recommendations* will commence with *modifications* to the current prevention programme, in order to correct the identified shortcomings of the current programme by addressing identified intrinsic and extrinsic injury trends, as well as anthropometric, physical and motor,

and biomechanical and postural shortcomings at high school level. Recommendations for further research and follow-up studies – which do not have a direct bearing on the hypotheses – will be summarised under *general recommendations*. Finally, the chapter will conclude with a brief discussion of possible *limitations* of this study.

6.2 CONCLUSIONS

Analysis of the results of this study revealed the following principal conclusions – based on Hypothesis 1 and Hypothesis 2:

HYPOTHESIS 1: An approved injury prevention programme has a significant effect on the incidence of rugby injuries (overall (a), intrinsic (b) and extrinsic injuries (c)) of 15- and 16-year old schoolboys over a two-year period.

As a distinction was made between overall injuries, intrinsic injuries and extrinsic injuries, these will be discussed separately. Furthermore, these conclusions will take the total study period of two years into account.

6.2.1 OVERALL INJURIES

Hypothesis 1a: An approved injury prevention programme has a significant effect on the incidence of overall rugby injuries of 15- and 16-year old schoolboys over a two-year period.

Firstly, it must be remembered that overall injury incidence equals the sum of the intrinsic injury incidence and extrinsic injury incidence (overall injury incidence = intrinsic injury incidence + extrinsic injury incidence). Therefore, as the prevention programme was not geared towards reducing extrinsic injury incidence – as there are too many unpredictable elements present in the occurrence of these injuries – injury trends related to overall injury

incidence revealed inconsistencies over the two-year period when the experimental groups were compared to the matching control groups.

For example, inspection of the 15-year old group reveals that the 15-year old experimental group (4.98 injuries per 1000 player hours) initially experienced a higher overall injury incidence than the control group (4.50). During the second half of the study, this situation turned around so that, compared to the experimental group (2.70), the 15-year old control group (5.24) experienced the higher overall injury incidence. The overall injury trends among the 16-year olds confirm the unpredictability of the overall injury incidence even further. This is because, in contrast to the 15-year old group, the situation in the 16-year olds was the reverse of that which was seen in the 15-year olds.

In summary, it was noted that in practice the ability of the prevention programme to control overall injury incidence actually depended on the programme's effect on the intrinsic as well as the extrinsic injury incidences (overall injury incidence = intrinsic injury incidence + extrinsic injury incidence). Therefore Hypothesis 1a is rejected with regard to overall rugby injuries, because it is clear from the results in Chapter 5 that changes which occurred in overall injury incidence could not be attributed to the prevention programme alone.

6.2.2 INTRINSIC INJURIES

Hypothesis 1b: An approved injury prevention programme has a significant effect on the incidence of intrinsic rugby injuries of 15- and 16-year old schoolboys over a two-year period.

The fact that the programme had a more pronounced effect on the intrinsic injury incidence of the experimental groups during the second year indicates the possibility that the specific prevention programme only reached its full potential during the second year of intervention. It may be concluded that during the first season, the programme restored certain impaired functions, and therefore had more of a rehabilitative effect than a preventative effect during the first half of intervention.

Considering intrinsic injuries (Table 5.1), it is clear that in comparison to the control groups, both the experimental groups always experienced the lesser intrinsic injury incidence (15-year olds=1.31 injuries per 1000 player hours v. 1.50, and 0.00 v. 2.91, 16-year olds=0.28 v. 0.92; 0.00 v. 1.48), even though it is normally expected that the experimental groups would experience more intrinsic injuries than the control groups. Furthermore, it can be seen that from the first to the second season a highly practically significant reduction was visible in the intrinsic injury incidences of the 15-year old ($d=1.45$) as well as the 16-year old ($d=1.04$) experimental groups, while an insignificant escalation was found in the two control groups ($d=0.52$ and $d=0.45$). This provides additional evidence that the groups which followed the prevention programme always experienced the smaller risk of intrinsic injury. The most likely explanation for these findings is that the prevention programme had a positive effect on the intrinsic injuries of the two experimental groups during the first season, second season and the total period of two years.

Therefore, Hypothesis 1b (intrinsic injuries) is accepted as it is clear that the prevention programme did have a significant positive effect on the intrinsic injury incidences of 15 and 16-year old schoolboys over a two year period.

6.2.3 EXTRINSIC INJURIES

Hypothesis 1c: An approved injury prevention programme has a significant effect on the incidence of extrinsic rugby injuries of 15- and 16-year old schoolboys over a two year period.

During the study period, the extrinsic injury incidence experienced by the two experimental groups always remained higher than those of the corresponding control groups. When comparing the extrinsic injury incidence results of the experimental groups to the control groups, results of the first season reveal mean values of 3.67 injuries per 1000 player hours v. 3.00 for the 15-year olds, and 2.48 v. 2.15 for the 16-year olds. Results for the second season reveal values of 2.70 v. 2.33 for the 15-year olds, and 3.62 v. 1.78 for the 16-year olds.

Although the differences were not always highly practically significant ($d \geq 0.8$), this confirms the inability of the prevention programme to reduce the extrinsic injury incidence experienced by the experimental groups to below that of the control groups. Differences and changes in extrinsic incidence in this study could not be attributed to the effect of the prevention programme. The reason for this was that the prevention programme was not geared towards reducing extrinsic injury incidences, as there are too many unpredictable elements (associated with contact situations) present in the occurrence of these injuries.

Hypothesis 1c (extrinsic injuries) is rejected, since it is evident that the prevention programme was unable to affect the extrinsic injuries of 15- and 16-year old schoolboys significantly.

HYPOTHESIS 2: An approved injury prevention programme has a significant effect on the selected anthropometric (a), physical and motor (b), and biomechanical and postural variables (c) of all the groups involved in this study over a period of two years.

Although for informative reasons the results in Chapter 5 were divided into three distinct periods (the first season, second season and the total period of two years), it is obvious from Hypothesis 2 that the total period of two years is considered most important for the aim of this study. Therefore this summary will focus on conclusions which have a direct bearing on the total period (two years).

6.2.4 ANTHROPOMETRIC VARIABLES

Hypothesis 2a: An approved injury prevention programme has a significant effect on the selected anthropometric variables of all the groups involved in this study over a period of two years.

A lack of contrasting trends between the anthropometric components of matching experimental and control groups confirms that the prevention programme was not specifically designed to change the anthropometric composition of subjects. Table 5.9 indicated the following moderate and highly practically significant inter-group differences for the whole two-year period: triceps skinfold ($d=0.8$ among 16-year olds), subscapular skinfold ($d=0.5$ among 16-year olds), midaxillary skinfold ($d=1.3$ among 15-year olds), calf skinfold ($d=1.3$ among 16-year olds), humerus breadth ($d=1.4$ among 15-year olds), femur breadth ($d=0.5$ among 15-year olds), fat percentage ($d=0.5$ among 16-year olds) and mesomorphy ($d=1.3$ among 15-year olds). These inter-group changes which occurred during the total period of two years (Table 5.9) may have been due to other factors, such as the natural growth phase of boys, rather than the effect of the prevention programme, since the prevention programme was not specifically designed to improve the anthropometric variables.

Hypothesis 2a, namely that the prevention programme would have a significant effect on selected anthropometric variables, is rejected as a result of the conclusion that inter-group changes may be due to other factors, such as natural physical growth.

6.2.5 PHYSICAL AND MOTOR VARIABLES

Hypothesis 2b: An approved injury prevention programme has a significant effect on the selected physical and motor variables of all the groups involved in this study over a period of two years.

The intra-group comparisons of physical and motor variables discovered that similar trends occurred in the physical and motor variables of all experimental and control groups. Considering this, it appeared possible that the improvements in the experimental groups could not be attributed to the effect of the prevention programme. Therefore inter-group comparisons – comparing changes in the experimental to those in the control groups – were needed to ascertain whether improvements in the physical and motor variables were due to the effect of the prevention programme (Table 5.6).

During the inter-group comparisons, moderate or highly practically significant improvements were revealed over the total two-year period for the vertical jump ($d=0.8$ and $d=0.5$), bleep (only 16-year olds) ($d=0.7$), pull-ups (only 15-year olds) ($d=0.6$) and push-up tests ($d=1.5$ and $d=1.1$) of the respective 15- and 16-year old experimental groups.

Seeing that the prevention programme had a moderately or highly practically significant effect on only four out of 11 physical and motor tests over the two year period, and that these improvements often occurred in only one of the age groups involved, leads to the conclusion that Hypothesis 2b (physical and motor variables) cannot be accepted.

6.2.6 BIOMECHANICAL AND POSTURAL VARIABLES

Hypothesis 2c: An approved injury prevention programme has a significant effect on the selected biomechanical and postural variables of all the groups involved in this study, over a period of two years.

The biomechanical and postural results in Table 5.8 made it clear that the characteristics of all the groups revealed certain mean biomechanical and postural values closer to the non-ideal (closer to a value of 2 than a value of 1) *before the implementation of the prevention programme* (T1), rendering these areas less mobile, dynamically loaded, with inadequate core stability, and therefore susceptible to intrinsic injury. The biomechanical and postural status at this stage (T1) was typical of the developmental phase of the adolescent player. However, some of the dynamic mobility and positional tests were already close to ideal (closer to a value of one, below a value of 1.5) at T1, and would therefore be difficult to improve on.

Intra-group comparisons were done to examine the biomechanical and postural changes within each group. The above-mentioned intra-group comparisons revealed several improvements in the biomechanical and postural status of the experimental groups. However, biomechanical and postural changes – although not necessarily practically

significant – also occurred within the two control groups (Table 5.8). Therefore further statistical techniques (*inter-group comparison*) were considered necessary to confirm that the improvements which developed in the experimental groups were practically significant when compared to the changes in the matching control groups over the same periods of time (Table 5.11).

In short, the inter-group comparison (Table 5.11) revealed numerous (38) moderately and highly practically significant effects in both age groups, considering the *total period of two rugby seasons*. According to the inter-group comparison, it can be said that in practice the prevention programme caused

- moderately or highly significant improvement in the left and right TA, left and right modified Thomas (ITB, quadriceps, iliopsoas), left and right gluteus maximus, left and right hip external rotation, leg length discrepancy, ASIS, PSIS, pelvic rami position, bilateral pelvic position, left and right TLF, functional flexion, left rotation (spinal) and left and right side flexion;
 - spinal head position (coronal axis), thoracic position (coronal axis); lumbar position (coronal axis), left and right hand behind back ROM, left and right shoulder positional, left and right winging positional, left and right shoulder outline composition; and
 - left and right straight leg raise, and left and right L3,4 prone knee bend tests
- of both the 15-year olds and 16-year olds over the course of the total period (T1-T6).

Additionally, moderately or highly practically significant improvements were also measured in the left and right VMO-L comparison (only 15-year olds), functional extension (only 15-year olds), spinal right rotational (only 15-year olds), left and right hand behind neck ROM (only 16-year olds), left and right throwing position (only 16-year olds) and left as well as right upper limb tension (only 15-year olds) tests of players during the total study period.

A probable explanation for the lack of moderately and highly significant improvement in the other biomechanical and postural variables considering the total period is that all of these variables (adductor; left and right hip internal rotation; VMO-L comparison of 16-year olds;

sacroiliac cleft; left and right sacral rhythm; functional extension of the 16-year olds; cervical position in the coronal axis; the positional tests in the sagittal axis; left and right hand behind neck ROM of the 15-year olds; left and right throwing position of the 15-year olds; upper limb tension of the 16-year olds; left and right slump) measured values at or very close to ideal during the periods in question (Table 5.8), and were subsequently more difficult to improve or could not be expected to improve (already ideal). However, this was *not true* for the knee complex of both age groups, foot and ankle region of both age groups, right spinal rotational test of the 16-year olds, and thoracic positional test (sagittal axis) of both groups, which warrants additional improvement.

All-in-all, the positive changes in the experimental groups outweighed those of the control groups. It can therefore be assumed that the prevention programme provided the experimental groups with a more balanced (closer to ideal) dynamic mobility, core stability and postural symmetry after the *total period of two rugby seasons*. This is important as the ability to obtain a more ideal biomechanical and postural status may be important in reducing intrinsic injuries. In fact, over the course of the study the two experimental groups improved to such an extent that, by the end of the intervention (T6), their biomechanical and postural status was superior to the comparable age group in the Hattingh (2003:92-93) study, except for the tests of left and right forefoot position (15- and 16-year olds) and the thoracic position in the sagittal axis (15-year olds).

In light of the above, seeing that in practice the prevention programme significantly altered the majority of biomechanical and postural variables which required improvement, the conclusion can be drawn to accept Hypothesis 2c (biomechanical and postural variables).

6.3 RECOMMENDATIONS

From this study, various needs have been identified with regard to the investigation and prevention of future rugby injuries. These can be sorted into two categories; specific recommendations (direct bearing on the different hypotheses) and general recommendations.

6.3.1 SPECIFIC RECOMMENDATIONS

A sub-aim of this study was *to propose modifications to the prevention programme if necessary*. During the discussion of the results in Chapter 5 some deficiencies were identified in the current rugby injury prevention programme. As mentioned in paragraph 5.6, these deficiencies will be addressed by recommending modifications to the prevention programme. These modifications to the prevention programme are the following:

Modifications with regard to injuries:

- The programme was not designed to prevent extrinsic injuries, such as concussions; however, these may be reduced by controlling extrinsic risk factors to injury, for example wearing protective devices, improving the laws of the game, improving refereeing and improving attitudes towards the game;
- in order to rehabilitate previous injuries before a team starts the competitive season, the programme should be implemented during the previous off-season, instead of the current pre-season;
- special attention should be paid to players with a previous injury history by identifying these players during the off-season and referring them for specialised medical tests, for example an isokinetic test to determine if a strength deficiency exists in the injured body part; these players could then be sent for rehabilitation and should be re-evaluated before the start of the pre-season.
- see Annexure B.2, paragraph 3.6 for guidelines during the implementation of the modifications.

Modifications with regard to anthropometric variables:

- Rugby-specific hypertrophy training may be added to improve anthropometric components, for example introducing the hypertrophy phases (weight training) as

described in the study of Hanekom (2003:169,171-173); these phases could be introduced during the off-season while bearing the adolescent development phase in mind (see Annexure B.2, paragraph 1.1 and 1.2);

- see Annexure B.2 for suggestions to prevent increases in fat percentage (1.1 (b)) during the off-season.

Modifications with regard to physical and motor variables:

- See Annexure B.2 for the required supplementary sport-specific running speed (2.1 (a)), agility (2.2 (a)), speed endurance (running) (2.3 (a)), upper limb (2.4 (a)) and upper abdominal strength (2.5 (a)) training;
- see Annexure B.2 for suggestions to prevent speed loss (2.1 (b)), strength loss (2.4 (a); 2.5 (a)), deterioration in agility (2.2 (b)), loss of speed endurance (2.3 (a)), aerobic endurance loss (2.6 (a)) and power loss (2.7 (a)) during the off-season.

Modifications with regard to biomechanical and postural variables:

- In the presence of a longer than expected season, a re-evaluation of previous biomechanical and postural weaknesses should be introduced just before the final competitive phase, to identify areas which merit supplementary attention up to the end of the season;
- to prevent deterioration in the biomechanical and postural status during the off-season, the volume (frequency) off exercises during the off-season period may be increased, while allowing for adequate rest and recovery. This may be achieved by doing exercises four times a week, instead of three times a week. Increased control over exercise compliance can be achieved by compelling players to complete two exercise sessions under supervision. See Annexure B.2, paragraph 3.5 for modifications focusing on the *right TA, left and right ITB, left and right iliopsoas,*

right spinal rotation, thoracic position in the coronal axis, and left and right L3,4 prone knee bend tests during the off-season;

- after one season of intervention, players may be accustomed to the difficulty level of the programme, and consequently the intensity should be increased slightly during the subsequent seasons;
- the use of orthopaedic appliances such as orthotics, strapping, etc. could be used to correct structural biomechanical and postural deformities, for example those present in the foot/knee;
- additional exercises for the *right rotation (spinal)* (16-year olds) (Annexure B.2, paragraph 3.1), *thoracic position* in the sagittal axis (15 and 16-year olds) (Annexure B.2, paragraph 3.2) and left and right *winging* (15-year olds) (Annexure B.2, paragraph 3.3) during the first year;
- added exercise during the second year in the areas of *right rotation (spinal)* (16-year olds) (Annexure B.2, paragraph 3.1), *thoracic position* in the coronal axis (15- and 16-year olds) (Annexure B.2, paragraph 3.4), *thoracic position* in the sagittal axis (15- and 16-year olds) (Annexure B.2, paragraph 3.2), and *left winging* (15-year olds) (see Annexure B.2, paragraph 3.3);
- results concerning the **total period** of intervention (**whole 2 years**) point out that the *right rotation (spinal)* (16 year olds) (see Annexure B.2, paragraph 3.1), and *thoracic position* in the coronal axis (15 and 16-year olds) (Annexure B.2, paragraph 3.4) should be purposely addressed.

6.3.2 GENERAL RECOMMENDATIONS

General needs regarding future research include the following:

- It is advised that future rugby studies utilise a statistical breakdown of intrinsic injuries to produce further interpretable results.

- Standardised methods of assessing physical activity and energy expenditure are needed for evaluation and interpretation of dose-response characteristics between specified types and volumes of training and the incidence of overuse injuries.
- Future rugby injury prevention research should include tests of lower abdominal strength, as well as the strength of each individual core stabilising muscle.
- An international injury register is needed to facilitate a closer working relationship between rugby authorities and researchers worldwide.
- There is a need for a cost-benefit analysis of the positive and negative effects of rugby activities on a player's socio-economic position.
- More research need to be directed towards identifying body movement strategies and whether they can be taught, subsequently becoming effective injury prevention strategies in rugby.
- Future studies need to be large scale interventions, enrolling thousands of participants.
- In South Africa, infrastructure for a comprehensive injury prevention programme (integrating surveillance, research, intervention, programme implementation and programme monitoring) should be developed and tested.

6.4 LIMITATIONS

This study has recognised limitations. One limitation may be that the intervention was assigned to a team (cluster), not an individual player. This option was chiefly chosen because schools wanted all their A-team players to be part of the prevention programme. Furthermore, although a randomised study of individual players and their training practices often provides realistic results, this may prove difficult for team sports like rugby, as these sports consist of different player positions, each with its own exposure to accident hazards (injury risk) and physical demands. Furthermore, differences even exist between individuals

in the same position, for example two A-team loose forwards with different work rates might not run the same distance during a match. This is complicated even more by the role that chance plays in occurrence of extrinsic injuries. However, by using whole teams as the population being studied, this study was able to meet the research requirements of players of similar age and physical condition who participate in a programme with rather similar exposure to accident hazards and physical demands. Furthermore, it was ensured that there were no differences in training protocols between teams, which could have been attributed to the fact that coaches of different backgrounds and experience are recruited to manage and supervise training.

A further limitation is that the prevention programme may have had a larger effect if it had been implemented earlier, during the start of the previous off-season and before the start of the first pre-season. The fact that some subjects dropped out due to injury or moving to another school/town was also a shortcoming. Despite all these limitations this study shows that – after two years of intervention – the prevention programme did have a positive effect on intrinsic injury incidence, on some of the physical and motor variables, as well as on the majority of the biomechanical and postural variables.

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ANNEXURE A.1

PLAYER INFORMATION

FULL NAMES AND SURNAME

DATE

SCHOOL TEAM/LEVEL

AGE

DATE OF BIRTH

PLAYER POSITION

POSTAL ADDRESS

Code:

HOME ADDRESS

Code:

CONTACT NUMBERS :

Phone (h)

Phone (cell)

DOCTOR'S NAME AND SURNAME

DOCTOR'S ADDRESS

DOCTOR'S PHONE (w)

(office use only)

COACH'S NAME AND SURNAME

COACH'S PHONE

ID#

--	--	--

ANNEXURE A.2

CURRENT AD PREVIOUS INJURY EXPERIENCE

Date _____ Name _____ Team/Level _____

(office use only ID#

CURRENT AND PREVIOUS INJURIES

<i>INJURY</i>	<i>CURRENT</i>	<i>PREVIOUS</i>	<i>Current status</i>	<i>Intrinsic/ Extrinsic</i>	<i>REMARKS</i>
<i>Head</i>					
<i>Total concussions</i>					
<i>Total skull fractures</i>					
<i>Face</i>					
<i>Dental</i>					
<i>Neck</i>					
<i>Shoulder</i>					
<i>Upper arm</i>					
<i>Lower arm</i>					
<i>Wrist</i>					
<i>Hand</i>					
<i>Fingers</i>					
<i>Thumb</i>					
<i>Chest</i>					
<i>Rib/Sternum</i>					
<i>Abdomen</i>					
<i>Spine</i>					
<i>Back</i>					
<i>Pelvis</i>					
<i>Hip/Groin</i>					
<i>Upper Leg</i>					
<i>Lower Leg/ MTSS</i>					
<i>Knee</i>					
<i>Ankle</i>					
<i>Foot</i>					
<i>Toes</i>					
<i>OTHER</i>					

NO	Injury	
	Diagnose	
	Date	
	Treatment	
	Complete recovery	
	Doctor/Physiotherapist	
NO	Injury	
	Diagnose	
	Date	
	Treatment	
	Complete recovery	
	Doctor/Physiotherapist	
NO	Injury	
	Diagnose	
	Date	
	Treatment	
	Complete recovery	
	Doctor/Physiotherapist	

ANNEXURE A.3

INJURY REPORT FORM

ID#

(office use only)

NAME: _____

SCHOOL: _____

PLAYER'S DOCTOR: _____

CURRENT SPORTS OTHER THAN RUGBY: _____

Mark appropriate boxes with an X

TEAM: u/15A 1 u/15B 2 u/16A 3 u/16B 4

DATE WHEN INJURED: DAY MONTH YEAR 200

PERIOD IN SEASON: BEGINNING OF SEASON 1 MID-SEASON 2

JUST AFTER MID-SEASON BREAK 3 END OF SEASON 4

If injured during a match, the number of matches that the injured person played this season was (including the match in which he was injured)

SEVERITY OF INJURY

Injury has caused or is estimated will cause	Total time off from training/games in days <input type="checkbox"/> <input type="checkbox"/> if missed 7 to 28 days - Mild <input type="checkbox"/> 1 if missed 29 to 84 days - Moderate <input type="checkbox"/> 2 if missed more than 84 days - Severe <input type="checkbox"/> 3
--	--

BACKGROUND TO INJURY

Has this injury now healed?	No <input type="checkbox"/> 1 Yes <input type="checkbox"/> 2
Has this injury occurred before?	Previous seasons <input type="checkbox"/> 1 this season <input type="checkbox"/> 2 no <input type="checkbox"/> 3

WHAT TEAM AND POSITION

AGE LEVEL	GRADE	TEAM POSITION
14 years <input type="checkbox"/> 01	A <input type="checkbox"/> 01 B <input type="checkbox"/> 02	<input type="checkbox"/> 1-15
15 years <input type="checkbox"/> 02		
16 years <input type="checkbox"/> 03		
17 years <input type="checkbox"/> 04		

TYPE OF INJURY

WOUNDS <input type="checkbox"/> 1 (e.g. cuts grazes) DEEP BRUISING <input type="checkbox"/> 2 (e.g. corks) LIGHT BRUISING <input type="checkbox"/> 3 (e.g. skin discolouration) CONCUSSION <input type="checkbox"/> 4 if OTHER please specify _____ <input type="checkbox"/> 9	MUSCLE/TENDON STRAIN <input type="checkbox"/> 5 (e.g. hamstrings, thigh, groin, calf or any muscle tear) LIGAMENT/JOINT SPRAIN <input type="checkbox"/> 6 (e.g. ankle sprain, knee, cartilage) JOINT DISLOCATION <input type="checkbox"/> 7 (e.g. finger, shoulder) FRACTURE <input type="checkbox"/> 8 (e.g. any bone break)
---	--

SITE OF INJURY

<p>HEAD</p> <p>scalp <input type="checkbox"/> 01</p> <p>skull <input type="checkbox"/> 02</p> <p>eye <input type="checkbox"/> 03</p> <p>nose <input type="checkbox"/> 04</p> <p>cheek <input type="checkbox"/> 05</p> <p>teeth <input type="checkbox"/> 06</p> <p>ear <input type="checkbox"/> 07</p> <p>jaw <input type="checkbox"/> 08</p> <p>NECK</p> <p>muscles <input type="checkbox"/> 09</p> <p>spine <input type="checkbox"/> 10</p> <p>throat <input type="checkbox"/> 11</p>	<p>TRUNK</p> <p>chest/ribs <input type="checkbox"/> 12</p> <p>upper spine <input type="checkbox"/> 13 (i.e. back of chest)</p> <p>upper back muscles <input type="checkbox"/> 14</p> <p>lower spine <input type="checkbox"/> 15 (i.e. back of abdomen)</p> <p>lower back muscles <input type="checkbox"/> 16</p> <p>abdomen <input type="checkbox"/> 17</p> <p>genitals <input type="checkbox"/> 18</p>	<p>ARM</p> <p>shoulder <input type="checkbox"/> 19</p> <p>collar bone <input type="checkbox"/> 20</p> <p>shoulder blade <input type="checkbox"/> 21</p> <p>upper arm <input type="checkbox"/> 22</p> <p>elbow <input type="checkbox"/> 23</p> <p>forearm <input type="checkbox"/> 24</p> <p>wrist <input type="checkbox"/> 25</p> <p>hand <input type="checkbox"/> 26</p> <p>finger <input type="checkbox"/> 27</p>	<p>LEG</p> <p>hip <input type="checkbox"/> 28</p> <p>thigh front <input type="checkbox"/> 29</p> <p>thigh back <input type="checkbox"/> 30</p> <p>inner thigh <input type="checkbox"/> 31 (e.g. groin)</p> <p>knee <input type="checkbox"/> 32</p> <p>lower leg <input type="checkbox"/> 33</p> <p>ankle <input type="checkbox"/> 34</p> <p>foot <input type="checkbox"/> 35</p> <p>toe <input type="checkbox"/> 36</p>
if OTHER please specify _____ <input type="checkbox"/> 37			

MECHANISM OF INJURY

<p>Comments _____</p>	<p>intrinsic <input type="checkbox"/> 1</p> <p>extrinsic <input type="checkbox"/> 2</p>
-----------------------	---

PHASE OF PLAY CAUSING INJURY

HOW DID THE INJURY OCCUR?	direct contact <input type="checkbox"/> 1 OR no contact <input type="checkbox"/> 2 (tackle, etc.)
	set play <input type="checkbox"/> 3 OR broken play <input type="checkbox"/> 4
	legally <input type="checkbox"/> 5 OR illegally <input type="checkbox"/> 6
	scrum <input type="checkbox"/> 01 pile-up <input type="checkbox"/> 07
	ruck <input type="checkbox"/> 02 catching <input type="checkbox"/> 08
	line-out <input type="checkbox"/> 03 gathering <input type="checkbox"/> 09
being tackled <input type="checkbox"/> 04 kicking a ball <input type="checkbox"/> 10	
tackling <input type="checkbox"/> 05 running <input type="checkbox"/> 11	
maul <input type="checkbox"/> 06 "off the ball" <input type="checkbox"/> 12 (e.g. out of play incident)	
if OTHER please specify _____ <input type="checkbox"/> 13	

PROTECTIVE EQUIPMENT

WAS PROTECTIVE EQUIPMENT RELEVANT TO THE INJURY SITE WORN?	no <input type="checkbox"/> 01
	mouth guard <input type="checkbox"/> 02
	adhesive elastic strapping <input type="checkbox"/> 03
	adhesive non-elastic strapping <input type="checkbox"/> 04 (e.g. tape)
	non-adhesive strapping <input type="checkbox"/> 05 (e.g. crepe bandage)
	knee guard <input type="checkbox"/> 06
	ankle guard <input type="checkbox"/> 07
	padding <input type="checkbox"/> 08 (e.g. skin pads, shoulder pads)
	jock-strap <input type="checkbox"/> 09
	if OTHER please specify _____ <input type="checkbox"/> 10

CLASSIFICATION OF INJURY

ASSESSMENT:

DIAGNOSIS:

TREATMENT:

INSTRUCTION TO PLAYER/CARE-GIVER:

REFER TO:

Special tests/medication _____
Player's doctor _____
Player's physiotherapist _____
Player's biokineticist _____
Player's sports scientist _____

OTHER INFORMATION:

COMMENTS: _____

REVISIT:

Medic/Sports Trainer's Name _____ Signature _____

ANNEXURE A.4

BIOMECHANICAL AND POSTURAL ASSESSMENT FORM

GROUP:		DATE:			
PERSONAL INFORMATION					
NAME:		AGE	WEIGHT	STATURE	
SPORT:			LEVEL:		
POSITION:					
DOMINANT HAND:		L	R	DOMINANT FOOT:	
				L	R
MEDICAL INFORMATION					
HISTORY:			OBSERVATION:		
PRESENT:			PALPATION:		
PLAN:					
BIOMECHANICS AND POSTURE					

LOWER LIMB

AREA	GRADE						CATEGORY/GRADE
	L	RL	RL	RL	R	R	
TA	1	1	2	2	3	3	1: $\geq 30^\circ$ / 2: 10-30° / 3: $< 10^\circ$
ITB	1	1	2	2	3	3	1: $< 10^\circ$ / 2: 10-30° / 3: $> 30^\circ$
QUAD	1	1	2	2	3	3	1: $> 50^\circ$ / 2: 30-50° / 3: $< 30^\circ$
ILIOPSOAS	1	1	2	2	3	3	1: $> 30^\circ$ / 2: 15-30° / 3: $< 15^\circ$
GLUTEUS MAX	1	1	2	2	3	3	1: $> 90^\circ$ / 2: 60-90° / 3: $< 60^\circ$
ADDUCTOR	1		2		3	3	1: $> 120^\circ$ / 2: 100-120° / 3: $< 100^\circ$
HIP INT ROT	1	1	2	2	3	3	1: $> 30^\circ$ / 2: 15-30° / 3: $< 15^\circ$
HIP EXT ROT	1	1	2	2	3	3	1: $> 90^\circ$ / 2: 60-90° / 3: $< 60^\circ$
KNEE Q-ANGLE	1	1	2	2			1: $< 9^\circ$ / 2: $\geq 9^\circ$
KNEE SQUINT	1	1	2	2			1: $< 10^\circ$ / 2: $\geq 10^\circ$
KNEE TILT	1	1	2	2			1: Not tilted / 2: Tilted
VMO	1	1	2	2			1: Normal / 2: Anomalies
Detail / Anomalies:							

AREA	GRADE						CATEGORY/GRADE
	L	R	L	R	L	R	
LONGITUDINAL ARCH	1	1	2	2	3	3	1:Flat / 2:Normal / 3:High
FORE FOOT	1	1	2	2			1:Normal / 2:Anomalies
REAR FOOT STANDING	1	1	2	2	3	3	1:>9° / 2:0-9° / 3:<0°
REAR FOOT LYING	1	1	2	2	3	3	1:>9° / 2:0-9° / 3:<0°
TRANSVERSE	1	1	2	2			1:Normal / 2:Flat
MOBILITY	1	1	2	2	3	3	1:Hyper / 2:Normal / 3:Hypo
TOES	1	1	2	2			1:Normal / 2:Anomalies
Detail / Anomalies:							

PELVIC GIRDLE

LEG LENGTH	1	2	3	1:Left=Right / 2:≤1cm discrepancy / 3:>1cm			
ASIS	1	2		1:Left=Right / 2:Asymmetrical			
PSIS	1	2		1:Left=Right / 2:Asymmetrical			
RAMI	1	2		1:Left=Right / 2:Asymmetrical			
CLEFT	1	2		1:Left=Right / 2:Asymmetrical			
PELVIS BILATERAL	1	2	3	1:≥2 but <3 cm discrepancy / 2:3-5 cm / 3:>5cm			
Detail / Anomalies:							

SPINAL

TLF	1	1	2	2	3	3	1:<1 cm / 2:1-3 cm / 3:>3 cm
SACRUM RHYTHM	1	1	2	2			1:Left=Right / 2:Asymmetrical
EXTENSION	1		2		3		1:<1 cm / 2:1-3 cm / 3:>3 cm
FLEXION	1		2		3		1:Easy ROM / 2:Limited ROM / 3:Hypo
ROTATION	1	1	2	2	3	3	1:>90° / 2:70-90° / 3:<70°
SIDE FLEXION	1	1	2	2	3	3	1:Easy ROM / 2:Limited ROM / 3:Hypo
Detail / Anomalies:							

CORONAL MID POSITION

HEAD	1	2		1:Normal / 2:Anomalies			
CERVICAL	1	2		1:Normal / 2:Anomalies			
THORACIC	1	2		1:Normal / 2:Anomalies			
LUMBAR	1	2		1:Normal / 2:Anomalies			
Detail / Anomalies:							

AREA	GRADE						CATEGORY/GRADE
	L	RL	L	RL	L	R	

SAGITTAL MID POSITION

HEAD	1	2					1:Normal / 2:Anomalies
CERVICAL	1	2					1:Normal / 2:Anomalies
THORACIC	1	2					1:Normal / 2:Anomalies
LUMBAR	1	2					1:Normal / 2:Anomalies

Detail / Anomalies:

UPPER LIMB - SHOULDER

HAND BEHIND BACK	1	1	2	2	3	3	1:≤1 cm / 2:1-3 cm / 3:>3 cm
HAND BEHIND NECK	1	1	2	2	3	3	1:≤1 cm / 2:1-3 cm / 3:>3 cm
SHOULDER POSITION	1	1	2	2			1:Neutral (<2/3) / 2:> Two thirds
WINGING	1	1	2	2			1:None / 2:Winging
OUTLINE	1	1	2	2			1:Muscular / 2:Bony
THROWING POSITION	1	1	2	2			1:≥Coronal mid / 2:<Coronal mid

Detail / Anomalies:

NEUROLOGICAL

SLR	1	1	2	2	3	3	1:>90° / 2:70-90° / 3:<70°
UPPER LIMB TENSION	1	1	2	2	3	3	1:180° - 0° (No tension) / 2:180° - 10° (Tension) / 3:180° to >10°
L3,4	1	1	2	2	3	3	1:Full ROM No tension / 2:Full ROM with tension / 3:Not touching
SLUMP	1	1	2	2	3	3	1:Full ROM; With dorsi flexion; No tension / 2:Full ROM; With dorsi flexion; With tension / 3:Limited ROM with tension

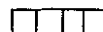
Detail / Anomalies:

-COMMENTS-

-SPECIAL TESTS-

ANNEXURE A.5

RUGBY DATA SHEET



PLAYER INFORMATION

Name and Surname:	
Date:	
School:	
Position:	
Team:	
Date of Birth:	
Telephone No:	

DATA SHEET

Body Composition:	Stature (cm)	
	Body weight (kg)	
	Triceps skinfold (mm)	
	Subscapular skinfold (mm)	
	Supraspinal skinfold (mm)	
	Midaxillary skinfold (mm)	
	Abdominal skinfold (mm)	
	Calf skinfold (mm)	
	Flexed upper arm girth (tensed) (cm)	
	Calf girth (cm)	
	Humerus breadth (cm)	
	Femur breadth (cm)	

Physical and Motor Components:	Vertical jump (cm)	Reach:	1.	2.
	10 m speed (sec)	1 st		
		2 nd		
	30 m speed (sec)	Bal		
		1 st		
		2 nd		
	Illinois agility (sec)	Bal		
		1.	2.	
	Speed endurance (sec)	1.	2.	3.
		4.	5.	6.
	Bleep (level)	1.		
	Pull-ups (n)	1.		
	Push-ups (n)	1.		
	7-stage abdominal strength test (n)		1.	
Grip strength (kg)	L.		R.	

ANNEXURE B.1

INJURY PREVENTION PROGRAMME

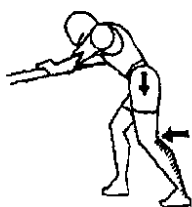
The injury prevention programme and its implementation during the different periods (periodisation) were discussed in Chapter 4. The following is a description of the exercises done by the experimental groups during each period of the injury prevention programme. Individuals only exercised areas which were classed as non-ideal/unsatisfactory.

PRE-SEASON PROGRAMME (3 WEEKS)

This preparation programme must be followed intensely over a period of 3 weeks, up to the start-of-season programme. All exercises except speed, agility and power exercises – must be done **five** times a week as graphically displayed and described. The speed, agility and power exercises should be done **twice** a week, on Mondays and Wednesdays. If uncertain ask the researcher/coach.

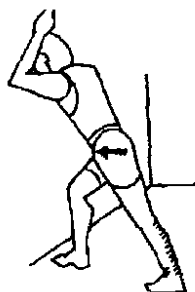
Lower limb exercises (pre-season)

1.



1. Stand facing a wall
2. Position the L/R leg at the back, with the heel flat on the floor
3. Place the other leg in front
4. Bend the back knee, while keeping the heel flat
5. Hold for 30 sec
6. Do three repetitions
7. Repeat on opposite side

2.



1. Stand facing a wall and hold onto the wall for support
2. Position the L/R leg at the back, with the heel flat on the floor
3. Place the other leg in front as shown
4. Keep the back leg straight throughout the exercise and the heel on the floor
5. Bend your arms until you feel a stretch in the calf of the back leg
6. Repeat for 3 x 30 seconds left and right side

3.



1. Stand with L/R side facing the wall
2. Cross the other leg behind the L/R leg and turn towards the wall
3. Twist trunk towards the wall as shown, using the hands for support
4. Bend the forward knee slightly, and push the hip away from the wall (see arrow) until you feel a stretch on the outside of the hip
5. Hold for 30 seconds
6. Do three repetitions on each side (left and right)

4.



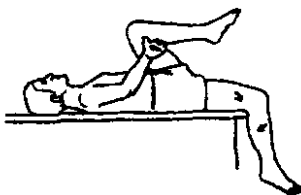
1. Lie on your stomach as shown
2. Hold onto your ankle and pull your ankle towards your buttocks
3. Your knees must stay together
4. When you feel a stretch, hold.
5. Hold for 30 seconds
6. Repeat on opposite side

5.



1. Stand holding the L/R ankle as shown
2. Keep knees together and pull knee upward so that you feel a stretch
3. Make sure your thigh stays in line with your body (don't let it point forward), and don't arch your back
4. Hold for 30 seconds
5. Do three repetitions
6. Repeat on opposite side

6.



1. Lie on bench with L/R leg hanging over the edge
2. Bend the other knee, keeping the L/R thigh flat on the bench
3. Pull the other knee towards the chest as shown
4. The hanging leg must relax
5. Hold for 30 seconds
6. Do three repetitions
7. Repeat on opposite side

7.



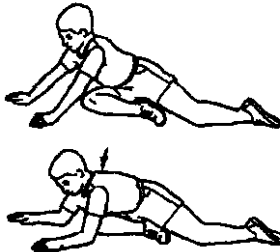
1. Assume position shown, with L/R leg straight and other leg in front
2. Move the pelvis towards the floor as shown by the arrows
3. Hold for 30 seconds
4. Do three repetitions
5. Repeat on opposite side

8.



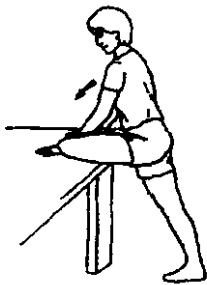
1. Lie on back, holding L/R knee and ankle as shown
2. Pull your knee and ankle across, towards your opposite shoulder
3. Hold for 30 seconds
4. Do three repetitions
5. Repeat on opposite side

9.



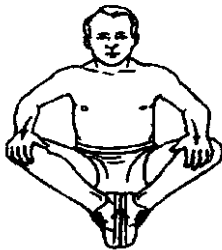
1. Assume position shown with L/R knee bent, toe pointing towards opposite hip, and back straight
2. Bend elbows and press trunk downward until you feel a stretch
3. Hold for 30 seconds
4. Do three repetitions
5. Repeat on opposite side

10.



1. Stand upright placing L/R leg on solid object as shown
2. Lean trunk forward so that you feel a stretch
3. Keep your back straight
4. Hold for 30 seconds
5. Do three repetitions
6. Repeat on opposite side

11.



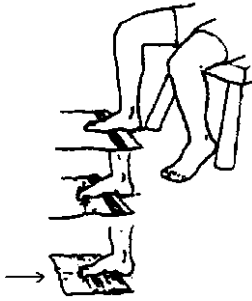
1. Sit upright with knees bent and feet together
2. Press downward on knees using your hands
3. Hold for 30 seconds
4. Do three repetitions

12.



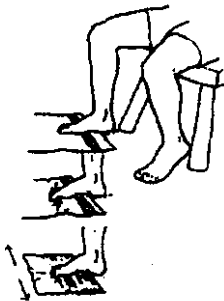
1. Sit upright with back supported against a wall (*unlike picture*)
2. Roll up a towel and place it under the L/R knee
4. Rotate L/R leg outward so that toes point slightly to the outside
5. Activate the VMO and straighten leg (knee extension)
6. Hold position for 5 seconds
7. Repeat 30 times per leg

13.



1. Place towel on slippery surface such as tiles
2. Place heel on floor and ball of foot on towel
3. Grab towel using your toes
4. Repeatedly scrunch up the towel towards you using the foot muscles
5. Repeat for 1 minute per foot
6. Do three repetitions per foot

14.



1. Place towel on a slippery surface
2. Grab the towel using your toes
3. Pull the towel to the inside using your foot
4. Repeat to the outside
5. Repeat for 1 minute
6. Do three repetitions
7. Repeat with other foot

15.



1. Sit and place L/R ankle as shown
2. Stabilise the heel of your foot with one hand and place the other hand around the toes as well as the ball of your foot
3. Pull the foot in the direction of the arrow until you feel a stretch
4. Hold for 30 seconds
5. Repeat three times
6. Repeat on opposite side

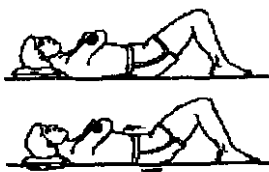
Pelvic girdle exercises (pre-season)

16.



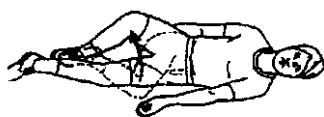
1. Lie on side as shown with the bottom leg straight
2. Keep hips on the floor and use arms to press trunk upright
3. Hold for 30 seconds
4. Do three repetitions
5. Repeat on the other side
6. The top knee may be bent, placed on the floor and moved closer to the hands for an increased stretch

17.



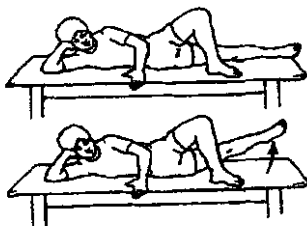
1. Lie on back with knees bent
2. Place a plastic soccer ball between the knees
3. Tighten lower abdominal muscles, squeeze buttocks and flatten back as shown, while squeezing the ball
4. Hold for 10 seconds
5. Do 10 repetitions

18.



1. Lie on your side, with bottom knee straight and top knee bent as shown
2. Place top foot on bottom leg, just below level of bottom knee
3. Lift/rotate top knee upward, keeping the pelvis stable throughout
4. Hold for 10 seconds at the top
5. Do 10 repetitions
6. Repeat on opposite side

19.



1. Lie on your side as shown, with L/R leg at the bottom
2. Raise bottom leg up towards ceiling
3. Hold for 10 sec then slowly lower
4. Do 10 repetitions
5. Repeat on opposite side

20.



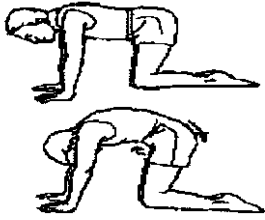
1. Lie on side with L/R leg on top
2. Raise top leg straight up, without letting it move forward
3. Hold for 10 seconds at top then slowly lower
4. Do 10 repetitions
5. Repeat on opposite side

21.



1. Lie on back, bend knee ("longer knee only"), and lift heel
2. Place hands on thigh as shown
3. Activate stabilisers and lower abdominals, and press knee against hands
4. Hold for 10 seconds
5. Do 10 repetitions

22.



1. Stand on all fours
2. Find pelvic neutral
3. Tilt pelvis as shown by tightening the lower abdominal muscles and squeezing the buttocks
4. Hold for 10 seconds then rotate back to pelvic neutral
5. Do 10 repetitions

23.



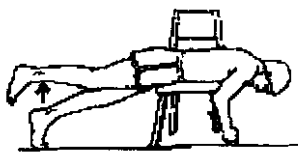
1. Lie on back with knees bent
2. Perform pelvic tilt and activate stabilisers to flatten back
3. Holding your back flat, raise L/R hip and knee as shown
4. Hold back flat and slowly lower foot as far as stable pelvis allows
5. Hold just above the floor for 10 seconds
6. Do 10 repetitions per leg

24.



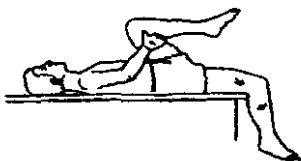
1. Start on hands and knees and maintain your pelvis in the neutral position (as demonstrated by the trainer) throughout the exercise
2. Push your feet and knees into the floor
3. Keep your elbows bent, tighten your arms and push them against the floor
4. Allowing no actual movement, try pulling your knees and hands towards each other (see arrows)
5. Hold for 10 seconds
6. Do 10 repetitions

25.



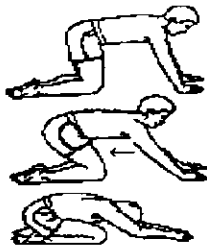
1. Lie with belly over chair and L/R knee slightly bent. Contract L/R glut. max. while relaxing hamstring
2. Raise thigh off floor towards ceiling. Learn to use only contra-lateral erector spinae/multifidus
3. Hold for 10 seconds when heel is level with buttocks
4. Do 10 repetitions
5. Repeat on opposite side

26.



1. Lie on bench with L/R leg hanging over edge
2. Bend other knee while keeping the L/R thigh flat on the bench
3. Pull the other knee up towards your chest as shown
4. Hold for 30 seconds
5. Do three repetitions
6. Repeat on opposite side

27.



1. Assume hands and knees position
2. Bend knees to move buttocks towards heels as shown, while maintaining posterior pelvic tilt
3. Lower head and hold
4. Hold for 30 seconds
5. Do three repetitions

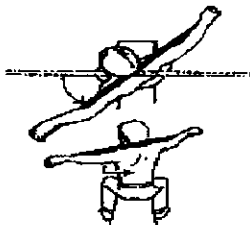
Spinal exercises (pre-season)

28.



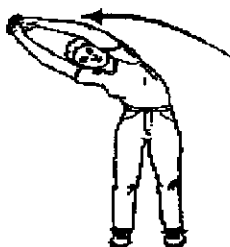
1. Assume position as shown
2. Keep hips on floor
3. Hold for 30 seconds
4. Do three repetitions

29.



1. Sit on bench with broomstick positioned on shoulders as shown
2. Rotate head and shoulders to L/R
3. Hold for 30 sec
4. Do three repetitions
5. Repeat to opposite side

30.



1. Clasp hands together and lean to the L/R until you feel a stretch
2. Hold for 30 seconds
3. Do three repetitions
4. Repeat on opposite side

31.



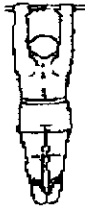
1. Stand upright with a normal posture
2. Tuck in chin as shown
3. Extend neck until you reach the neutral/middle position
4. Hold for 10 seconds
5. Repeat 10 times

32.



1. Do a chin tuck as in previous exercise
2. Then place chin on chest
3. Use your hands to bend your neck forward
4. Maintain an upright posture throughout
5. Hold for 30 seconds
6. Do three repetitions

33.



1. Grab a horizontal bar as shown
2. Hang, keeping your legs straight and your body relaxed
3. Hold for 30 seconds
4. Do three repetitions

34.



1. Lie on the floor as shown
2. Tighten your buttocks and pinch your shoulder blades together
3. Raise one leg and the opposite arm 15 cm
4. Hold for 10 seconds
5. Repeat with opposite leg and arm
6. Do 10 repetitions

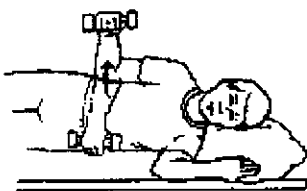
Upper limb/shoulder exercises (pre-season)

35.



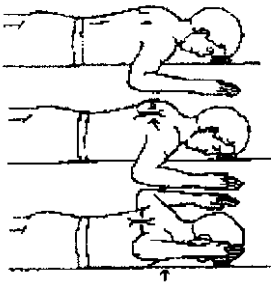
1. Stand with hands placed on door frame and feet 30-60 cm away from wall as shown
2. Lean into the door opening until you feel a stretch
3. Hold for 30 seconds
4. Do three repetitions

36.



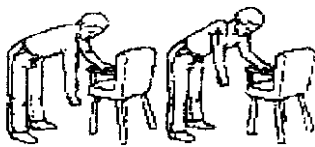
1. Lie on your side with your L/R arm on top, gripping a 1-2 kg weight
2. Rotate arm upward, keeping elbow bent as shown
3. Hold for 10 seconds and slowly lower
4. Do 10 repetitions
5. Repeat on opposite side

37.



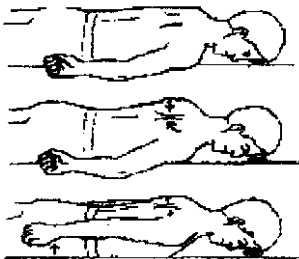
1. Lie as shown
2. Pinch shoulder blades together, activating scapular stabilisers
3. Lift up arms
4. Hold for 10 seconds, then slowly lower arms
5. Do 10 repetitions

38.



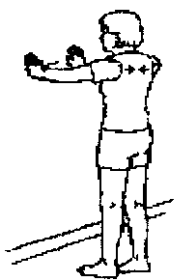
1. Lean forward over solid object, letting L/R arm hang straight down
2. Pinch shoulder blade backward to raise shoulder upward
3. Hold for 5 seconds
4. Do 20 repetitions
5. Repeat on opposite side

39.



1. Lie on stomach with arms resting at sides
2. Pinch shoulder blades together
3. Now, raise arms off floor as shown
4. Hold for 10 seconds and slowly lower
5. Do 10 repetitions

40.



1. Stand with hands against wall as shown
2. Pinch shoulder blades together
3. Lean against wall, while keeping arms straight
4. Hold for 10 seconds
5. Do 10 repetitions

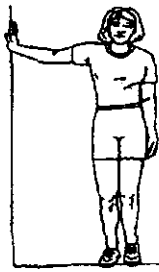
Neurological exercises (pre-season)

41.



1. Lie on back holding L/R leg with towel/rope as shown
2. Put your chin on your chest
3. Hold for 20 seconds
4. Do three repetitions per leg

42.



1. Place your hand against the wall as shown, with fingers facing upward and elbow bent
2. Flatten the palm of your hand against the wall and straighten your elbow
3. Hold for 1 second, then bend elbow again
4. Do 10 repetitions
5. Repeat on opposite side

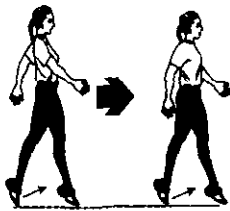
43.



1. Lie on your stomach as shown
2. Hold onto your foot and make sure you pull your foot and toes towards your buttocks
3. Your knees must stay together
4. When you feel a stretch, hold
5. Hold for 30 seconds
6. Do three repetitions per leg

Speed, agility and power exercises (pre-season)

44.



1. Run as shown
2. Keep the legs straight and toes pointed
3. You must make fast ground contact with the ball of the foot
4. Pull through with the hips
5. Run for 20 m
6. Do three repetitions, twice a week

45.



1. Place four markers in a straight line at 5 m intervals
2. Start 5 m from the first marker and run as fast as possible
3. Run "zigzag" between the markers, from first to last marker and back
4. Do three repetitions, twice a week

46.



1. Assume position on hands and knees on the floor
2. Stand up as fast as possible in the following sequence: hands up, one foot up, then the other foot up
3. Repeat six times
4. Do three sets, twice a week

47.



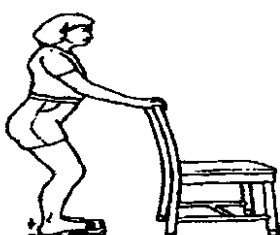
1. Skip, driving the knees upward as fast as possible
2. Arm action must be very aggressive as well
3. Skip as high as possible on each jump
4. Stay in one place
5. Do 6 repetitions
6. Do three sets, twice a week

START-OF-SEASON PROGRAMME. LEVEL 1 (6 WEEKS)

This maintenance programme must be followed intensely for 6 weeks, up to the level 2 programme (advanced maintenance). All exercises – except speed, agility and power exercises – are done **three** times a week as graphically displayed and described. The speed, agility and power exercises should be done **twice** a week, on Mondays and Wednesdays. If uncertain ask the trainer/coach.

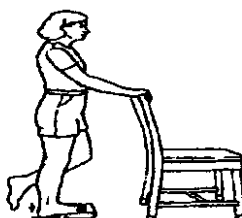
Lower limb exercises (start-of-season, level 1)

1.



1. Stand with the ball of your L/R foot on a step as shown
2. Lower the heel of your foot then bend your knee until you feel a stretch
3. Hold for 30 seconds
4. Do three repetitions
5. Repeat on opposite side

2.



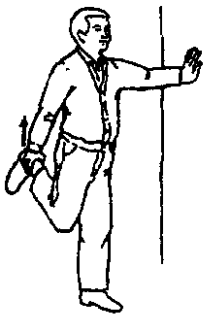
1. Position the ball of your L/R foot on a step as shown
2. Keep your leg straight
3. Lower you heel until you feel a stretch
4. Hold for 30 seconds
5. Do three repetitions
6. Repeat on opposite side

3.



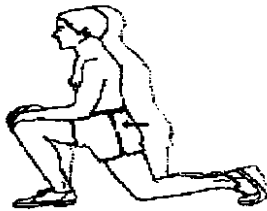
1. Stand with L/R side facing wall
2. Cross the leg closest to the wall in front of the other leg as shown
3. Bend the front knee slightly and lean your body towards the wall (see arrows) while moving your hip away from the wall
4. You may stretch both hands overhead to lean against the wall
5. Hold for 30 seconds
6. Do three repetitions
7. Repeat on opposite side

4.



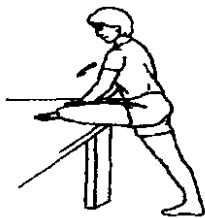
1. Stand holding the L/R ankle as shown
2. Keep your knees together and pull your knee upward so that you feel a stretch
3. Make sure your thigh stays in line with your body (don't let it point forward) and don't arch your back
4. Hold for 30 seconds
5. Do three repetitions
6. Repeat on opposite side

5.



1. Assume position with L/R knee on soft surface
2. Tilt your pelvis slightly back (posterior) and hold this position
3. Now lean your whole body forward, keeping your chest upright
4. Hold for 30 seconds
5. Do four repetitions
6. Repeat on opposite side

6.



1. Stand upright placing L/R leg on a fixed object as shown
2. Lean your trunk forward so that you feel a stretch
3. Keep your back straight
4. Hold for 30 seconds
5. Do three repetitions

7.



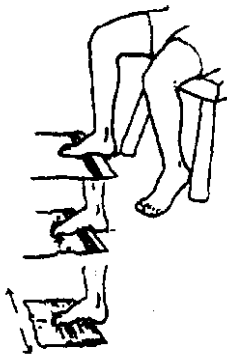
1. Sit with knees bent, feet together
2. Press knees downward towards the floor by pressing down with the elbows and leaning forward as shown
3. Hold for 30 seconds
4. Do three repetitions

8.



1. Sit upright with back supported against a wall (*unlike picture*) and 2.5 kg weight around L/R ankle
2. Roll up a towel and place it under the L/R knee
3. Rotate L/R leg outward so that toes point slightly to the outside
4. Activate the VMO and straighten leg (knee extension)
5. Hold position for 5 seconds
6. Repeat 30 times per leg

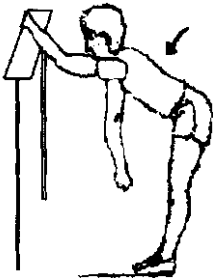
9.



1. Place towel on a slippery surface, with a 1 kg weight on top of the L/R tip of the towel
2. Grab the towel using your toes
3. Pull the towel to one side (away from the weight) using your foot
4. Repeat for 1 minute
5. Repeat to the opposite side for 1 minute
6. Do three repetitions to each side (inside and outside)
7. Repeat with other foot

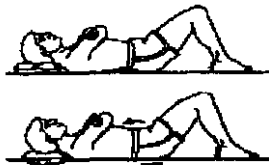
Pelvic girdle exercises (start-of-season, level 1)

10.



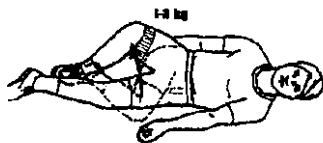
1. Put L arm on table (when L leg is "shorter")
2. L arm must be in line with R shoulder
3. Legs should be spaced at shoulder width and kept straight
4. Lean down in direction of arrow
5. Place your weight on the left leg
6. You may press your hip slightly to the left to increase the stretch
7. Hold for 30 seconds
8. Do three repetitions

11.



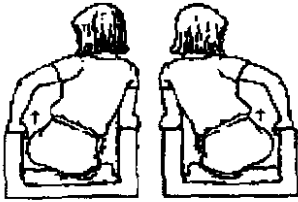
1. Lie on back with knees bent
2. Place a plastic soccer ball between your knees
3. Tighten lower abdominal muscles, squeeze buttocks and flatten back as shown while squeezing the ball
4. Hold for 10 seconds
5. Do 10 repetitions
6. Repeat the above with a belt around the knees and press out

12.



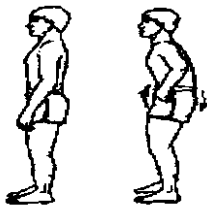
1. Lie on your side, with bottom knee straight and top knee bent as shown,
2. Place a 1-2 kg weight around the top thigh, just above the knee
3. Place top foot on bottom leg, just below level of bottom knee
4. Lift/rotate top knee upward, keeping spine and pelvis stable throughout
5. Hold for 10 seconds at the top
6. Do 10 repetitions
7. Repeat on opposite side

13.



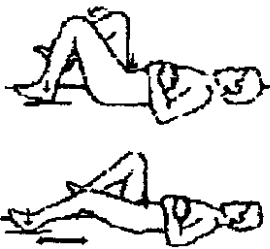
1. Sit upright on a chair/bench as shown
2. Activate the core stabilising muscles on the side of the "longer leg"
3. Lift the buttock on the side of the "longer leg" slightly without using your arms
4. Hold for 10 seconds then relax
5. Do 10 repetitions on side of "longer leg" only

14.



1. Stand as shown
2. Find pelvic neutral (as demonstrated by the trainer)
3. Tilt pelvis as shown by tightening the lower abdominal muscles and squeezing the buttocks
4. Hold for 10 seconds then rotate back to pelvic neutral
5. Do 10 repetitions

15.



1. Lie on back with both feet lifted, hips and knees flexed to 90 °
2. Initiate lower abdominal hollowing with activation of stabilisers to flatten back
3. Maintain this contraction and slowly lower one heel to touch the floor
4. Keep heel on floor and slowly extend the leg out as far as trunk control allows
5. Hold stable position for 10 seconds before returning to start
6. Repeat 10 times L and R

16.



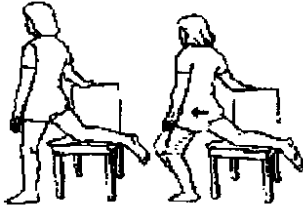
1. Lie on your belly with a pillow/your hands underneath forehead
2. Tighten the L/R buttock first then raise L/R leg of floor
3. Hold for 10 seconds, slowly relax
4. Do 10 repetitions per leg

17.



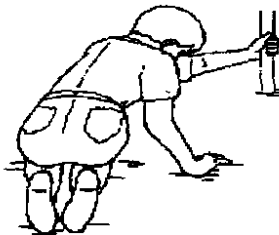
1. Lie on your back with your feet on the floor and hands behind your neck
2. Curl your trunk upward, pressing your chest towards your knees
3. Only curl up until your shoulders are lifted from the floor
4. Pause in the upper position for 2 seconds then relax
5. Do 20 repetitions
6. Repeat the above while crossing elbow to opposite knee

18.



1. Assume position with L/R knee on bench
2. Tilt the pelvis in the posterior direction and bend the opposite knee until you feel a stretch
3. Do not allow your lower back to arch
4. Hold for 30 seconds
5. Do three repetitions
6. Repeat on opposite side

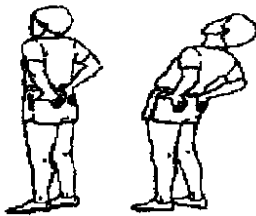
19.



1. Hold onto solid object with L/R hand as shown (hand should reach across)
2. Sit back onto heels
3. Hold for 30 seconds
4. Do three repetitions
5. Repeat on opposite side

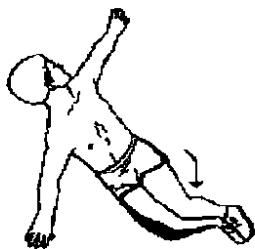
Spinal exercises (start-of-season, level 1)

20.



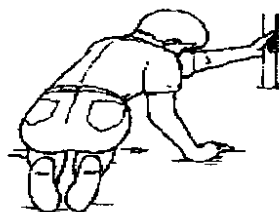
1. Place hands with palms on upper part of buttocks
2. Press with hands against pelvis and bend backward until you feel a stretch
3. Hold for 15 seconds
4. Do three repetitions

21.



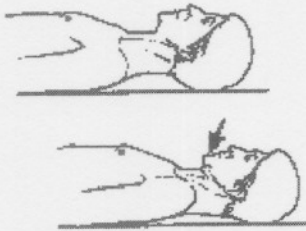
1. Lie on back with knees bent, arms out to side
2. Keep knees together and rotate to L/R, turning head in opposite direction as shown, until you feel a stretch
3. Hold for 30 seconds
4. Do three repetitions
5. Repeat on opposite side

22. *(Omit exercise if already done under Pelvic girdle)*



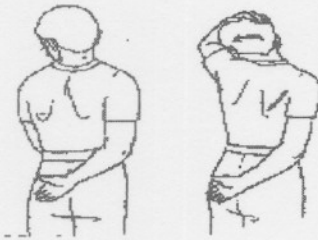
1. Hold onto solid object with L/R hand as shown (hand should reach across)
2. Sit back onto heels
3. Hold for 30 seconds
4. Do three repetitions
5. Repeat on opposite side

23.



1. Lie down on your back
2. Tuck your chin in as shown
3. Press down into the floor
4. Hold position for 10 seconds
5. Do 10 repetitions

24.



1. Put your L/R hand behind back as shown
2. Turn your chin towards your opposite armpit
3. Position your other hand behind your head and pull in direction of arrow
4. Hold for 30 seconds
5. Do three repetitions
6. Repeat on opposite side

25.



1. Stand on all fours with trunk and neck in optimum (neutral) position
2. Contract the L/R buttocks and lift the same (L/R) leg to horizontal
3. Also lift the opposite arm
4. Hold the position for 5 seconds
5. 2 x 10 repetitions
6. Repeat on opposite side

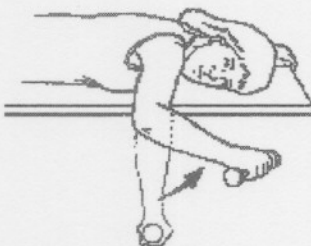
Upper limb/shoulder exercises (start-of-season, level 1)

26.



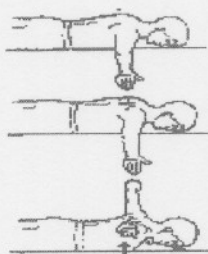
1. Stand with L/R hand and forearm placed on door frame as shown
2. Lean forward until you feel a stretch
3. Hold for 30 seconds
4. Do three repetitions
5. Repeat on opposite side

27.



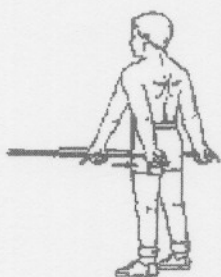
1. Hold a 2-3 kg weight in your L/R hand
2. Lie on bed as shown, with arm out to side, elbow bent and the crease of the elbow over edge of bed
3. Keeping elbow bent, rotate arm upward (toward ceiling)
4. Hold for 5 seconds and slowly lower
5. 2 x 10 repetitions

28.



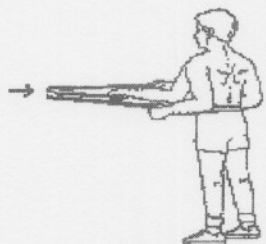
1. Lie on belly with arms positioned at 90-degree angles with your body
2. Pinch shoulder blades together
3. Raise arms 5-10 cm off floor
4. Hold for 10 seconds
5. Do 10 repetitions

29.



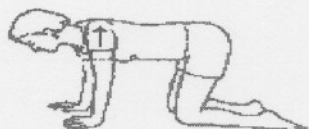
1. Anchor rubber tubing around a solid object
2. Stand holding rubber tubing, with arms positioned in front of body
3. Step away from object so that tubing starts to stretch
4. Pinch shoulder blades together
5. Hold this position while pulling arms straight backward
6. Hold for 10 seconds and slowly relax
7. Do 10 repetitions

30.



1. Anchor rubber tubing to a solid object
2. Hold tubing in both hands and bend elbows
3. Squeeze shoulder blades together
4. Pull tubing backwards, until hands are next to the body
5. Hold for 10 seconds
6. Do 10 repetitions

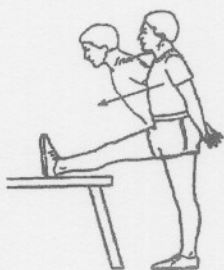
31.



1. Assume position on floor as shown
2. Straighten arms and squeeze shoulder blades together
3. Lean down with your weight
4. Hold for 10 seconds
5. Do 10 repetitions

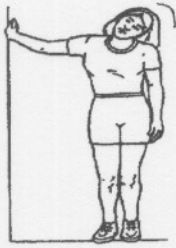
Neurological exercises (start-of season, level 1)

32.



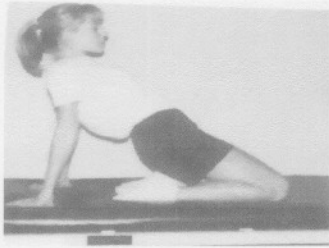
1. Position L/R foot on bench as shown, with toes pointing upward
2. Straighten L/R knee and maintain a straight back
3. Move trunk in direction of arrows and tilt pelvis slightly anterior
4. Put chin on chest and flex L/R foot towards body to stretch nerve
5. Hold for 20 seconds
6. Do three repetitions
7. Repeat on opposite side

33.



1. Place your L/R hand against the wall as shown, with fingers pointing up
2. Flatten the palm of your hand against the wall and straighten your elbow
3. Bend head away from L/R arm and hold for 1 second
4. Repeat steps one to three 10 times
5. Repeat on opposite side

34.



1. Kneel on a soft surface as shown
2. Lean backwards with upper body so that buttocks move towards heels
3. Shoulders should be behind (posterior to) buttocks, arms assisting in supporting weight
4. Hold for 30 seconds
5. Do three repetitions

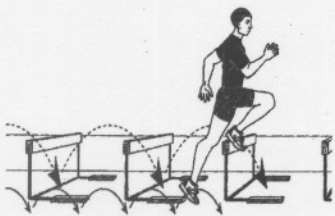
Speed, agility and power exercises (start-of-season, level 1)

35.



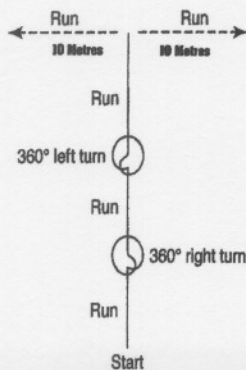
1. Lean against a wall with your arms, at a 45 to 60 degree angle to the wall
2. Always stay on the balls of your feet
3. Bring one knee up with a fast action
4. From this position bring the same knee down again and the other knee up
5. Do six repetitions per leg
6. Do two sets, twice a week

36.



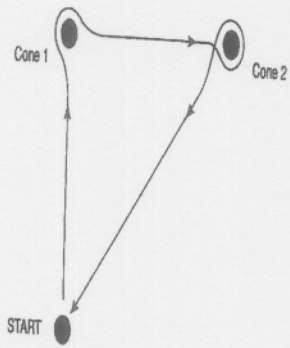
1. Set eight 15 to 30 cm hurdles 75 cm apart
2. Run with one leg outside the hurdles and the other leg over the hurdles
3. Keep the outside leg as straight as possible and the inside leg (“hurdling leg”) as quick as possible
4. Do two sets per leg, twice a week

37.



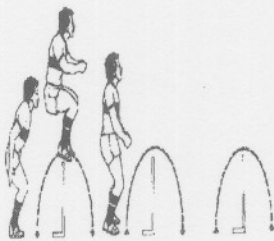
1. Stand at the start in a two-point stance
2. Sprint 5 m forward
3. Rotate 360 ° and sprint another 5 m
4. Rotate 360 ° and sprint another 5 m
5. Sprint right or left for 10 m
6. Do three repetitions to the left and three to the right
7. Do two sets, twice a week

38.



1. Stand at start in two-point stance
2. Sprint 5 m forward to the first cone, and turn sharply around it to the right
3. Sprint to the second cone and make a left turn around it
4. Sprint 5 m to the finish
5. Do 6 repetitions
6. Do two sets, twice a week

39.



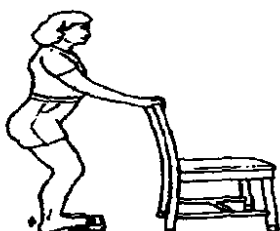
1. Propel your body over six barriers by jumping forward
2. Use ankle-knee-hip extension and maintain a vertical body posture
3. Tuck your knees to your chest when clearing an obstacle
4. Use a double-arm swing to maintain balance and to achieve height
5. Do two sets, twice a week

START-OF-SEASON PROGRAMME. LEVEL 2

This advanced maintenance programme must be followed intensely up to the mid-season programme. As with level 1 exercises, all exercises – except speed, agility and power exercises – are done **three** times a week. The speed, agility and power exercises should be done **twice** a week, on Mondays and Wednesdays.

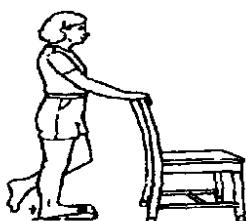
Lower limb exercises (start-of-season, level 2)

1.



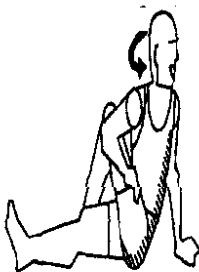
1. Stand with the ball of your L/R foot on a step as shown
2. Lower the heel of your foot, then bend your knee until you feel a stretch
3. Hold for 40 seconds
4. Do three repetitions
5. Repeat on opposite side

2.



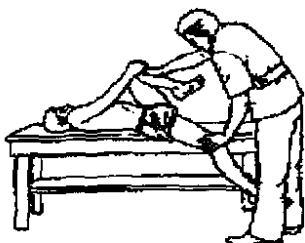
1. Position the ball of your L/R foot on a step as shown
2. Keep your leg straight
3. Lower your heel until you feel a stretch
4. Hold for 40 seconds
5. Do three repetitions
6. Repeat on opposite side

3.



1. Sit on floor and bend L leg at the knee, and cross it over the R (straight) leg
2. Place your R elbow against the outside of your L thigh
3. Rotate your trunk and head towards the left while pressing with the R elbow against the L thigh
4. Hold for 30 seconds
5. Do three repetitions per leg

4.



1. Lie on bench with L/R leg hanging over the side as shown
2. Bend the other knee, and pull it towards the chest as shown
3. Your partner/trainer should assist the stretch by slowly pressing down on the two knees as illustrated
4. Hold for 30 seconds
5. Do three repetitions per leg

5.



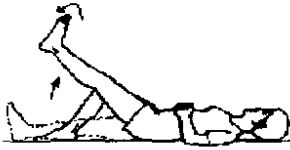
1. Stand propping L/R leg on Swiss ball as shown
2. Keep lower back straight, then lean trunk forward until you feel a stretch
3. To finish, rotate trunk in direction away from top leg
4. Hold for 30 seconds
5. Do three repetitions
6. Repeat on opposite side

6.



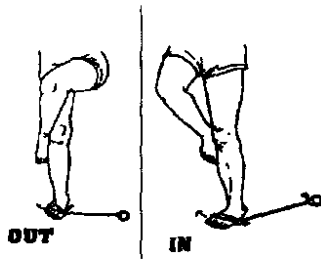
1. Assume position with L/R leg out to the side and other knee bent
2. Keep L/R knee locked, press thigh downward, and shift weight towards bent leg
3. Hold for 30 seconds
4. Do three repetitions
5. Repeat on opposite side

7.



1. Sit upright, with your lower back supported against a wall (*unlike picture*)
2. Straighten the L/R leg, and keep the other knee bent
3. Rotate the L/R leg to the outside, so the toes point slightly out
4. Activate the L/R VMO and lift the leg from the floor
5. Hold for 10 seconds
6. Do 10 repetitions per leg

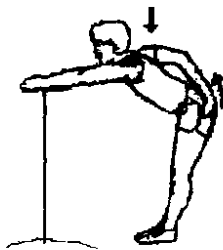
8.



1. Do only the IN or only the OUT version of this exercise, as instructed by the trainer
2. Sit with R/L leg extended and place other foot next to L/R knee for support
3. Anchor rubber tubing around a solid object and around L/R foot as shown
4. Move foot either inward or outward, as specified (*inversion/ eversion*), and slowly return
5. Do 3 x 15 repetitions per foot

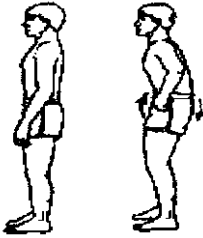
Pelvic girdle exercises (start-of-season, level 2)

9.



1. Do this exercise only with the “shorter” leg
2. Place feet at shoulder width and straighten legs
3. If L leg is “shorter”, place L arm on table, directly opposite R shoulder
4. Place other hand around L hip, with fingers grasping area of L lateral ilium
5. Lean down with trunk and head and pull with R hand in direction of arrow
6. You may lean slightly to the left with the L hip to increase the stretch
7. Hold for 30 seconds, repeat three times

10.



1. Do this exercise while squeezing a **plastic soccer ball** between the knees
2. Stand as shown
3. Find pelvic neutral (as demonstrated by the trainer)
4. Tilt pelvis as shown by tightening the lower abdominal muscles and squeezing the buttocks
5. Hold for 10 seconds then rotate back to pelvic neutral
6. Do 10 repetitions

11.



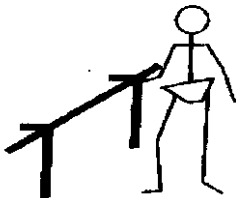
1. Assume position on hands and knees
2. Keep knee bent and lift L/R hip out to side
3. Keep the spine and pelvis stable throughout
4. Hold for 10 seconds and slowly lower
5. Do 10 repetitions with each leg

12.



1. Lie on your side, positioned as shown
2. Push your upper hand into the floor and flex your feet towards your head
3. Raise the upper leg to hip level
4. Raise the lower leg toward the upper one, leaving a space between the legs
5. Hold for 10 seconds then relax
6. Do 10 repetitions on L and R side

13



1. Stand with hands supported on a tabletop/horizontal bar
2. Keep both legs straight throughout exercise
3. The “longer leg” is the weight-bearing leg
4. Use the trunk side flexors on the side of the “longer leg” to tilt the pelvis laterally upward until the heel comes off the floor
5. Hold for 10 seconds
6. Do 10 repetitions on the side of the “longer leg”

14.



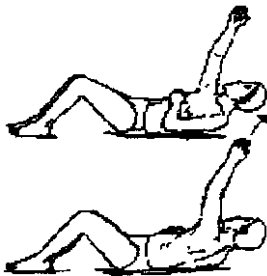
1. Lie on back with both feet lifted, hips and knees flexed to 90 °
2. Initiate lower abdominals and stabilisers to flatten back
3. Maintain this contraction and slowly lower one heel to 5 cm above the floor
4. Keep back flat and slowly extend the leg as far as stable pelvis allows, while keeping the leg 5 cm above the floor
5. Hold stable position for 10 seconds before returning to start
6. Repeat 10 times L and R

15.



1. Lie on back with knees bent as shown and find pelvic neutral
2. Lift balls of feet, tighten buttocks and raise them off the floor
3. Lift until pelvis and spine are in a straight line
4. Hold for 10 seconds, while keeping the pelvis stable and buttocks tight
5. Slowly lower
6. Do 10 repetitions

16.



1. Lie on back with knees bent
2. Reach diagonally upward with L/R arm, lifting head and L/R shoulder blade off the floor
3. Hold for 2 seconds
4. Do 2 x 20 repetitions on L and R side

17.



1. Lie on your back with feet positioned on ball
2. Tighten and lift buttocks
3. Curl feet towards buttocks
4. Hold for 2 seconds
5. Do 2 x 10 repetitions

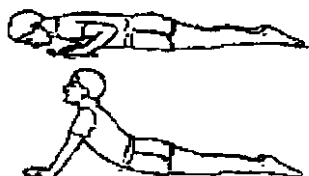
18.



1. Lie on back with hands positioned around knees as shown
2. Pull knees towards chest
3. Hold for 40 seconds
4. Do 2 repetitions

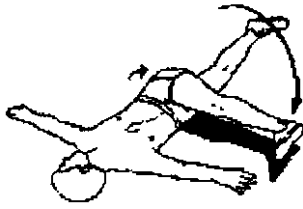
Spinal exercises (start-of-season, level 2)

19.



1. Lie on stomach with hands positioned beneath shoulders
2. Straighten arms while keeping pelvis on the floor
3. Hold for 20 seconds when you feel a stretch
4. Do three repetitions

20.



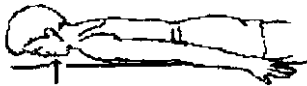
1. Lie on your back with arms positioned next to the sides
2. Keep legs straight
3. Cross legs as shown
4. Move the R/L leg in direction of arrow until you feel a stretch
5. Hold for 30 seconds
6. Do three repetitions

21.



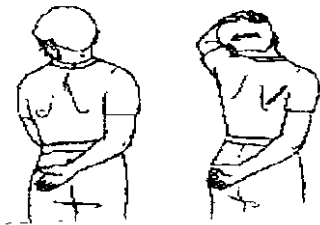
1. Place L/R hand behind head
2. Use the other hand to grasp the L/R elbow as shown
3. Pull in direction of arrows until you feel a stretch
4. Hold for 30 seconds
5. Do three repetitions
6. Repeat on opposite side

22.



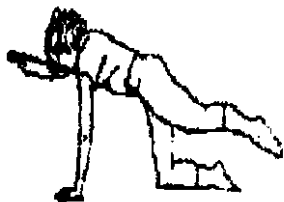
1. Lie on your stomach as shown
2. Do a chin tuck to lift head slightly of the floor
3. Hold for 10 seconds
4. Do 10 repetitions

23.



1. Put your L/R hand behind back as shown
2. Turn your chin towards your opposite armpit
3. Position your other hand behind your head and pull in direction of arrow
4. Hold for 30 seconds
5. Do three repetitions
6. Repeat on opposite side

24.



1. Stand on all fours with trunk and neck in optimum (neutral) position
2. Contract the L/R buttocks and lift the same (L/R) leg to horizontal
3. Also lift the opposite arm
4. Hold the position for 10 seconds
5. Do 10 repetitions
6. Repeat on opposite side

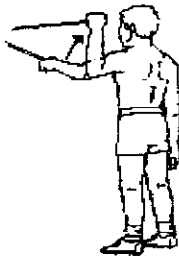
Upper limb/shoulder exercises (start-of-season, level 2)

25.



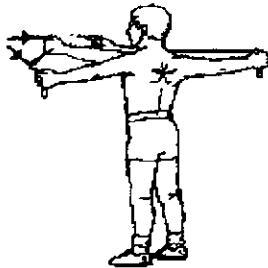
1. Use a broomstick for this exercise
2. Grasp the broomstick with both hands, palms facing forward, hands spaced slightly wider than the girth of the head
3. Place broomstick behind head, move elbows to the rear and pull broomstick down towards the floor
4. Hold for 30 seconds
5. Do three repetitions

26.



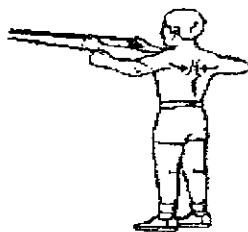
1. Anchor rubber tubing to a solid object, at shoulder height
2. Take tubing in L/R hand and lift L/R elbow to shoulder height
3. Pinch shoulder blades together
4. Start with L/R hand level to the floor and then rotate arm so that hand moves upward (see arrow), keeping elbow in one position throughout
5. Hold 5 seconds and slowly lower to starting position
6. Do 2 x 10 repetitions per arm

27.



1. Place middle of rubber tubing around pole, just lower than shoulder level
2. With each hand, grasp one end of tubing
3. Raise hands in front of you to just below shoulder height, and straighten arms so elbows are only slightly bent
4. Pinch shoulder blades together, and move arms as far as possible to the rear (reverse) and hold for 10 seconds
5. Do 10 repetitions

28.



1. Anchor middle of rubber tubing to a solid object at shoulder level
2. Hold tubing in both hands, arms straight in front of you as shown
3. Pinch shoulder blades back, and bend your elbows as you pull your elbows straight back
4. Hold for 10 seconds
5. Do 10 repetitions

29.



1. Assume push-up position on floor as shown
2. Squeeze shoulder blades together, and keep them "pinched" throughout
3. Straighten arms to raise your trunk
4. Slowly lower and hold for 10 seconds at bottom
5. Do 10 repetitions

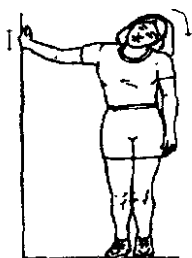
Neurological exercises (start-of season, level 2)

30.



1. Lie on your back with L/R knee bent, fingers locked behind L/R knee
2. Slowly straighten L/R leg so you feel a stretch
3. Hold this position, then put your chin on your chest, and flex the L/R foot slowly towards you and back again
4. Do 10 repetitions (move L/R foot 10 times up and down)
5. Repeat on opposite side

31.



1. Place your L/R hand against the wall, with fingers pointing upward
2. Flatten the palm of your hand against the wall and straighten your elbow
3. Bend head away from L/R arm and hold for 1 second
4. Repeat step one to three 10 times
5. Repeat on opposite side
6. Repeat exercise, but rotate arm clockwise so fingers point down

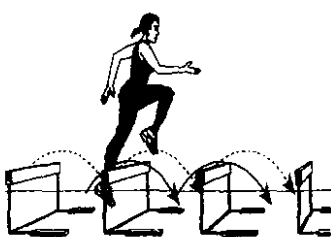
32.



1. Lie as shown with pillow under L/R knee
2. Take hold of your foot and pull your foot and toes towards your buttocks
3. Your knees must stay together
4. When you feel a stretch, hold
5. Hold for 30 seconds
6. Repeat twice per leg

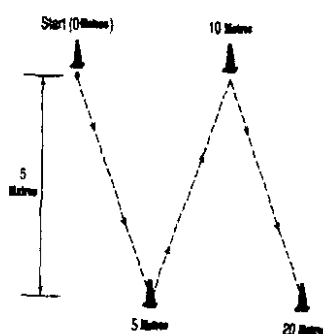
Speed, agility and power exercises (start-of-season, level 2)

33.



1. Set eight 15 to 30 cm hurdles about 75 cm apart
2. Run with one leg outside the hurdles and the other leg over the hurdles
3. Emphasise fast “knee up/toe up” with quick heel-to-gluteus recovery
4. Perform each exercise with a fast one-foot strike between hurdles, maintaining the same lead leg throughout each drill
5. Do two sets per leg, twice a week

34.



1. Place cones as indicated
2. Stand in a two-point stance
3. Sprint from cone to cone, stepping off the outside leg and cutting sharply around cones
4. Do two repetitions, twice a week

35.



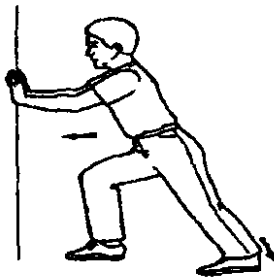
1. Load the lower body by swinging both arms back while flexing the hips and knees
2. Begin the forward jump with the L/R leg as the arms swing forward
3. Assist bound by kicking the opposite leg forward and up into the air
4. The “kicking” leg is the one returning to the ground
5. Upon landing, repeat quickly with the same technique (opposite leg jumps)
6. Perform six bounds on each leg
7. Do two sets, twice a week

MID-SEASON PROGRAMME (1 WEEK)

This maintenance and conditioning programme must be followed intensely for 1 week. All exercises – except speed, agility and power exercises – are done **four** times a week. The speed, agility and power exercises should be done **twice** a week, on Mondays and Wednesdays.

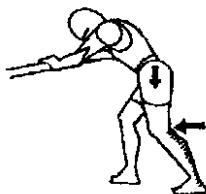
Lower limb exercises (mid-season)

1.



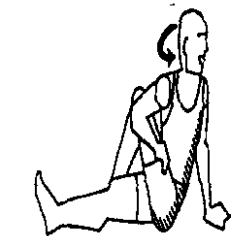
1. Stand facing a wall
2. Position the L/R leg at the back, with the heel flat on the floor
3. Place the other leg in front
4. Bend the front leg and arms so you feel a stretch
5. Hold for 30 seconds
6. Do three repetitions
7. Repeat on opposite side

2.



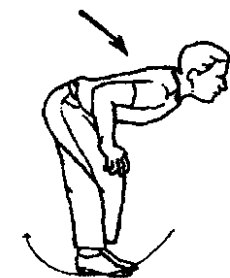
1. Stand facing a wall
2. Position the L/R leg at the back, with the heel flat on the floor
3. Place the other leg in front
4. Bend the back leg, while keeping the heel flat
5. Hold for 30 seconds
6. Do three repetitions
7. Repeat on opposite side

3.



1. Sit on floor and bend L leg at the knee, and cross it over the R leg
2. Place your R elbow against the outside of your L thigh
3. Rotate your trunk and head towards the left while pressing with the R elbow against the L thigh
4. Hold for 30 seconds
5. Do three repetitions per leg

4.



1. Stand, bearing the most of your weight on your L/R leg
2. Bend the other leg and cross it in front as shown
3. Lean forward, bending at the hip and keeping your back straight
4. If the R leg is in front, rotate your body to the R and hold
5. Repeat three times for 30 seconds per leg

5.



1. Assume position with L/R knee on soft surface
2. Tilt your pelvis slightly back (posterior) and hold this position
3. Now lean your whole body forward, keeping your chest upright
4. Hold for 30 seconds
5. Do four repetitions
6. Repeat on opposite side

6.



1. Assume position shown, with L/R leg straight and other leg in front
2. Move the pelvis towards the floor as shown by the arrows
3. Hold for 30 seconds
4. Do three repetitions
5. Repeat on opposite side

7.



1. Stand propping L/R leg on Swiss ball as shown
2. Bend L/R hip 90 ° and L/R knee 45 °
2. Keep lower back straight, then lean trunk forward until you feel a stretch
3. Next, rotate trunk in direction away from top leg
4. Hold for 30 seconds
5. Do three repetitions
6. Repeat on opposite side

8.



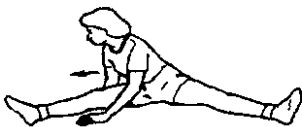
1. Lie on back, resting L ankle on R knee
2. Hold R thigh as shown and pull R leg towards chest until you feel a stretch
3. Use L elbow to press against L knee
4. Hold for 30 seconds
5. Do three repetitions
6. Repeat on opposite side

9.



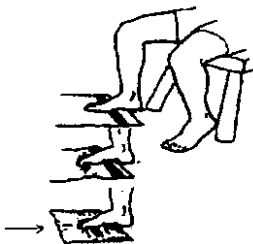
1. Assume position with L/R leg out to the side and other knee bent
2. Keep L/R knee locked, press thigh downward and shift weight towards bent leg
3. Hold for 30 seconds
4. Do three repetitions
5. Repeat on opposite side

10.



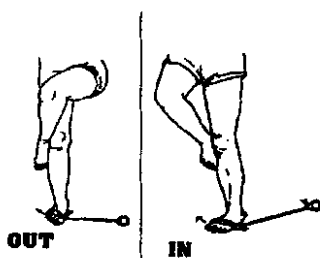
1. Sit on the floor with legs spread as shown
2. Straighten legs and lean forward over the L/R leg
3. Keep your back straight
4. Hold for 30 seconds
5. Do three repetitions
6. Repeat on opposite side

11.



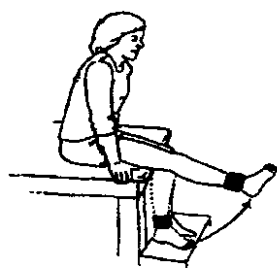
1. Place towel on slippery surface such as tiles
2. Place heel on floor and ball of foot on towel
3. Grab towel using your toes
4. Repeatedly scrunch up towel towards you using the foot muscles
5. Repeat for 1 minute per foot
6. Do three repetitions per foot

12.



1. Do only the IN or only the OUT version of this exercise, as instructed by the trainer
2. Sit with R/L leg extended and place other foot next to L/R knee for support
3. Anchor rubber tubing around a solid object and around L/R foot as shown
4. Move foot either inward or outward, as specified (inversion/ eversion), and slowly return
5. Do 3 x 15 repetitions per foot

13.



1. Fasten a 2-3 kg weight around L/R ankle
2. Rotate the L/R leg slightly outward so the toes point out
3. Activate the L/R VMO and straighten the leg
4. Hold for 10 seconds at the top
5. Lower only 30 ° and straighten again
6. Do 10 repetitions
7. Repeat on opposite side

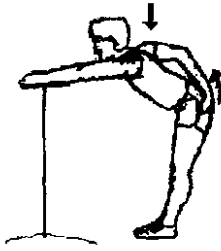
14.



1. Sit upright, with your lower back supported against a wall (*unlike picture*)
2. Straighten the L/R leg, and keep the other knee bent
3. Rotate the L/R leg to the outside, so toes the point out slightly
4. Activate the L/R VMO and lift the leg from the floor
5. Hold for 10 seconds
6. Do 10 repetitions
7. Repeat with opposite leg

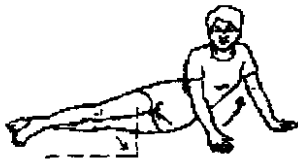
Pelvic girdle exercises (mid-season)

15.



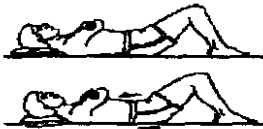
1. Do this exercise only with the “shorter” leg
2. Place feet at shoulder width and straighten legs
3. If L leg is “shorter”, place L arm on table, directly opposite R shoulder
4. Place other hand around L hip, with fingers grasping area of L lateral ilium
5. Lean down with trunk and head and pull with R hand in direction of arrow
6. You may lean slightly to the left with the L hip to increase the stretch
7. Hold for 30 seconds, and repeat 3 times

16.



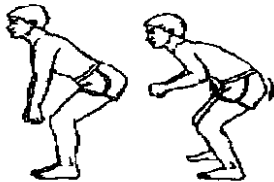
1. Lie on side as shown with the bottom leg straight, top knee bent 90 °, and knees in contact with floor
2. Keep hips on the floor and use arms to press trunk upright
3. Hold for 30 seconds
4. Do three repetitions
5. Repeat on the other side
6. The top knee may be bent, put on the floor and moved closer to the hands for an increased stretch

17.



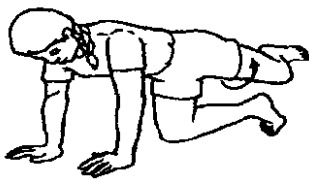
1. Lie on back with knees bent
2. Place a plastic soccer ball between the knees
3. Tighten lower abdominal muscles, squeeze buttocks and flatten back as shown while squeezing the ball
4. Hold for 10 seconds
5. Do 10 repetitions

18.



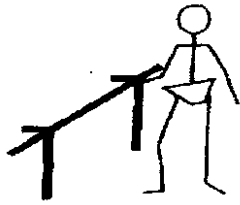
1. Stand with feet at shoulder width, knees bent, trunk flexed slightly forward
2. Hold the spine straight, and find pelvic neutral; this is the starting position
3. Activate the stabilisers and tilt the pelvis posteriorly (in direction of arrows)
4. Hold for 10 seconds and tilt back to starting position
5. Do 10 repetitions

19.



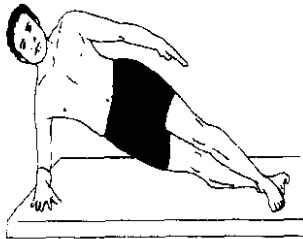
1. Assume position on hands and knees
2. Keep knee bent and lift L/R hip out to side
3. Keep the spine and pelvis stable throughout
4. Hold for 10 seconds and slowly lower
5. Do 10 repetitions per leg

20.



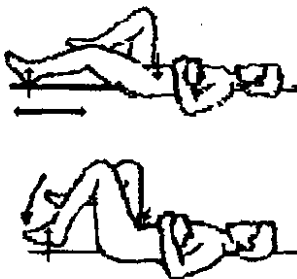
1. Stand with hands supported on a tabletop/bar
2. Keep both legs straight throughout exercise
3. The “longer leg” is the weight-bearing leg
4. Use the trunk side flexors on the side of the “longer leg” to tilt the pelvis upward laterally until the heel comes off the floor
5. Hold for 10 seconds
6. Do 10 repetitions on the side of the “longer leg”

21.



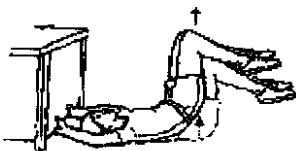
1. Position yourself on the floor, on your L/R side with elbow directly below shoulder, hips on the floor, and legs spread as shown
2. Ensure your body is positioned in a straight line
3. Support your weight on your forearm and feet and lift the buttocks
4. Stabilise the trunk by tightening the abdominals
5. Hold for 10 seconds in position as shown
6. Do 10 repetitions

22.



1. Lie on back with both feet lifted; hips and knees flexed to 90 °
2. Initiate lower abdominals and stabilisers to flatten back
3. Maintain this contraction and slowly lower one heel to 5 cm above the floor
4. Keep back flat and slowly extend the leg out far as the stable pelvis allows, while keeping the leg 5 cm above the floor
5. Hold stable position for 10 seconds before returning to start
6. Repeat 10 times L and R

23.



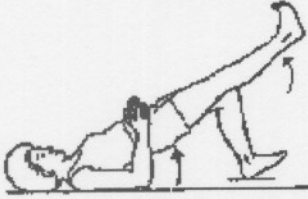
1. Lie on your back with hips and knees bent 90 °
2. Hold on to a fixed object as shown
3. Tighten lower abdominals to raise hips and knees straight upward
4. Hold for 2 seconds
5. Do 15 repetitions
6. Do 2 sets

24.



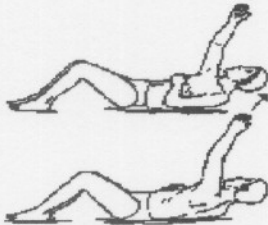
1. Lie on your back with feet positioned on ball
2. Tighten and lift buttocks
3. Curl feet towards buttocks
4. Hold for 2 seconds
5. Do 2 x 10 repetitions

25.



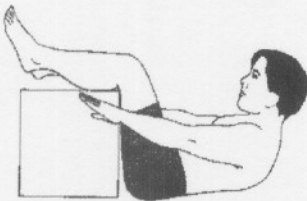
1. Lie on your back with L/R leg bent, and ball of L/R foot raised as shown
2. Find pelvic neutral, activate stabilisers and tighten buttocks (glut max)
3. Raise buttocks off the floor so pelvis is level with supporting thigh
4. Keep pelvis level and stabilised
5. Hold for 10 seconds, slowly relax
6. Do 10 repetitions
7. Repeat on opposite side

26.



1. Lie on back with knees bent
2. Reach diagonally upward with L/R arm, lifting head and L/R shoulder blade off the floor
3. Hold for 2 seconds
4. Do 20 repetitions on L and R side
5. Do 2 sets

27.



1. Lie on your back with your feet on a bench and arms at your sides
2. Curl your trunk upward, pressing your chest towards your knees
3. Only curl up until your shoulders are lifted from the floor
4. Pause in the upper position for 2 seconds then relax
5. Do 20 repetitions

28.



1. Assume position as shown with L/R foot on a bench, and other leg straight
2. Press pelvis down towards the floor as shown, while keeping the back straight
3. Hold for 30 seconds
4. Do three repetitions
5. Repeat on opposite side

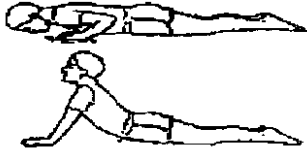
29.



1. Sit in chair
2. Bend forward as shown and hold onto the legs of the chair with your hands
3. Use your arms to pull your trunk down until you feel a stretch
4. Hold for 30 seconds
5. Do three repetitions

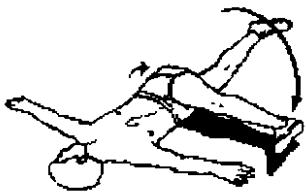
Spinal exercises (mid-season)

30.



1. Lie on tummy with hands positioned beneath shoulders
2. Straighten arms while keeping pelvis on the floor
3. Hold for 20 seconds when you feel a stretch
4. Do three repetitions

31.



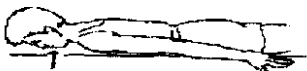
1. Lie on your back with arms positioned to the sides
2. Keep legs straight
3. Cross legs as shown
4. Move the R/L leg in direction of arrow until you feel a stretch
5. Hold for 30 seconds
6. Do three repetitions

32.



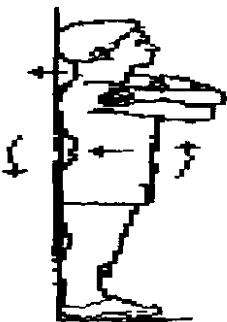
1. Place L/R hand behind head
2. Use the other hand to grasp the L/R elbow as shown
3. Pull in direction of arrows until you feel a stretch
4. Hold for 30 seconds
5. Do three repetitions
6. Repeat on opposite side

33.



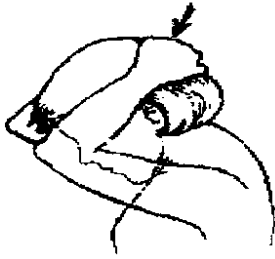
1. Lie on your stomach as shown
2. Do a chin tuck to lift your head slightly of the floor
3. Hold for 10 seconds
4. Do 10 repetitions

34.



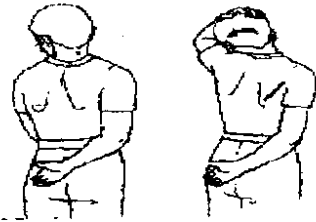
1. Stand, with your heels and buttocks against a wall
2. Activate your pelvic, scapular and cervical stabilisers
3. Perform a posterior pelvic tilt, scapular retraction and chin-tuck
4. Press lower back, scapulae and head against wall for 10 seconds
5. Do 10 repetitions
6. If you are unable to flatten your back against the wall, move your heels further from the wall

35.



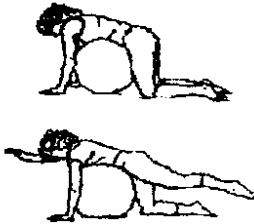
1. Do a chin tuck as in previous exercise
2. Place chin on chest
3. Use your hands to bend your neck forward
4. Maintain an upright posture throughout
5. Hold for 30 seconds
6. Do three repetitions

36.



1. Put your L/R hand behind back as shown
2. Turn your chin towards your opposite armpit
3. Position your other hand behind your head and pull in direction of arrow
4. Hold for 30 seconds
5. Do three repetitions
6. Repeat on opposite side

37.



1. Stand on hands and knees, with a Swiss ball positioned beneath abdomen
2. Activate stabilisers, tighten buttocks, raise L/R leg and opposite arm
3. Raise L/R leg and opposite arm only until they are parallel to the floor
4. Hold for 5 seconds
5. Repeat with opposite arm and leg
6. Do 2 x 10 repetitions per side

Upper limb/shoulder exercises (start-of-season, level 2)

38.



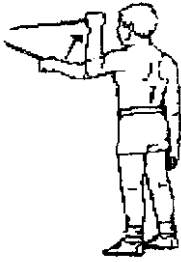
1. Use a broomstick for this exercise
2. Grasp the stick with both hands, palms facing forward, hands spaced slightly wider than the girth of the head
3. Place broomstick behind head, move elbows to the rear and pull stick down towards the floor
4. Hold for 30 seconds
5. Do three repetitions

39.



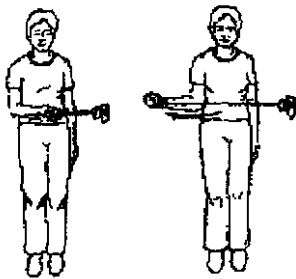
1. Stand with hands placed on door frame and feet 30-60 cm away from wall as shown
2. Lean into the door opening until you feel a stretch
3. Hold for 30 seconds
4. Do three repetitions

40.



1. Anchor rubber tubing to a solid object at shoulder height
2. Take rubber tubing in L/R hand and lift L/R elbow to shoulder height
3. Pinch shoulder blades together
4. Start with L/R hand level to the floor and then rotate arm so that hand moves upward (see arrow), keeping elbow in one position throughout
5. Hold for 5 seconds and slowly lower to starting position
6. Do 2 x 10 repetitions per arm

41.



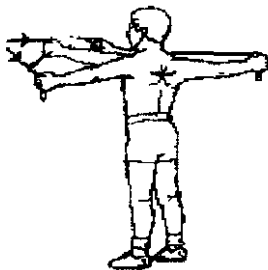
1. Anchor rubber tubing to a solid object at elbow height
2. Grasp rubber tubing in L/R hand as shown
3. Pinch shoulder blades together and rotate arm outward, keeping elbow bent
4. Hold for 5 seconds and slowly reverse to starting position
5. Do two sets of 10 repetitions
6. Repeat on opposite side

42.



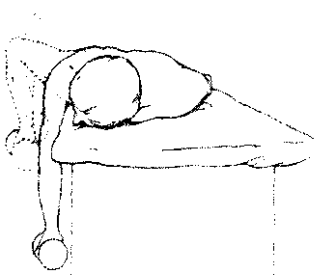
1. Lie on stomach as shown with towel under forehead and arms over head
2. Pinch shoulder blades together, point thumbs up
3. Raise arms 3-7 cm off the floor
4. Hold for 5 seconds
5. Do 10 repetitions
6. Do 2 sets

43.



1. Place middle of rubber tubing around pole, just lower than shoulder level
2. With each hand, grasp one end of rubber tubing
3. Raise hands in front of you, to just below shoulder height, and straighten arms so elbows are only slightly bent
4. Pinch shoulder blades together, and move arms to the rear (reverse) and hold for 10 seconds
5. Do 10 repetitions

44.



1. Lie on your belly on a bench, with L/R arm off the bench
2. Hold a light dumbbell in L/R hand
3. Pinch your shoulder blades together and pull the weight upwards to chest level
4. Pause 10 seconds and then lower
5. Do 10 repetitions per side

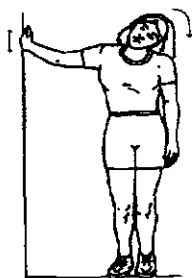
Neurological exercises (mid-season)

45.



1. Lie on your back with L/R knee bent, fingers locked behind L/R knee
2. Slowly straighten L/R leg so you feel a stretch
3. Hold this position, then put your chin on your chest, and flex the L/R foot slowly towards you and then back again
4. Do 10 repetitions (move L/R foot 15 times up and down)
5. Repeat on opposite side

46.



1. Place your L/R hand against the wall as shown, fingers pointing upward
2. Flatten the palm of your hand against the wall and straighten your elbow
3. Bend head away from L/R arm and hold for 1 second
4. Repeat step one to three 15 times
5. Repeat on opposite side
6. Repeat exercise with fingers pointing down (rotate fingers clockwise to 6 o'clock position)

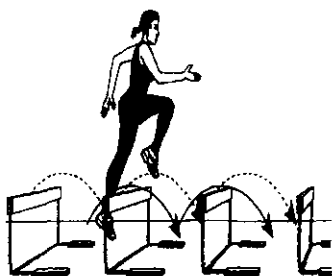
47.



1. Lie as shown with pillow under L/R knee
2. Take hold of your foot and pull your foot and toes towards your buttocks
3. Your knees must stay together
4. When you feel a stretch, hold.
5. Hold for 30 seconds
6. Repeat three times per leg

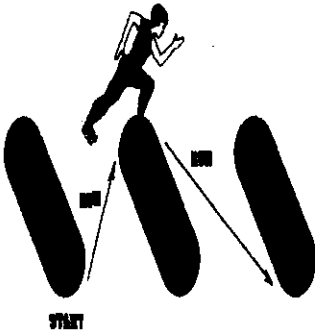
Speed, agility and power exercises (mid-season)

48.



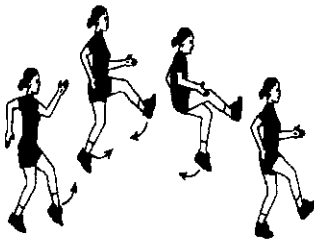
1. Set eight 15 to 30 cm hurdles about 75 cm apart
2. Run with one leg outside the hurdles and the other leg over the hurdles
3. Emphasise fast "knee up/toe up" with quick heel-to-gluteus recovery
4. Perform each exercise with a fast one-foot strike between hurdles, maintaining the same lead leg throughout each drill
5. Do three sets per leg twice a week

49.



1. Pace bags 5 m apart as shown
2. Begin at one end of the bags on the right side
3. Sprint forward from a two-point stance to the left side of the next bag
4. Use an explosive side step to propel around the bag towards the next bag
5. Repeat exercise but start on the left side of the first bag
6. Repeat 6 times (do three repetitions starting on R side of bag, and three starting L)
7. Do three sets twice a week

50.



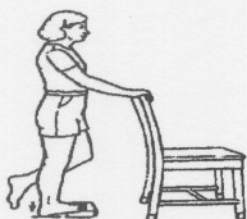
1. Jump up and forward by kicking one leg up and pushing with the other leg
2. While in the air switch the legs so you can land on the leg with which you had initially kicked up
3. Upon landing, repeat exercise (scissors jump) as quickly as possible with the other leg
4. Do three repetitions with each leg
5. Do three sets twice a week

MID-SEASON PROGRAMME. LEVEL 3

This most advanced programme must be followed intensely up to the last games (start of post-season transition phase). All exercises – except speed, agility and power exercises – are done **three** times a week. The speed, agility and power exercises should be done **twice** a week, on Mondays and Wednesdays.

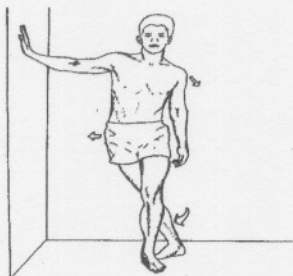
Lower limb exercises (mid season, level 3)

1.



1. Position the ball of your L/R foot on a step as shown
2. Keep your leg straight
3. Lower you heel until you feel a stretch
4. Hold for 30 seconds
5. Do three repetitions
6. Repeat on opposite side

2.



1. Stand with L/R side (tight side) facing the wall
2. Position yourself as shown, with L/R leg crossed behind other leg
3. Place L/R leg in external rotation
4. Bend trunk away from wall while shifting pelvis towards wall
5. Hold for 30 seconds
6. Do three repetitions
7. Repeat on opposite side

3.



1. Place pillow under L/R knee, and other foot in front as shown
2. Grab L/R foot with L/R hand, pulling the toes towards the buttocks
3. Move your trunk forward by bending the front knee
4. Hold for 30 seconds
5. Do three repetitions
6. Repeat on opposite side

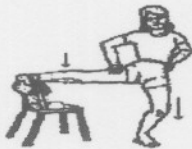
(Caution: Do not do if knee is injured or hurts during stretch)

4.



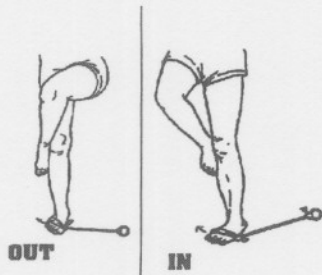
1. Stand propping L/R leg on Swiss-ball as shown
2. Keep lower back straight, then lean trunk forward until you feel a stretch
3. Turn trunk in direction away from top leg
4. Hold for 30 seconds
5. Do three repetitions per side

5.



1. Stand with L/R leg out to the side and support it on a stable object
2. Straighten L/R leg and bend the opposite knee until you feel a stretch
3. Hold for 30 seconds
4. Do three repetitions
5. Repeat on opposite side

6.



1. Use stronger rubber tubing than during the previous exercise phase
2. Do only the IN or only the OUT version of this exercise, as instructed by the trainer
3. Sit with R/L leg extended and place other foot next to L/R knee for support
4. Anchor rubber tubing around a solid object and around L/R foot as shown
5. Move foot in either inward or outward direction, as specified (inversion/ eversion) and slowly return
6. Do 3 x 15 repetitions per foot

7.



1. Start with your back against the wall, feet shoulder width apart and about 45 centimetres away from wall
2. Flatten your back against the wall and activate your L and R VMO
3. Slide down the wall until you are in a "chair position"
4. Hold for 10 seconds
5. Do 10 repetitions

Pelvic girdle exercises (mid-season, level 3)

8.



1. Do this exercise only for the "shorter" leg
2. Place feet at shoulder with and straighten legs
3. If L leg is "shorter", place L arm on table, directly opposite R shoulder
4. Place other hand around L hip, with fingers grasping area of L lateral ilium
5. Lean down with trunk and head and pull with R hand in direction of arrow
6. You may lean slightly to the left with the L hip to increase the stretch
7. Hold for 3 times 30 seconds

9.



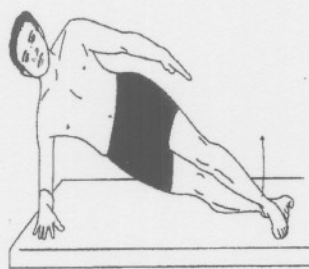
1. Lie on stomach with L/R knee bent and the other leg straight
2. Place the straight leg on top of the L/R foot (bent leg)
3. The L/R foot should be under the knee of the other leg
4. Lift L/R knee 5-7 centimetres from the floor and hold
5. Hold for 10 seconds, pelvis and other leg remaining stable throughout
6. Do 10 repetitions per leg

10.



1. Stand tall, feet 10 cm from wall
2. Buttocks, shoulders and head against wall in correct posture
3. Hollow lower abdominals to flatten back, activate stabilisers
4. Slowly lift one leg, while keeping back flat, shoulders and pelvis level
5. Bend hip as far as pelvic control allows (maximum 90°)
6. Hold for 10 seconds
7. Do 10 repetitions per leg

11.



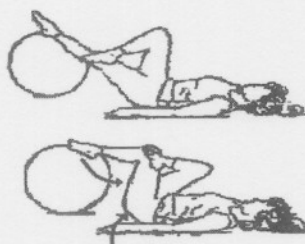
1. Position yourself on the floor, on your L/R side with elbow directly below shoulder, hips on the floor and legs spread as shown
2. Ensure your body is positioned in a straight line
3. Support your weight on your forearm and feet and lift the buttocks
4. Stabilise the trunk by tightening the abdominals
5. Lift the leg which is on top slightly (10 cm), keeping the legs straight
6. Hold for 10 seconds and return to starting position
7. Do 10 repetitions

12.



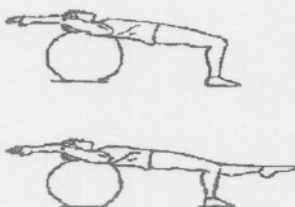
1. Lie on back with both feet lifted; hips and knees flexed to 90 °
2. Initiate lower abdominals and stabilisers to flatten back
3. Maintain this contraction and slowly lower both heels to touch the floor
4. Keep back flat, heels on the floor and slowly extend the heels out as far as stable pelvis allows
5. Hold stable position for 10 seconds before returning to start
6. Repeat 10 times

13.



1. Lie on your back with L/R foot positioned on ball
2. Place the other foot as shown, just below L/R knee to provide stability
3. Tighten and lift buttocks
4. Curl L/R foot towards buttocks
5. Hold for 2 seconds
6. Do 2 x 10 repetitions per leg

14.



1. Position yourself with Swiss-ball underneath shoulder blades, feet together
2. Find pelvic neutral, activate stabilisers and tighten buttocks
3. Raise pelvis until parallel with floor and slowly straighten L/R leg
4. Hold for 10 seconds, keeping thighs level and pelvis stable
5. Repeat 10 times per leg, alternating legs

15.



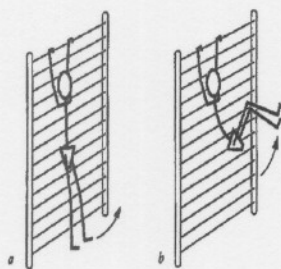
1. Lie on your back on a soft, level surface
2. Bend knees and bring legs over head, using hands to keep balance
3. Hold when you feel a stretch
4. Hold for 30 seconds
5. Do three repetitions

16.



1. Stand as shown, on your knees and the balls of your feet, with good head and shoulder posture
2. Find pelvic neutral, activate your core stabilisers
3. Move your trunk slowly to the rear, while maintaining a good posture
4. Start the movement by bending at the knees
5. Only go back as far as a stable posture allows
6. Hold for 5 seconds, slowly return to starting position
7. Do two sets of 10 repetitions

17.



1. Start by hanging, keeping lumbar spine in contact with wall
2. Bend knees and raise them until they are level with hips (90°)
3. Pull your abdominal muscles in as you move your knees up slowly
4. Hold the 90° flexed position for 2 seconds, then round your spine to lift the tailbone from the wall
5. Reverse very slowly to the starting position
6. Do two sets of 10 repetitions

Spinal exercises (mid-season, level 3)

18.



1. Assume position with strap anchored below waist
2. Straiten arms to raise trunk upward
3. Hold position when you feel a stretch
4. Hold for 30 seconds
5. Do three repetitions

19.



rope

1. Lie on your back with arms positioned to the sides
2. Keep legs straight
3. Cross legs as shown, with rope/towel tied around L/R ankle
4. Use the rope/towel to pull L/R leg in direction of arrow until you feel a stretch
5. Hold for 30 seconds
6. Do three repetitions per leg

20.



1. Assume position on hands and knees
2. Tilt head and shoulders to the L/R (as prescribed), while swinging hips and feet to the head to make a C shape with the spine
3. Hold position for 30 seconds
4. Do three repetitions

21.



1. Assume kneeling position as shown, weight supported by ball, two small dumbbells in hands
2. Do a chin tuck and pinch shoulder blades together to assume optimal posture
3. Keeping back straight, raise arms as shown
4. Hold for 5 seconds
5. Do two sets of 10 repetitions

22.



1. Assume hands and knees position on large ball, balancing on both hands and knees.
2. Maintain balance, stabilise pelvis, scapulae and head in neutral position
3. Keeping spine level, raise one arm and opposite leg as shown (as prescribed)
4. Hold for 5 seconds, repeat with opposite arm and leg if prescribed
5. Do two sets of 10 repetitions

Upper limb/shoulder exercises (mid-season, level 3)

23.



1. Lie face down on the floor, arms out to the side
2. Your partner stands astride you, takes hold of your arms, and pulls them slowly upwards until you feel a stretch
3. You must stay relaxed throughout
4. Hold for 30 seconds
5. Do three repetitions

24.



1. Anchor rubber tubing around fixed object at shoulder height
2. Grasp tubing in both hands, with arms elevated to shoulder level, elbows bent and fists pointing forward as shown
3. Pinch shoulder blades together and rotate arms upward
4. Hold for 10 seconds, slowly return to start
5. Do 10 repetitions

25.



1. Anchor rubber tubing around fixed object at shoulder height
2. Grasp tubing in both hands, with arms elevated to shoulder level and pointing straight forward as shown
3. Pinch shoulder blades together and pull arms up and back as shown
4. Hold for 10 seconds and slowly relax
5. Do 10 repetitions

26.



1. Half kneel on bench, with weight supported by R knee and R arm
2. Place L foot flat on floor for balance
3. Grip a light dumbbell, pinch shoulder blades together and pull dumbbell towards side of chest
4. Hold for 10 seconds
5. Do 10 repetitions
6. Repeat on opposite side

27.



1. Take a wide grip of the lateral pull down bar
2. Sit on the chair of the lateral pull down machine, adjusting the knee grips
3. Squeeze shoulder blades together
4. Pull the bar to the back of your shoulders, hold for 2 seconds returning slowly
5. Do 2 x 10 repetitions

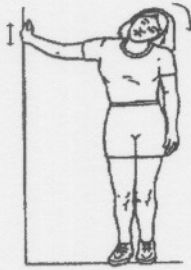
Neurological exercises (mid-season, level 3)

28.



1. Sit on a chair with hands behind back
2. Slump forward and place chin on chest
3. Slowly straighten L/R knee as far as possible and hold position
4. Flex L/R foot upward in direction of arrow and hold
5. Hold for 1 second and slowly return to starting position
6. Do 10 repetitions
7. Repeat on opposite side
8. Do two sets per leg

29.



1. Place your L/R hand against the wall as shown, with fingers facing upward
2. Flatten the palm of your hand against the wall and straighten your elbow
3. Bend head away from L/R arm and hold for 1 second
4. Repeat steps one to three 10 times
5. Repeat on opposite side
6. Repeat exercise with fingers pointing down (rotate wrist clockwise so fingers point in six o'clock direction)

30.



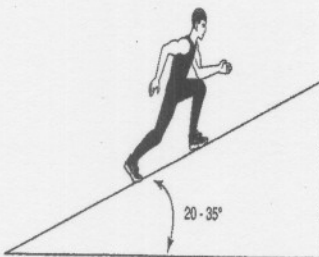
(Do not do this exercise if already done under lower limb exercises)

1. Place pillow under L/R knee, and other foot in front as shown
2. Grab L/R foot with L/R hand, pulling toes towards buttocks
3. Move your trunk forward by bending the front knee
4. Hold for 30 seconds
5. Do three repetitions
6. Repeat on opposite side

(Caution: Do not do if knee is injured or hurts during stretch)

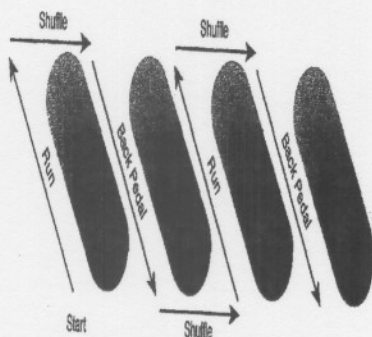
Speed, agility and power exercises (mid-season, level 3)

31.



1. Use a 20- to 35-degree hill
2. Sprint for 6 seconds up the hill
3. Count your strides and place a marker at your end position
4. Try to beat the distance with fewer strides in subsequent timed sprints
5. Do two sets of six sprints

32.



1. Start in a two point stance, on the outside of the first bag and sprint until you are in front of the bag
3. Shuffle your feet to the right without crossing your feet
4. When you reach the space between the bags, back-pedal until you are one step past the bags
5. Continue as illustrated (see arrows), keeping shoulders square and head up
6. Stay in a two point stance, and use a good, fast running style
7. Do two sets of six repetitions

33.



1. Place three boxes (height 30 cm) about 1.5 m apart
2. Jump high, landing on the first box and upon landing jump as quickly as possible from it with full extension
3. When landing on the floor, recoil immediately, exploding onto the second box
4. Continue the movement onto and over the third box
5. Do two sets

POST-SEASON TRANSITION PROGRAMME

This three-week period starts as soon as the final games end. The first two weeks consist of “active rest”, while the third week consists of complete rest.

During the *first two weeks* players continue other sport activities (jogging, swimming, squash, etc.) twice a week, on non-consecutive days, for 40 minutes. Individuals with biomechanical and postural shortcomings (variables identified as non-ideal/unsatisfactory during end-of-season testing) must do the prescribed exercises twice a week, on non-consecutive days. During the *third week*, players take a break from any form of exercise. No speed, agility or power exercises are done during these three weeks.

Biomechanical and postural programme (post-season transition programme)

Week 1-2:

This programme must be followed for two weeks. All prescribed exercises are done **twice** a week, on non-consecutive days. The relevant exercises are the same as those in the *start-of-season (level 2) programme*.

Week 3:

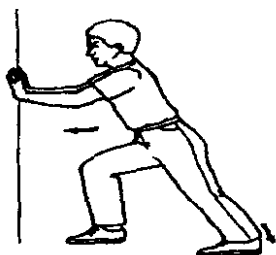
Complete rest. Do not do any form of formal exercise for 1 week.

OFF-SEASON PROGRAMME

This low-key programme continues up to the start of the pre-season. All exercises – except speed and agility exercises – must be done **three** times per week. Speed, agility and power exercises are not done during this period.

Lower limb exercises (off-season)

1.



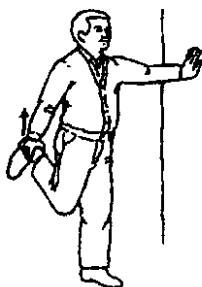
1. Stand facing a wall and hold onto the wall for support
2. Position the L/R leg at the back, with the heel flat on the floor
3. Place the other leg in front as shown
4. Keep the back leg straight throughout the exercise and the heel on the floor
5. Bend your arms until you feel a stretch in the calf of the back leg
6. Hold for 30 seconds
7. Do three repetitions each with L and R leg

3.



1. Stand with L/R side facing wall
2. Cross the leg closest to the wall in front of the other leg as shown
3. Bend the front knee slightly and lean your body towards the wall (see arrows), while moving the hip away from the wall
4. You may stretch both hands overhead to lean against the wall
5. Hold for 30 seconds
6. Do three repetitions on each side

4.



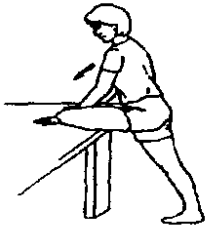
1. Stand holding the L/R ankle as shown
2. Keep knees together and pull knee upward so that you feel a stretch
3. Make sure your thigh stays in line with your body (don't let it point forward), and don't arch your back
4. Hold for 30 seconds
5. Do three repetitions
6. Repeat on opposite side

5.



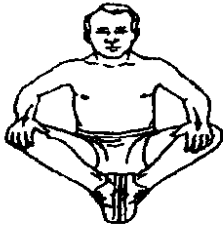
1. Assume position shown, with L/R leg straight and other leg in front
2. Move the pelvis towards the floor as shown by the arrows
3. Hold for 30 seconds
4. Do three repetitions
5. Repeat on opposite side

6.



1. Stand upright, placing L/R leg on solid object as shown
2. Lean trunk forward so that you feel a stretch
3. Keep your back straight
4. Hold for 30 seconds
5. Do three repetitions

7.



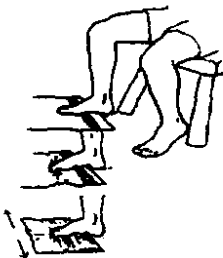
1. Sit upright with knees bent and feet together
2. Press downward on knees using your hands
3. Hold for 30 seconds
4. Do three repetitions

8.



1. Sit upright with back supported against a wall (*unlike picture*), with a 2.5 kg weight around L/R ankle
2. Roll up a towel and place it under the L/R knee
3. Rotate L/R leg outward so that toes point slightly to the outside
4. Activate the VMO and straighten leg (knee extension)
5. Hold position for 5 seconds
6. Repeat 20 times per leg

9.



1. Place towel on a slippery surface
2. Grab the towel using your toes
3. Pull the towel to the inside or outside (as instructed) using your foot
4. Repeat for 1 minute
5. Do three repetitions
6. Repeat with other foot

10.



1. Sit and place L/R ankle as shown
2. Stabilise the heel of your foot with one hand and place the other hand around the toes as well as the ball of your foot
3. Pull the foot in the direction of the arrow until you feel a stretch
4. Hold for 30 seconds
5. Repeat three times
6. Repeat on opposite side

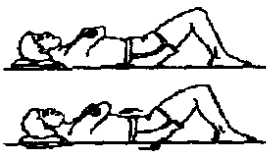
Pelvic girdle exercises (off-season)

11.



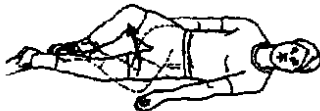
1. Lie on side as shown with the bottom leg straight
2. Keep hips on the floor and use arms to press trunk upright
3. Hold for 30 seconds
4. Do three repetitions
5. Repeat on the other side

12.



1. Lie on back with knees bent
2. Place a plastic soccer ball between the knees
3. Tighten lower abdominal muscles, squeeze buttocks and flatten back as shown, while squeezing the ball
4. Hold for 10 seconds
5. Do 10 repetitions

13.



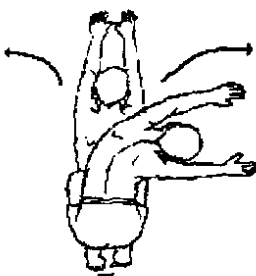
1. Lie on your side, with bottom knee straight, and top knee bent as shown
2. Place top foot on bottom leg, just below level of bottom knee
3. Lift/rotate top knee upward, keeping the pelvis stable
4. Hold for 10 seconds at the top
5. Do 10 repetitions
6. Repeat on opposite side

14.



1. Lie on your back arms resting on chest, hips and knees bent 90°
2. Find pelvic neutral, activate your stabilisers and hollow your lower abs
3. Hold the 90° flexed position, then round your spine to lift the tailbone and shoulders from the floor
4. Revert very slowly to the starting position
5. Do two sets of 10 repetitions post

15.



1. Assume hands and knees position with arms outstretched
2. Sit with your buttocks on your heels, then “walk” arms and trunk sideways to the L/R until you feel a stretch
3. Hold for 30 seconds
4. Do three repetitions
5. Repeat to opposite side

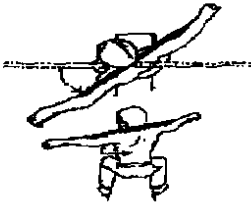
Spinal exercises (off-season)

16.



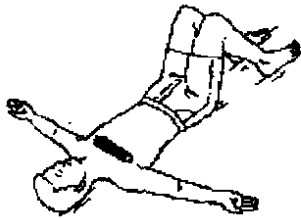
1. Assume position as shown
2. Keep hips on floor
3. Hold for 30 seconds
4. Do three repetitions

17.



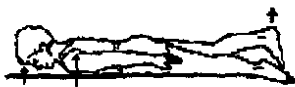
1. Sit on bench with broomstick positioned on shoulders as shown
2. Rotate head and shoulders to L/R
3. Hold for 30 sec
4. Do three repetitions on each side

18.



1. Fold a medium-sized towel in the middle (along its length), and roll it up tightly
2. Place the towel on the floor (firm surface)
3. Lie supine on your back on the towel, knees bent as shown
4. The towel should be positioned in the middle of the shoulder blades, stretching from the left side to the right side of the thorax
5. Relax and hold position for 5 minutes

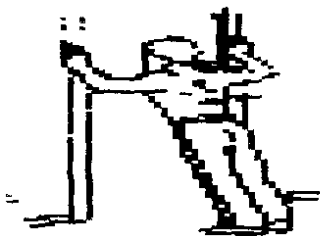
19.



1. Lie on your stomach, with arms next to sides
2. Do a chin tuck to lift head slightly, and pinch shoulder blades to raise shoulders from the floor
3. Tighten L/R buttock and raise the L/R leg slightly from the floor
4. Hold position for 10 seconds
5. Repeat with opposite leg
6. Do 10 repetitions per leg

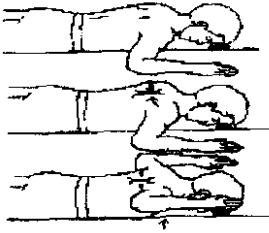
Upper limb/shoulder exercises (off-season)

20.



1. Stand with hands placed on door frame and feet 30-60 cm away from wall as shown
2. Lean into the door opening until you feel a stretch
3. Hold for 30 seconds
4. Do three repetitions

21.



1. Lie as shown
2. Pinch shoulder blades together, activating scapular stabilisers
3. Lift up arms
4. Hold for 10 seconds and slowly lower
5. Do 10 repetitions

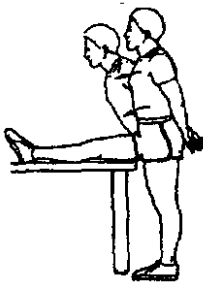
22.



1. Lie on your side with your L/R arm on top, gripping a 1-2 kg weight
2. Rotate arm upward, keeping elbow bent as shown
3. Hold for 10 seconds and slowly lower
4. Do 10 repetitions
5. Repeat on opposite side

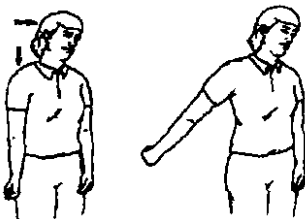
Neurological exercises (off-season)

23.



1. Place L/R leg on a high bench
2. Bend forward at the hip, keeping the back straight
3. Move your L/R foot towards you and place chin on chest to increase the stretch
4. Hold for 20 seconds
5. Do three repetitions
6. Repeat on opposite side

24.



1. Stand as shown, hands below hips, L/R wrist rotated so that back of L/R hand rests against L/R leg
2. Keep L/R arm straight, wrist rotated and extend arm to the rear
3. Bend head in direction away from L/R shoulder, while still looking forward
4. Hold for 1 second
5. Do 10 repetitions on affected side

25.



1. Lie on your stomach as shown
2. Hold onto your foot and make sure you pull your foot and toes towards your buttocks
3. Your knees must stay together
4. When you feel a stretch, hold.
5. Hold for 30 seconds
6. Do three repetitions per leg

ANNEXURE B.2

MODIFICATIONS TO THE PREVENTION PROGRAMME

1. *Modifications with regard to anthropometric variables:*

1.1 Hypertrophy

1.1 (a)

Gymnasium training to increase in size/mass (hypertrophy) should not be the aim of the growing adolescent. However, safe resistance exercises will benefit players. The gymnasium exercises (hypertrophy exercises) as described in the study of Hanekom (2003:169,171-173) for week 1-6 and week 9-14 can be introduced during the off-season, while bearing the adolescent development phase of 15- and 16-year old players in mind. The improvements can be maintained during the remaining part of the season by decreasing the frequency of exercise from four times a week to twice a week.

1.2 Fat percentage

1.2 (a)

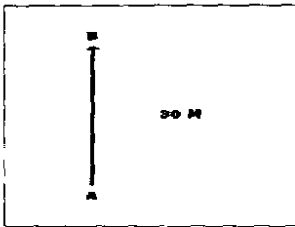
The hypertrophy training (1.1 (a)), combined with the aerobic endurance training (2.6 (a)) during the off-season, will assist in maintaining an acceptable fat percentage during the off-season.

2. Modifications with regard to physical-and-motor variables:

2.1 Running speed

2.1 (a)

Add this basic speed drill to the pre-season programme, start-of-season programmes (levels 1 and 2), and mid-season programmes (1-week conditioning, and level 3).



1. Assume starting position and run straight from marker A to marker B
2. Focus on hard leg drives for the first 10 metres, then start driving tall in an upright posture, stepping over knees and finishing tall.
3. Walk back to starting position
4. Repeat six times
5. Twice a week on non-consecutive days

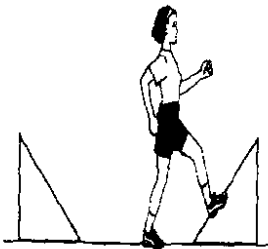
2.1 (b)

During the off-season the players should continue with the basic speed drill mentioned in 2.1 (a) (6 repetitions twice a week) to maintain a certain level of running speed.

2.2 Agility

2.2 (a)

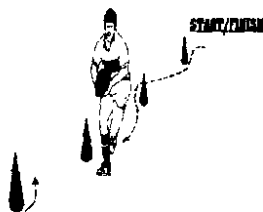
Add this angle board drill to the pre-season programme, start-of-season programmes (level 1 and 2), and mid-season programmes (1-week conditioning, and level 3).



1. Start in a two-point stance, on a flat surface between two angle boards
2. Cross the R foot over and strike the left angle board
3. Shuffle with the L foot, bringing the R foot back to its starting position
4. Cross the L foot over and strike the right angle board
5. Shuffle with R foot, and bring L foot back to its original position
6. Repeat as fast as possible for 10 seconds
7. Do three sets twice a week

2.2 (b)

During the off-season the players should continue with this basic agility drill

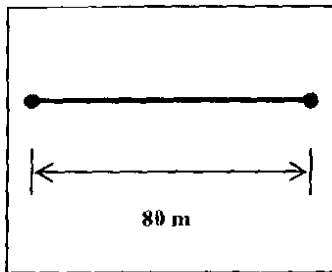


1. Place four markers in a straight line at 5 m intervals
2. Start 5 m from the first marker and run as fast as possible
3. Run "zigzag" between the markers, from the first to last marker and back
4. Do three repetitions once a week

2.3 Speed endurance (running)

2.3 (a)

Do this running drill for speed endurance. Read carefully to see how this drill must be applied during the different periods of the prevention programme.



1. Sprint in a straight line over 80 m at 95% of maximum
2. Recover 10 seconds between sprints
3. Repeat six times, aiming to run all six sprints in the same time
4. Repeat twice a week during the pre-season programme and mid-season (1-week conditioning) programme
5. Repeat once a week during the start of season programme (level 1 and level 2), mid-season programme (level 3) and off-season programme.

2.4 Upper limb strength

2.4 (a)

The gymnasium exercises for hypertrophy proposed in 1.1 (a) (Hanekom, 2003) can be introduced during the off-season, while bearing the adolescent development phase of 15- and 16-year old players in mind. In addition to the anthropometric benefits associated with these exercises, these exercises will also assist in maintaining the required level of upper limb strength during the off-season.

2.5 Upper abdominal strength

2.5 (a)

Introduce this abdominal machine exercise during the off-season programme, and progressively increase the resistance with each subsequent phase of the prevention programme.



1. Sit as shown, with your back to the machine
2. Align the pivot of the machine with the lower portion of the lumbar spine
3. Grip the machine arms, and "hollow" the stomach
4. Begin the movement by moving the sternum down, rather than forward
5. Roll forward, keeping the elbows in, back on the backrest, avoiding the tendency to lean forward
6. Reverse slowly to starting position
7. Do three sets of 15 repetitions three times a week

2.6 Aerobic endurance

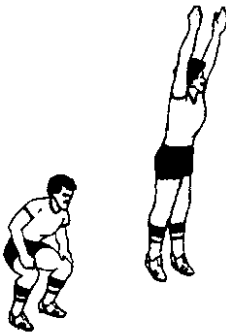
2.6 (a)

During the off-season players should perform low-impact aerobic activities (swimming/rowing/stepper/cycling) three times a week, on non-consecutive days, for 25 minutes.

2.7 Power

2.7 (a)

The following plyometric drill should be added during the off-season



1. Stand with feet shoulder width apart, hands down the sides
2. Begin by quickly lowering into a half squat position
3. Explode upwards as high as possible, throwing the arms up
4. Upon landing, repeat as quickly as possible
5. Strive to attain maximum height each time
6. Repeat six times
7. Do two sets twice a week on the same days as the speed, speed endurance and agility drills

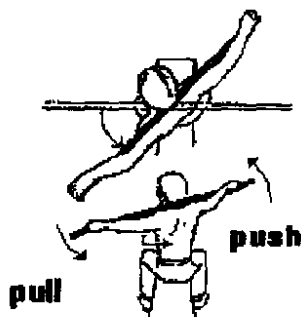
3. *Modifications with regard to biomechanical and postural variables:*

- To prevent deterioration in the biomechanical and postural status during the off-season, the volume of exercises during the off-season period may be increased, while allowing for adequate rest and recovery. This may be achieved by doing exercises four times a week, instead of three times a week. Increased control over exercise compliance can be achieved by compelling players to complete two exercise sessions under direct supervision.

3.1 **Right rotation (spinal)**

3.1 (a)

Players with non-ideal/unsatisfactory spinal rotation should perform this exercise throughout the year with the help of a partner. A therapist should instruct players how to do the exercise safely.



1. Ask a therapist/partner to assist with this exercise
2. Sit on bench with broomstick positioned on shoulders as shown
3. Rotate head and shoulders to the R until you feel a stretch
4. Your partner then holds onto the ends of the stick and increases the stretch slightly by using his arms to rotate the stick slightly further
5. You should tell your partner when to stop
6. Hold for 30 seconds
7. Do three repetitions on restricted side

3.2 **Thoracic position in the sagittal axis**

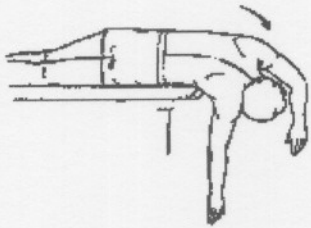
This postural deviation is often functional, occurring as a product of quadratic dominance (Hattingh, 2003). This is more probable among players who have also participated in other sports for prolonged periods, for example several racquet sports (tennis, squash) and throwing sports (cricket bowler, baseball pitcher, javelin). If players also participate in sports other than rugby, they should be encouraged to practice techniques on the non-dominant side as well.

3.2 (a)

Players with a non-ideal/unsatisfactory thoracic position (sagittal axis) should perform the following **two** additional exercises on the deficient side, throughout the season.



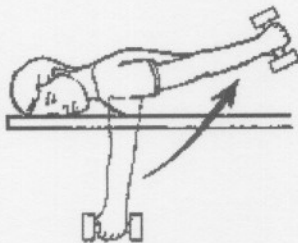
1. Do this exercise throughout the year
2. Place a ball between the wall and relevant shoulder
3. Squeeze the shoulder blade involved against the spine
4. Visualise that the shoulder is the centre of a watch face
5. The stability position for the L shoulder is the 5 o'clock position, and for the R shoulder the 7 o'clock position (see arrow)
5. Slowly move the shoulder through all the hours of the watch
6. Use slow, controlled movements
7. Do three repetitions four times a week (Steyn, 2005)



1. Lie on L/R side over edge of table
2. The side which requires stretching should be on top
3. Allow upper arm to sag overhead as shown
4. Hold for 30 seconds
5. Do three repetitions four times a week

3.2 (b)

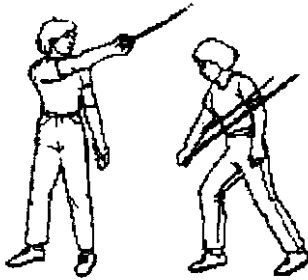
Players with identified deficiencies should add the following drill during the off-season and pre-season phases of the prevention programme



1. Lie prone on a bench gripping a small dumbbell in the relevant hand (deficient side)
2. Pull the shoulder blade involved down towards the lumbar spine
3. Lift weight upward as shown, ensuring the thumb points down during the movement
4. Hold the position at the top for 10 seconds, or until muscles fatigue
5. Do 10 repetitions three times a week

3.2 (c)

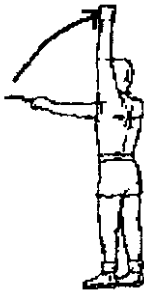
Do the following drill during the start-of-season phases of the prevention programme



1. Anchor rubber tubing to fixed object
2. Grab tubing with L/R arm (deficient side) across body as shown
3. Squeeze shoulder blades together
4. Pull arm out and down, following the movement with your head
5. Notice that the hand rotates as the arm movement occurs
6. Hold for 10 seconds, and slowly reverse
7. Do 10 repetitions three times a week

3.2 (d)

Do the following drill during the mid-season phases of the prevention programme



1. Anchor rubber tubing around fixed object at shoulder height
2. Grasp tubing in one hand (deficient side), with arm elevated to shoulder level and pointing straight forward as shown
3. Pinch shoulder blades together and pull arm up and back as shown
4. Hold for 5 seconds and slowly relax
5. Do 10 repetitions
6. Repeat three times per week

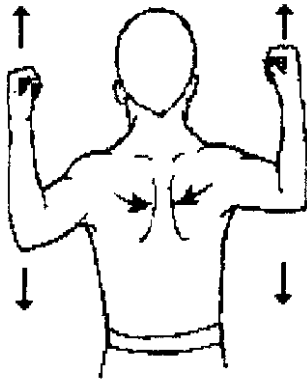
3.2 (e)

Note that if a deviation in the thoracic position occurs in combination with a leg length discrepancy (innominate shift) in the pelvic region, it should be ensured that players follow all the pelvic girdle exercises in the prevention programme.

3.3 Winging

3.3 (a)

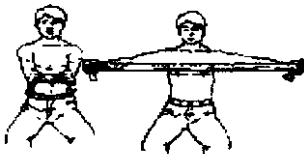
Do the following exercise during the off-season and pre-season phases of the prevention programme. Omit exercise number 39 during the pre-season phase and replace it with this exercise.



1. Stand with your back against a wall, elbows lifted to shoulder level
2. Pinch shoulder blades together, while touching the wall with your heels, buttocks, head, shoulder blades, elbows and hands
3. Shift elbows slowly up and down while keeping contact with the wall
4. Only move as far as "wall contact" allows
5. Keep shoulder blades pinched throughout
6. Do 10 repetitions up and down
7. Do five sets three times a week
8. If only one scapula is affected (winging), pinch both shoulder blades together, but only move the affected side up and down against wall

3.3 (b)

Add this exercise to the mid-season programme (level 3) and the off-season programme



1. Hold rubber tubing in outstretched arms as shown, and pinch shoulder blades
2. Pull arms backward keeping elbows straight, arms level and shoulder blades pinched
3. Hold for 5 seconds and slowly reverse
4. Do two sets of 10 repetitions, twice a week during the **mid-season** (level 3)
5. Do one set of 10 repetitions twice a week during the **off-season**

3.3 (c)

Add this cable rowing exercise throughout the year. Start during the first pre-season, and increase the resistance as the season progresses. Do only one set during the off-season.



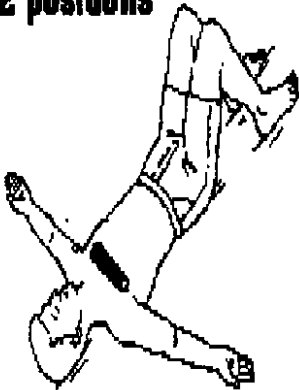
1. Sit on the seated rowing machine, knees bent, Grip the bar and pinch shoulder blades
2. Keep your spine straight and pelvis in the neutral position
3. Pull the bar towards you, attempting to scrape the sides of your body with your elbows
4. Hold for 5 seconds and slowly reverse until arms are stretched out in front
5. Maintain the correct posture throughout
6. Do two sets of 10 repetitions twice a week during the **pre-season, start-of-season, and mid-season** periods, and 1 set of 10 repetitions during the **off-season**.

3.4 Thoracic position in the coronal axis

3.4 (a)

Add this exercise to the pre-season, start-of-season, and mid-season phases of the prevention programme. Repeat 5 times a week.

2 positions



1. Fold a medium-sized towel in the middle (down its length), and roll it up tightly
2. Place the towel on the floor (firm surface)
3. Lie supine with your back on the towel, knees bent as shown
4. For the first part of the exercise the towel should be positioned just lower than the inferior tip of the shoulder blades, stretching from the left side to the right side of the thorax
5. Relax for 3 minutes in the first position
6. After 3 minutes the towel should be moved higher, to the middle of the shoulder blades, towel stretching from left to right
7. Relax and hold this second position for 3 minutes
8. Repeat five times a week

3.4 (b)

Add this exercise to the mid-season (level 3) programme, and instruct players also to use this movement to self-correct their posture during normal daily activities.



1. Stand with your back against a wall
2. Lift your sternum using thoracic extension (instead of just taking a deep breath)
3. Simultaneously draw the shoulder blades down and in
4. The movement is one of “rolling” the thoracic spine up the wall while keeping the lumbar spine (lower back) stable
5. Avoid arching the lower back
6. Hold position for 10 seconds
7. Do 10 repetitions three times a week

3.5 Biomechanical and postural exercises during the off-season

3.5 (a)

During the **off-season** the volume of specific exercises should be stepped up. Areas which required improvement in terms of the research were the *right TA* (15-year olds), *left and right ITB* (15-year olds), *left and right iliopsoas* (15-year olds), *right spinal rotation* (15-year olds), *thoracic position in the coronal axis* (15-year olds) and *left and right L 3,4 prone knee bend* tests (15-year olds).

The under-mentioned is a list of the exercise names and exercise numbers which need to be done more frequently. The numbers refer to the corresponding numbers in the tested off-season prevention programme. These exercises should be completed 4 times a week, instead of 3 times a week during the off-season phase. To increase the effectiveness of this phase at least two out of four exercise sessions should be executed under supervision.

- TA (1)
- ITB (number 3)
- Iliopsoas (number 5)
- Right spinal rotation (17)
- Thoracic position in the coronal axis (number 18, 19 21)
- L 3,4 prone knee bend (number 25)

3.6 Guidelines for the implementation of modifications to the prevention programme

3.6 (a) Allow for adequate rest and recovery

- Do not perform speed, speed endurance, agility or power exercises on consecutive days.
- Rest 2 to 3 minutes between sets of speed, agility and power exercises.
- Do speed, speed endurance, agility and power exercise sessions on the same days as the weight training (hypertrophy) sessions; however, the speed, speed endurance, agility, and power exercise session should be done first, before weight training.
- The days when no speed, speed endurance, agility, power and weight lifting exercise sessions are performed serve as recovery days.

3.6 (b) Injury prevention

- Do running and jumping exercises on a firm grass surface.
- Allow for adequate warm-up and cool-down periods during exercise sessions involving running, jumping and weight lifting. Some aerobic work and biomechanical-and-postural exercises are suitable warm-up exercises.
- Place the emphasis on the correct form/posture during the execution of all exercises.
- Weights/resistances to be used serve as a guideline. The weight/resistance should be adjusted according to the strengths and abilities of the individual players.