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PREPARTICIPATION EVALUATION AND IDENTIFICATION OF AETIOLOGICAL RISK FACTORS IN THE EPIDEMIOLOGY OF SPORTS INJURIES AMONG YOUTHS

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PREPARTICIPATION EVALUATION AND IDENTIFICATION OF AETIOLOGICAL RISK FACTORS IN THE EPIDEMIOLOGY OF SPORTS INJURIES AMONG YOUTHS

BY

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DEDICATION

This thesis is dedicated to my parents.

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SYNOPSIS

TITLE : Preparticipation Evaluation and Identification of Aetiological Risk Factors in the Epidemiology of Sports Injuries among Youths.

PROMOTOR : Prof GJ van Wyk (University of Pretoria)
CO-PROMOTOR: Prof MF Coetsee (University of Zululand)

DEPARTMENT : Human Movement Studies

DEGREE : Doctor Philosophiae

In a preliminary study the incidence and nature of sports injuries among 483 primary school children was observed prospectively. A total of 76 injuries were incurred. Netball had a significantly higher (p<0,05) injury incidence (injuries per player-hours) than hockey (1:16,4 vs 1:61,6) and soccer had a significantly lower (p<0,001) incidence than rugby (1:20,6 vs 1:6,6). No injuries ocurred among tennis players. Ligament sprains (42%) and contusions (41%) predominated and most injuries occurred in the lower extremity (48%), followed by the head, neck and trunk collectively (30%).

The primary study focussed on the preparticipation evaluation and identification of aetiological risk factors for injury among a cohort (N=125) of high school rugby players. Notable health history findings among subjects were syncope with exercise (1,3%); problematic paired organs (10,3%); familial heart disease (15,4%); concussion (21,8%); and previous musculoskeletal injury (61,5%) which was the most significant

(p<0,05) and frequent problem experienced. Medical examination detected problems with the cardiovascular (7,7%), urinary (9,0%); and orthopaedic systems (33,3%) respectively - with the last component having the highest diagnostic utility (62%) in yielding new findings not reported in the history. As an adjunct, subjects were screened for morphological status and muscular function. The prevalence of obesity (8%) was noted. Ipsilateral and contralateral imbalances in peak isokinetic (60°/s) torque of the quadriceps/hamstring musculature were recorded. Dominant-limb absolute (Nm) quadriceps (Q) vs hamstring (H) torque results for asymptomatic subjects (n=70) stratified by age were: 13 yrs - 100,0 ± 29,8 vs 76,9 ± 20,8; 14 yrs - 134,2 ± 29,8 vs 93,0 ± 21,7; 15 yrs - 156,8 ± 37,4 vs 109,5 ± 28,5; 16 yrs - 162,3 ± 24,2 vs 116,8 ± 23,0; 17 yrs - 223,6 ± 46,0 vs 142,6 ± 28,3. Relative (Nm/kg) quadricep and hamstring torques were: 13 yrs - 1,98 ± 0,23 vs 1,50 ± 0,08; 14 yrs - 2,32 ± 0,30 vs 1,63 ± 0,23; 15 yrs - 2,44 ± 0,38 vs 1,70 ± 0,30; 16 yrs - 2,50 ± 0,22 vs 1,80 ± 0,20; 17 yrs - 2,87 ± 0,39 vs 1,85 ± 0,22. H/Q ratios were: 13 yrs - 77,7 ± 6,0%; 14 yrs - 69,9 ± 9,6% ; and 15-17 yrs - 68,1 ± 9,0%. The final pre-participation evaluation disposition led to clearance being withheld from 6,4% of the players, pending referral for additional evaluation, with the remainder being granted unlimited participation.

A total of 171 injuries were recorded prospectively as sustained by 76 players over the 14 weeks injury surveillance phase of the season. This resulted in an overall injury incidence of 1:21 player-hours. When considering only those injuries resulting in a loss of at least seven days participation (major injuries), a significantly lower (p<0,01) incidence of 1:212 player-hours was recorded. In the extrinsic risk factor analysis, significantly more overall (84%;p<0,001) and major (82%;p<0,01) injuries occurred during matches than in practices. The overall injury incidence (injuries / 100 player-hours) was lowest in the under-14 age group (3,6), while the under-19 "A" (1st team) players (5,2) were particularly injury prone. The highest overall (34,0) and major (5,7) weekly injury incidence was observed during the four weeks following the Easter vacation. Players were injured significantly more (p<0,001) during various facets of broken play (92%) than the set-pieces (8%) of scrums (7%) and line-outs (1%). Both the overall and major injury risk was greatest whilst being tackled (30 & 35%) and during open play (23 & 29%), while tackling (24%) was particularly conducive to major injury. The playing positions at highest overall and major injury risk were flyhalf (16 & 24%) and fullback (13 & 16%) while flank (16%) and wing (12%) were prone to major injury. The significant majority (98,8%;p<0,001) of injuries were acute in nature with the predominant (86%) injury mechanism being contact/collision. The lower-limbs were at significantly greater (p<0,05) overall (42%) and major (41%) injury risk. Osseous contusions were the commonest overall injury (32%) while muscle injuries, ligament sprains (29% each), fractures and concussion (18% each) were the most prevalent major injuries.

In the intrinsic risk factor analysis, an injury was defined as either requiring medical referral or causing a loss of at least seven days participation. Morphological profiles of exposed (injured) players versus non-injured controls indicated a significantly greater mean stature (176,8 ± 8,6 vs 172,1 ± 8,7 cm:p<0,01); body mass (69,7 ± 11,3 vs 63,9 ± 12,6 kg:p<0,05); lean body mass (60,0 ± 9,7 vs 52,3 ± 9,6 kg:p<0,001); and a lower body fat (13,9 ± 3,1 vs 17,9 ± 6,6%:p<0,001), respectively. Individual somatotype component variations did not differ significantly (p>0,05), being slightly lower for endomorphy (2,4 ± 0,9 vs 2,9 ± 1,5) but similar for mesomorphy (4,8 ± 1,0 vs 4,9 ± 1,2); and ectomorphy (3,2 ± 1,0 vs 3,2 ± 1,4). Muscular function profiles of exposed (injured) players versus non-injured

controls indicated a significantly greater mean grip strength (70,5 ± 8,5 vs 64,9 ± 9,9 kg/kg:p<0,01); muscle power (15,3 ± 1,0 vs 14,3 ± 1,4 W/kg:p<0,001); and running agility (6,9 ± 0,4 vs 7,1 ± 0,4 sec:p<0,001). Gross range of motion variations in the shoulders (2,4 ± 0,3 vs 2,5 ± 0,3) did not differ significantly (p>0,05), but gross low-back/hamstring flexibility scores (3,5 ± 1,2 vs 2,9 ± 1,1) were significantly higher (p<0,05) among the exposed (injured) group.

On conclusion of the primary study it was evident that youths intending to participate in sports-related activity are not necessarily in a complete state of health. A full sport-specific preparticipation evaluation concentrating on the orthopaedic system on first entry and a subsequent annual history of participants is thus recommended as routine practice. The intrinsic aetiological risk factor analysis suggested that contrary to general expectations - somatotype was independent of injury risk while morphological and muscular superiority predisposed rather than precluded from injury. Thus, while these qualities are essential for successful performance they are not necessarily synonymous with safe participation, as the characteristic contact and collision nature of rugby challenges the musculoskeletal system to the maximum. Consequently it is suggested that further preventive research focus on extrinsic risk factor modification with particular attention being given to continued rule-revision and/or additional protective equipment usage.

KEY WORDS: PREPARTICIPATION EVALUATION; AETIOLOGICAL RISK FACTORS; EPIDEMIOLOGY; SPORTS INJURY PREVENTION; YOUTHS

SINOPSIS

TITEL : Voordeelname Evaluering en Identifisering van Etiologiese Risiko-faktore by die Epidemiologie van Sportbeserings onder Jeugdiges.

PROMOTOR : Prof GJ van Wyk (Universiteit van Pretoria)
MEDE-PROMOTOR: Prof MF Coetsee (Universiteit van Zululand)

DEPARTEMENT : Menslike Bewegingskunde

GRAAD : Doctor Philosophiae

Met 'n voorlopige studie is die voorkoms en aard van sportbeserings onder 483 laerskool kinders waargeneem. 'n Totaal van 76 beserings is opgedoen. Netbal het 'n beduidend hoër (p<0,05) beserings-insidensie (beserings per speler-ure) as hokkie (1:16,4 vs 1:61,6) getoon en sokker het 'n beduidend laer (p<0,001) insidensie as rugby (1:20,6 vs 1:6,6) getoon. By tennis het geen beserings voorgekom nie. Ligamentbeserings (42%) en kneusings (41%) was dominant en die meeste beserings het in die onderste ledemate (48%) voorgekom, gevolg deur die kop, nek en romp gesamentelik (30%).

Die hoofstudie het gefokus op die voordeelname evaluering en identifisering van etiologiese risiko-faktore vir besering onder 'n groep (N=125) hoërskool rugbyspelers. Noemenswaardige bevindinge uit die gesondheidsgeskiedenis van proefpersone was sinkopie met oefening (1,3%); problematiese gepaarde organe (10,3%); familiêre hartsiekte (15,4%); harsingskudding (21,8%); en vorige spier- en skelet-beserings (61,5%) wat die algemeenste en mees beduidende (p<0,05)

probleem was. Mediese ondersoeke het probleme geïdentifiseer in die kardiovaskulêre- (7,7%), urinêre- (9,0%); en ortopediese stelsels (33,3%) onderskeidelik - terwyl die laasgenoemde komponent die hoogste diagnostiese waarde (62%) getoon het deur nuwe bevindinge te ontdek wat nie by die gesondheidsgeskiedenis aangedui is nie. Proefpersone is ook vir morfologiese status en spierfunksie getoets. Die voorkoms van obesiteit (8%) is opgeteken. Ipsilaterale en kontralaterale wanbalanse in piek isokinetiese (60°/s) wring-krag van die qaudricep/hampees spiere is gevind. Absolute (Nm) quadricep (Q) teenoor hampees (H) wringkrag van die dominante ledemaat vir asimptomatiese proefpersone (n=70) volgens ouderdom was: 13 jr - 100,0 ± 29,8 vs 76,9 ± 20,8; 14 - jr 134,2 ± 29,8 vs 93,0 ± 21,7; 15 jr - 156,8 ± 37,4 vs 109,5 ± 28,5; 16 jr - 162,3 ± 24,2 vs 116,8 ± 23,0; 17 jr - 223,6 ± 46,0 vs 142,6 ± 28,3. Relatiewe (Nm/kg) quadricep en hampees wringkrag was: 13 jr - 1,98 ± 0,23 vs 1,50 ± 0,08; 14 - jr 2,32 ± 0,30 vs 1,63 ± 0,23; 15 jr - 2,44 ± 0,38 vs 1,70 ± 0,30; 16 jr - 2,50 ± 0,22 vs 1,80 ± 0,20; 17 jr - 2,87 ± 0,39 vs 1,85 ± 0,22. H/Q verhoudings was: 13 jr - 77,7 ± 6,0% ; 14 jr - 69,9 ± 9,6%; en 15-17 jr - 68,1 ± 9,0%. Die finale voordeelname evalueringsbesluite het daartoe gelei dat toelating tot deelname by 6,4% van die spelers voorbehou is, hangende verwysing vir bykomstige evaluasie, terwyl die oorblywendes tot onbeperkte deelname toegelaat is.

'n Totaal van 171 beserings is gedurende die 14 weke beseringsmonitorfase van die seisoen deur 76 spelers opgedoen. Dit het tot 'n algehele beserings-insidensie van 1:21 speler-ure gelei. Indien slegs beserings wat tot die verlies van ten minste sewe dae se deelname (ernstige beserings) gelei het, in ag geneem word, is 'n beduidend laer ($p<0,01$) insidensie van 1:212 speler-ure opgeteken. By die ektrinsieke risiko-faktor ontleding is bevind dat beduidend meer algehele (84%;$p<0,001$) en ernstige beserings (82%; $p<0,01$) tydens wedstryde as oefeninge opgedoen is. Die algehele beserings-insidensie (beserings / 100 speler-ure) was die laagste by die onder-14 ouderdomsgroep (3,6), terwyl die onder-19 "A" (1ste span) spelers (5,2) besonder beserings-geneigd was. Die hoogste algehele (34,0) en ernstige (5,7) weeklikse beserings-insidensie is tydens die vier weke na die Paasvakansie waargeneem. Spelers is beduidend meer ($p<0,001$) beseer gedurende die verkeie fasette van gebrokespel (92%) as vastespel (8%) van skrums (7%) en lynstane (1%). Beide die algehele en ernstige beserings-risiko was die grootste terwyl 'n speler doodgevat is (30 & 35%) en gedurende oopspel (23 & 29%), terwyl die uitvoering van 'n doodvat (24%) veral tot ernstige beserings gelei het. Die speelposisies met die hoogste algehele en ernstige beserings-risiko was losskakel (16 & 24%) en heelagter (13 & 16%) terwyl flanke (16%) en vleuels (12%) tot ernstige beserings geneigd was. Die beduidende meerderheid (98,8%; $p<0,001$) van beserings was van 'n akute aard en die dominante (86%) beserings-meganisme was kontak/botsing. Die onderste ledemate het die beduidend hoogste ($p<0,05$) algehele (42%) en ernstige (41%) beserings-risiko getoon. Beenkneusings (32%) was die algemeenste soort besering terwyl spierbeserings, ligamentbeserings (29% elk), frakture en harsingskudding (18% elk) die meeste ernstige beserings opgemaak het.

By die intrinsieke risiko-faktor ontleding, is 'n besering gedefinieer as een wat mediese verwysing benodig het of tot die verlies van ten minste sewe dae se deelname gelei het. Morfologiese profiele van blootgestelde (beseerde) spelers teenoor onbeseerde-kontroles het 'n beduidend hoër gemiddelde liggaamslengte ($176,8 \pm 8,6$ vs $172,1 \pm 8,7$ cm:$p<0,01$); liggaamsmassa ($69,7 \pm 11,3$ vs $63,9 \pm 12,6$ kg:$p<0,05$); vetvrye liggaamsmassa ($60,0 \pm 9,7$ vs $52,3 \pm 9,6$ kg:$p<0,001$); en 'n laer liggaamsvet ($13,9 \pm 3,1$ vs $17,9 \pm 6,6$%:$p<0,001$), onder-skeidelik aangetoon. Geen beduidende verskille ($p>0,05$) in individuele somatotipe komponente is gevind nie, met 'n effens laer endomorfie by beseerde spelers ($2,4 \pm 0,9$ vs $2,9 \pm 1,5$) maar soortgelyke mesomorfie ($4,8 \pm 1,0$ vs $4,9 \pm 1,2$);

en ektomorfie (3,2 ± 1,0 vs 3,2 ± 1,4). Spierfunksie profiele van blootgestelde (beseerde) spelers teenoor onbeseerde-kontroles het 'n beduidend hoër gemiddelde greepkrag (70,5 ± 8,5 vs 64,9 ± 9,9 kg/kg:$p<0,01$); spier-plofkrag (15,3 ± 1,0 vs 14,3 ± 1,4 W/kg:$p<0,001$); en hardloop-behendigheid (6,9 ± 0,4 vs 7,1 ± 0,4 sek:$p<0,001$) getoon. Bewegingsomvang van die skouers (2,4 ± 0,3 vs 2,5 ± 0,3) het nie beduidend verskil nie ($p>0,05$), maar laer-rug/hampees lenigheid (3,5 ± 1,2 vs 2,9 ± 1,1) was beduidend hoër ($p<0,05$) by die blootgestelde (beseerde) groep.

By die afhandeling van die hoofstudie, was dit duidelik dat voornemende jong sportmanne nie noodwendig in volkome gesondheid verkeer nie. Derhalwe word 'n volledige sport-spesifieke voordeelname evaluering, wat op die ortopediese stelsel gefokus is, by eerste toetrede en 'n daaropvolgende jaarlikse gesondheidsgeskiedenis as roetine praktyk aanbeveel. Die etiologiese risiko-faktor ontleding het in teenstelling met algemene verwagtinge aangedui dat somatotipe onafhanklik van beserings-risiko was, terwyl meerwaardige morfologie en spierfunksie geneigdheid tot besering eerder verhoog as verminder het. Terwyl sulke eienskappe noodsaaklik mag wees vir suksesvolle deelname blyk hulle egter nie noodwendig sinoniem te wees met veilige deelname nie, aangesien die inherente kontak en botsende aard van rugby die skelet- en spier-stelsel tot die uiterste beproef. Gevolglik word daar aanbeveel dat verdere voorkomende navorsing op ektrinsieke risiko-faktor manipulasie fokus, met besondere aandag aan voortgesette reël-veranderings en/of bykomstige gebruik van beskermende toerusting.

SLEUTELTERME: VOORDEELNAME EVALUERING; ETIOLOGIESE RISIKO-FAKTORE; EPIDEMIOLOGIE; SPORT-BESERINGS; BESERINGS-VOORKOMING; JEUGDIGES.

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CHAPTER 1

INTRODUCTION

1. PROLOGUE

Active participation in sport and related activity among youths is a universally accepted phenomenon. In the near future various factors such as South Africas' re-admission into international sport; the increased coverage of youth sport in the general media and on television in particular; and the transition in the educational structure of the country, are bound to increase the number of youths participating in sports-related activity. The acclaimed potential benefits of participation in sports-related physical activity may, however, be impeded by injury. Although the likelihood of injury varies according to the nature of the sporting activity it remains an inherent adverse risk of participation. Youth sport, with its underlying competitive dimension, is equally subject to the above rule and should the suggested increase in youth sports participation be realized, this may lead to a concomitant increase in the incidence of injury.

The prevalence of sports injuries has generally been interpreted as an unthwarted epidemic posing a threat to a specific population (Vinger & Hoerner,1981). In turn, epidemiology studies the distribution of disease or physiological conditions in human populations (in this case being the prevalence of sports injuries) and the factors that influence this distribution (Caspersen,1989; Walter & Hart,1990). As such, epidemiology has traditionally been concerned with the aetiology or cause of disease. In accordance with this view Goldberg (1989) and Rice (1989) maintain that the initial step in developing a basis for sports injury prevention is an epidemiological study of such injuries, with the intent of determining the risk of participation and to identify the variables associated with injury. There is distinct agreement about the classification of variables associated with injury into extrinsic and intrinsic risk factors. The former are related to the type of activity and the manner in which it is practised, in conjunction with the equipment and environmental conditions involved. The latter intrinsic category, refers to the individual physical characteristics of the participant (Lysens et al.,1984; Brown,1988; Arnheim ,1989).

Numerous epidemiological investigations have been conducted in overseas countries to examine the incidence of injuries among the youth population participating in various sports-related activities (Garrick,1977; Garrick & Requa,1978a; Chambers,1979; Garrick & Requa,1981; Requa & Garrick,1981; Shively et al.,1981; Chandy & Grana,1985; De Haven & Lintner,1986; Watson & Di Martino,1987; Mueller & Cantu, 1990), including those incurred during physical education classes (Austin et al.,1980; Zaricznyj et al.,1980; Hammer et al.,1981; Tursz & Crost,1986).

In Sweden, for example, sports-related injuries were found to be responsible for 16,7% of all accidents among children under 16 years of age (Nathorst-Westfelt,1982). More recently a French study by Tursz and Crost (1986) reported that, even though widespread participation in sport by children and adolescents is a new trend in their country, sports-related injuries represented 11% of all accidents among children, of which 24% were sustained during physical education classes. On the other hand in the United States of America (USA) where sports participation is an integral part of youth life, Zaricznyj et al.(1980) documented sports-related injuries to school children across all age groups and indicated a respective injury rate of 3% for elementary school pupils (ages 5-11), 7% for junior high school pupils (ages 12 and 13) and 11% for high school students (ages 14 and over), with 38% of all injuries being sustained during physical education classes.

An observation of studies reflecting the injury patterns among youths in foreign countries is that sports-related trauma is more frequent in older adolescent children, aged 12 years and over (Sullivan et al.,1980; Zariczny j et al., 1980; Micheli & Smith,1982; Tursz et al.,1985; Tursz & Crost,1986; Goldberg,1989). Additionally, it has been reported that in terms of gender, boys and girls of secondary school age reflect similar rates of injury incurred during physical education classes (Austin et al.,1980; Davidson & Maguin,1984) and non-contact sports (Garrick & Requa,1978a; Shively et al.,1981). This is, however, not the case in higher risk sports where there is a male predominance of injury (Andren-Sandberg & Lindstrand ,1982; Bedford & Macauley,1984; Watson,1984) - with adolescent boys at times suffering an incidence twice as high as that of girls in the same age group. Adolescent boys participating in contact or collision sport thus appear to be the population with the greatest risk for sports-related injury among the youth (Crompton & Tubbs,1977; Zariczny j et al.,1980).

Despite the observation that most sports-related injuries among youths may follow a benign course and are of mild severity, epidemiologists also emphasize that concern about their long-term prognosis cannot be discounted (Garrick & Requa,1978b; Garrick,1980a; Jeanneret,1981; Burke et al. ,1983; Tursz & Crost,1986; Goldberg,1989). Any prolonged post-injury disruption of normal daily activities, certainly justifies preventive measures to avoid sports-related injuries. In considering the above, administrators of organised physical activity programmes should accept a sense of compelled responsibility towards participants in attempting to safeguard their well-being.

2. STATEMENT OF THE PROBLEM

In the past the South African Teachers' Federal Council (1990) has stressed the particular obligation of sports-related injury prevention among youths. Thus far research efforts have of necessity been directed specifically towards the epidemiology of schoolboy rugby injuries and have focussed only on extrinsic risk factors (Nathan et al.,1983; Malan & Strydom,1987; Roux et al.,1987; Noakes, 1990).

Consequently, there appear to be two areas in which further research pertaining to sports-related injuries among youths is warranted within the South African context:

1. To determine the epidemiology of injury among different sports, age-groups and genders; and

2. To determine intrinsic risk factors in the aetiology of injury among high school rugby players, which evidently still poses a substantial problem.

With respect to the latter problem, the Sports Medicine literature reflects that a suitable method of identifying potential intrinsic risk factors for injury among prospective sportsmen is through a pre-participation physical evaluation. As such, this procedure is frequently argued to be the cornerstone of preventive sports-health care of young participants (Garrick,1980b; Shaffer,1982; Micheli & Yost,1984). The basic framework of the preparticipation evaluation has been defined to include the gathering of information through an appropriate health history, medical examination and/or physical evaluation, with the purpose of exposing potential intrinsic risk factors that may predispose the participant to injury (Strong & Linder,1982; McKeag,1985; Linder,1989).

The implementation of preparticipation evaluation among youth participants has been advocated for some time in foreign countries, even to the extent that in some areas of the USA it is deemed mandatory practice (Shaffer,1978; Goldberg et al.,1980; Harvey,1982; Blum,1985). In contrast, although the practice of screening exercising adults is well established in South Africa, the need for the preparticipation evaluation of sportsmen of other age groups, and of rugby players in particular (Roy,1986; Malan & Strydom,1987; Noble et al.,1989; Malan,1990), remains to be addressed.

3. AIMS OF THE STUDY

In cognizance of the foregoing reasoning a two-part epidemiological study of sports-related injuries was undertaken. The study consisted of a preliminary and a subsequent primary investigation, as described hereafter:

3.1 PRELIMINARY STUDY

In an attempt to supplement the current dearth of sports injury data relating to South African youths - the incidence, nature and aetiology of injuries among a cohort of primary school boys and girls participating in five popular sports was studied, viz.: i) Soccer; ii) Rugby; iii) Netball; iv) Hockey; and v) Tennis.

3.2 PRIMARY STUDY

The primary research study undertaken, comprised the preparticipation evaluation and prospective identification of aetiological risk factors for injury among high school rugby players.

This primary study was carried out in two phases, namely:

1. The initiation and implementation of an appropriate multidisciplinary preparticipation physical evaluation procedure to assess potential intrinsic risk factors for injury; and

2. An injury surveillance study was conducted in order to re-assess extrinsic risk factors and examine the role of potential intrinsic risk factors, identified at baseline evaluation, in the aetiology of injuries occurring among the cohort of subjects during a subsequent season of participation.

3.3 DELIMITATION

The scope of research undertaken, including both preliminary and primary investigations, was thus delimited to an analytical epidemiological study of sports-related injuries among youths and the identification of aetiological risk factors in the occurrence of injury.

CHAPTER 2

LITERATURE REVIEW

SECTION ONE

SPORTS MEDICINE IN CONTEXT

1.1 DEFINITION AND SCOPE OF SPORTS MEDICINE

In a general sense, the scientific and medical aspects of sport and related physical activity are associated with the realm of Sports Medicine (Morris,1984). The formal origins of this field of study have been linked to the initial formation of the International Federation for Sports Medicine (FIMS) during the IInd Winter Olympic Games in 1928. More specifically, the first modern definition describing the scope of this field, as adopted by the FIMS Scientific Commission in 1977, reads as follows:

> " **Sports Medicine includes those theoretical and practical branches of medicine which investigate the influence of exercise, training and sport on healthy and ill people, as well as the effects of a lack of exercise, to produce useful results for prevention, therapy and rehabilitation ..."** (Hollmann,1988,p.xi).

Similarly the American College of Sports Medicine (ACSM), founded in 1954 as a counterpart to FIMS, has refined the above definition to broadly designate Sports Medicine as a multidisciplinary field including the physiological, biomechanical, psychological and pathological phenomena associated with exercise and sport (Arnheim,1989). This dynamic field of study has undergone world wide development and sustained progress in recent years, as is evident from the abundant literature, research and scientific journals that are now devoted entirely to Sports Medicine.

Initially the provision of health and medical care for individuals involved in physical activity and sport was the sole domain of a physician. Sports Medicine has, however, not been reserved as specific medical discipline and has in the last decade developed into an area of interest and study for allied health care professions (Mellion,1988). Due to the extent and variety of planning, research and activities encompassed in the observed definitions, Sports Medicine as a field of study has expanded to include individuals with different educational backgrounds, training and occupations. Accordingly, physicians and other scientists specializing in the field of human movement have consistently propagated a multidisciplinary approach to the formation of a sports medicine team (Roy & Irvin,1983; Lombardo,1985;Kulund,1988; Ryan & Allman,1989).

1.2 SPORTS MEDICINE IN SOUTH AFRICA

In South Africa the international growth in Sports Medicine is being paralleled to some degree. The South African Sports Medicine Association (SASMA), which was founded in 1984, publishes its own journal and hosts a biannual international congress. In conjunction with the Secretary General of FIMS attending the IVth SASMA Congress in 1991, it was announced that South Africa would be accepted as the 83rd member of this influential body. The mission of SASMA is, inter alia, to ensure that adequate care is taken to prevent, treat and rehabilitate sports injuries (Van Velden,1991). In particular the role of Biokinetics, as a professional discipline related to Sports Medicine, has emerged as a significant development in the South African context (Strydom,1987; Noakes,1987; Strydom & Coetsee,1989; Erasmus,1990; Van Velden,1990).

In summary, Booher and Thibodeau (1989) have referred to Sports Medicine as an umbrella term that involves all medical and paramedical professionals who are concerned with and provide expertise aimed at enhancing the performance and health care of exercising individuals.

1.3 EPIDEMIOLOGY AND PREVENTION OF SPORTS-RELATED INJURY

An epidemiological approach to the study and prevention of sports-related injuries has been referred to in the opening chapter. To recapitulate, epidemiology is the study of the distribution of disease, which in context is interpreted as sports injury, and of factors that influence this distribution, that is, the aetiology of injury.

Walter and Hart (1990) have listed the following relevant and important research areas which lend themselves to the application of epidemiological techniques:

1. Estimation of the prevalence and severity of injury and/or fatalities in populations of exercising individuals and sportsmen - such as evaluating the type and frequency of musculoskeletal injury;

2. Identification of risk factors and high risk participants - such as studying the relationship of training and equipment to the injury rate, or intrinsic factors which may be predictive of injury; and

3. Development of preventive interventions - where having identified significant risk factors, modifications to reduce the risk of morbidity or mortality are considered.

In further reflection of the application of epidemiological methodology to specific research areas, the American Orthopaedic Society for Sports Medicines' Research Committee has emphasized the promotion of clinical and laboratory musculoskeletal research applicable to the understanding, care and prevention of injuries in sport (Noyes & Albright, 1988).

1.3.1 APPLICATION OF EPIDEMIOLOGICAL RESEARCH METHODOLOGY

In their elucidation of sports-related epidemiology, Caspersen (1989) and Walter and Hart (1990) have distinguished between descriptive, analytic and experimental epidemiology. In descriptive epidemiology the issue of injury distribution is addressed, which can be described by incidence and prevalence rates or by the duration of injury. In such descriptive studies researchers frequently make use of routinely available or official data, such as annual health and injury statistics. In contrast, analytic epidemiology is concerned with the determinants or aetiology of injury and such studies are usually based on data collected specifically for a given study, rather than relying on routinely available data. Such analytical data is primarily observational in nature, as opposed to experimental. Experimental data by comparison, is typically generated by systematically evaluating an intervention or preventive measure by way of a randomized controlled trial.

1.3.2 TYPES OF EPIDEMIOLOGICAL DESIGNS

In essence the epidemiological approaches described above can thus be classified into two categories; experimental and observational, with the latter including both descriptive and analytical approaches (Wade, 1988). Observational epidemiological studies of sports-related injury commonly show three variations in design (Rudicel, 1988), according to the method of data collection employed, namely:

i) Retrospective designs - which operate backward in time and examine risk exposure that took place before the injuries occurred;

ii) Cross-sectional designs - which study a population at one point in time and attempt to identify associations between an outcome and potential etiological factors, usually expressed in the form of prevalence rates; and

iii) Prospective designs - which are oriented forward in time, where a group of subjects or participants are identified and/or evaluated at baseline and followed prospectively over a period of time during which the occurrence of all outcomes or injuries are monitored and documented. After the follow-up is complete, the researcher may calculate an absolute rate of injury for the entire group or for specific subgroups of interest. If the subgroups have been defined at baseline then comparisons among them can be used to identify significant risk factors for injury. The prospective design is also referred to as a cohort design, with the study group constituting the cohort.

1.4 SURVEILLANCE OF SPORTS-RELATED INJURY

As reflected in the preceding paragraphs, in order to gain knowledge about sports-related injuries, it is necessary to record and report injuries. As such, Damron (1981) has cited the primary goal of sports-related epidemiological studies as providing factual evidence to protect and defend the integrity of the particular activity - the benefits of which are dependant on efforts to prevent and control injuries. Thus, in an epidemiological approach to the practise of Sports Medicine, prevention stands firmly in the foreground (Hollmann,1988). This argument is based on the common dictum that the best method of managing and caring for sport-related injury is to prevent it from occurring. It stands to reason therefore, that much of a human movement scientists' and/or biokineticists' time and effort be directed toward the prophylactic aspect in conjunction with their more established rehabilitative role (Schwellnus,1987; Strydom & Coetsee,1989).

SECTION TWO

AETIOLOGY OF SPORTS-RELATED INJURY

It is generally accepted that when the human body is suitably stimulated through exercise, positive adaptations will occur in the muscles, skeleton, joints and related soft tissues (Åstrand & Rodahl,1977; Fox & Mathews,1981; Brooks & Fahey,1984). The human anatomy thus has the ability to adapt to the strain to which it is subjected and to tolerate a progressively increasing load. The body structures also resemble other compounds, however, in the sense that when their innate strength is exceeded or overloaded they will be damaged (Nigg,1985; Denoth,1986). As a result, it is the interaction of the following two related factors which according to Noble (1990), cause an injury to occur:

i) the force/load involved; and
ii) the ability of the musculoskeletal system to resist the load.

In cognizance an enquiry into the science of injury management should be preceded by a study of the mechanisms and aetiology thereof. Such a study would imply the review and an understanding of i) the biomechanics of injury; ii) the mechanical behaviour of biological tissues whilst being abnormally loaded; iii) the causal classification of injury; and iv) the functional anatomy impaired by injury.

2.1 BIOMECHANICS OF INJURY

Biomechanics can be defined as the study of forces acting on and in the human body and of the effects produced by these forces (Hay,1985). Aside from the generation of human movement (Ariel,1989), one of the negative effects of forces acting on and in the body, is the potential causation of musculoskeletal injury (Watkins,1983). Evaluating the mechanism of such injury-producing forces is crucial for several reasons. In the past the importance of identifying the mechanics of injury for the early diagnosis and successful treatment of sports-related trauma has been emphasized (Slocum,1959; O'Donoghue,1959). More importantly in the context of this review, Nigg (1985) and Williams (1988) have emphasized that the prevention and control of injuries can also be based on the knowledge of injury mechanics, where an understanding of the specific causal nature of injuries forms a basis for the logical development of preventive measures.

2.1.1 FORCES, LOADS, STRESS / STRAIN

Force is one of the basic concepts in mechanics and may be defined as any action that causes or tends to cause a change in the motion of a body (Gowitzke & Milner,1988). In injury-mechanics the forces involved are both external and internal. External forces originate outside a particular structure and when applied to an object they are termed loads. The most common loads applied to the body that may produce injury are direct contact with another object, muscle contraction and inertia of a body part (Le Veau,1986). The internal forces within a structure, reacting to these loads tend to resist any changes in shape or size and are termed mechanical stresses. Stress is thus the internal resistance of a material which reacts to an externally applied load. In the human body it is the bones, cartilage, ligaments, tendons and muscles that provide resisting forces to the applied loads (Le Veau,1986). Mechanical stress inside these tissues cannot, however, always resist the applied loads completely. As a result some change in shape or size does occur and this change or deformation is termed strain (Le Veau,1990).

A force, whether it is external (load) or internal (reaction stress), can only be fully described when considering four important characteristics: i) magnitude; ii) a point of application; iii) a line of application; and iv) direction (Le Veau,1977). The role of the magnitude of the force in producing injury is overt, that is, the larger the force the more pronounced the injury. The remaining characteristics of a force as described above should, however, according to Nigg (1985) who labels them as the geometry of the force, also be recognized in their role of determining the type of external load placed on and internal stress experienced in the various tissues of the body.

2.1.2 TYPES OF LOADING

As indicated, stress is generally developed within objects, including the human body, by various forms of loading. The two principal types of mechanical loading are tension and compression. When applied individually, both these forms of loading may result in injury due to shearing of the tissues (Peterson & Renstrom,1986). Alternatively, when these forms of loading are combined, the effect produced is that of bending and torsion which in turn may in the event of overloading of a particular segment, lead to injury (Watkins,1986; Le Veau,1986). Tension and compression are considered uniaxial loads, typically being applied over the exact centre of the object in line with a single central axis. Bending and torsion, in contrast, are the result of loads acting at a distance from a relative fixed axis, and are therefore caused by rotational torque or moments (Le Veau,1986). These various forms of loading are further clarified as follows (Le Veau,1986; Wiktorin & Nordin, 1986):

Tension Loads

During tensile loading equal and opposite loads are applied outward along the same line from the surface of the structure and tensile stress and strain result inside the structure. In tensile loading the object thus becomes longer and narrower due to the resulting compression.

Compression Loads

Compression occurs when an object has equal loads acting along the same line toward the surface of the structure but in opposite directions to each other and compressive stress and strain result inside the structure. With compressive loading the object will become shorter but also wider as it exhibits tensile strain as well.

Shearing Loads

During shear loading opposite loads are applied parallel to the surface of the structure and shear stress and strain result inside the structure. Whenever a structure is subjected to tensile or compressive loading shear stress is produced.

Cantilever Loads

Cantilever loads result when a combination of compression and tension loads are applied to a structure in a manner which causes it to bend around an axis. During bending one surface becomes convex and the other concave. Tension stress is developed within the convex side, while compression stress is established in the concave side. These stresses are at their maximum at the surfaces of the structure and decrease towards the centre.

Torsion Loads

In torsion, a load is applied to a structure in a manner which causes it to rotate around an axis and thus produce a torque within the structure. In the process of torsion the two ends of the structure rotate in opposite directions, producing compression, tension and shear stresses. The moments developed are maximum at the outer surface and decrease to zero at the neutral axis of the structure.

To recapitulate, the type of load applied and the ability of the musculoskeletal system to resist the load determine the limits of tolerance and resistance to injury (Noble,1990). An understanding of how the body resists sports-related injuries thus requires insight into the mechanical behaviour of its tissues under loading.

2.2 MECHANICAL BEHAVIOR OF BIOLOGICAL TISSUES

According to Norkin and Levangie (1985), an analysis of the mechanical behaviour of the various forms of connective tissue comprising the musculoskeletal system reveals the common property of visco-elasticity. This characteristic provides important information in understanding injury mechanisms. In general, the authors indicate that the response of a visco-elastic material to loading can theoretically be modelled as a combination of the response of a viscous fluid (initially resistant to deformation) and an elastic solid (the ability to stretch and return to its original state).

In elaboration of the above concept, Le Veau (1986) points out that in terms of elasticity each type of biological material displays a limit or yield point and that in general, deformation below the elastic limit within an elastic range, allows the material to return to its original length or shape when the deforming force is removed. However, the result of applying a force beyond the elastic limit is that the stressed material will be stretched into a plastic (permanent) range and not return to its original length when the force is removed, thus maintaining a certain amount of deformation. If the load is applied still further through the plastic range to a maximal level, the material will fail and rupture will result at the point of ultimate strength.

The viscous property of visco-elastic materials constitutes time-dependant behavior under loading (Alter,1988). Generally, a rapid application of force will cause a faster and greater elongation, yet generate a higher resistance or stiffness in the material, as opposed to a slower rate of loading (Nordin & Frankel,1989; Teitz,1989).

The combined visco-elastic properties of a material allows for the additional responses of creep and stress-relaxation (Nordin & Frankel,1989). The former phenomenon occurs when a load is suddenly applied to an object and is sustained for a period of time. The object deforms immediately with the application of the load and then continues to deform gradually over time. In contrast, stress-relaxation is the stress response that occurs when a body is suddenly stretched and held at a constant length. If the amount of deformation remains constant, less load becomes necessary to maintain the deformation and after a period of time there is a slow loss of tension, with the magnitude of stress within the object gradually decreasing to zero (Le Veau,1986). In summary therefore, visco-elastic materials, as is characteristic of the tissues of the musculoskeletal system, respond to a constant load with gradually increasing deformation (creep) and to constant deformation with a gradual decreasing of stress (stress-relaxation).

2.3 CAUSAL CLASSIFICATION OF INJURY

The manner in which either of the forces described in the preceding section are generated to overload a particular segment of the musculoskeletal system, provides the basis for the subsequent causal classification of injury. Various systems have been proposed to classify injuries incurred during sport and related activity (La Cava,1961; Corrigan,1968; Williams,1971;1972;1973; Williams & Sperryn, 1976). The one most generally supported (Williams,1980; Noakes,1985; Arnheim,1985; Giam,1988; Noble,1989;1990), is that which utilizes the origin of the overload/force as criteria and in so doing distinguishes between intrinsic and extrinsic injuries.

2.3.1 INTRINSIC AND EXTRINSIC INJURY

Intrinsic injuries result from overload caused by internal forces which are generated within the body itself, without any external forces being applied (Noble,1990). Such injuries are then considered to be self-inflicted (Williams,1973) and are related to factors inherent to ones' anatomy (Noakes,1983;1985). Extrinsic injuries on the other hand, result from overload caused by external forces being applied to the musculoskeletal system such as body-contact in contact/collision sport, being struck by an implement or item of equipment and colliding with a hazardous environmental obstacle. On the whole, extrinsic injuries are considered more severe than intrinsic, since greater forces and higher velocities are involved with various outside agents acting on the body (Williams,1973; 1980).

2.3.2. ACUTE AND CHRONIC INJURY

A further aetiological and classification analysis of injury in sport and related activity, indicates that irrespective of whether internal or external forces are involved, overloading may be singular or repetitive (Ciullo & Zarins,1983). In the first instance, loading can take the form of a sudden massive force which results in macrotrauma induced by a singular internal or external force. Such injuries are usually referred to as acute (traumatic) injuries (Liljedahl,1971; Blazina,1972; Jones et al.,1988).

Excessive loading can also be in the form of repetitive forces of low magnitude originating from stereotypical cyclic activity with a limited movement pattern, of which running is a prime example (Sperryn,1985a; Smith & Stanitski,1987). While the forces created in such a manner are not severe enough to cause acute injury, researchers agree that this situation leads to a condition of microtrauma with microscopic injury and inflammation of the particular tissues (Orava et al.,1981; Klafs & Arnheim, 1981; Renstrom & Johnson,1985; Watkins,1986). In the absence of adequate rest this microtrauma gradually accumulates and eventually results in what is referred to as a chronic (overuse) injury (Stanish,1984; Sperryn,1985b; Jones et al.,1988; Teitz,1989).

2.4 MUSCULOSKELETAL IMPAIRMENT AND NOMENCLATURE OF INJURY

As human motion forms the basis of sports-related activities, it is appropriate to define the function of the musculoskeletal anatomy in human movement. From a kinesiological perspective, bones serve as points of attachment via tendons for skeletal muscle and as the muscles contract and shorten, force is produced and applied to the bones, which then act as levers. It is the joints or articulations, supported by the ligaments and associated connective tissue structures between bones, that serve as the pivot points or fulcrums and permit actual movement to occur (Hay & Reid, 1982; Kaufmann,1988). Subsequently in the event of a sports-related injury, it is these anatomical structures and their kinesiological functions that are typically impaired.

Thus far the various causative biomechanical forces, the mechanical behaviour of the musculoskeletal system under loading and the associated classification system of sports-related injury have been considered. For the purpose of supplementing the comprehensiveness of this review, the common terminology and characteristic conditions of basic categories of injury which may arise as the result of the above factors, will be presented in the following section. The ensuing definitions of these common forms of injury together with the associated causes and symptoms describing their presentation are those widely used in the Standard Nomenclature of Athletic Injuries (Arnheim,1989).

2.4.1 SKELETAL MUSCLE TRAUMA

Skeletal muscle tissue can be traumatized by three major mechanical forces: compression, tension and shear stress - causing various acute and chronic types of injury (Figure 2.1).

ACUTE MUSCLE INJURY

Contusions

As is characteristic of soft tissue, muscle can withstand and absorb sudden traumatic blows to the body. If such compressive force is excessive, however, then a contusion - defined as a bruise to the skin and subcutaneous tissues, is incurred. The intensity thereof can range from superficial to deep tissue compression with haemorrhage (bleeding) caused by an interruption in the continuity of the circulatory system and resulting in induration (flow of blood into the surrounding tissues) and haematoma (blood clot) formation. In severe cases the crushing of soft tissue can penetrate to the skeletal structures, causing an osseous contusion (bone bruise).

Muscle contusions are usually rated by the extent to which the muscle is able to produce range of motion in a body part after injury. For example, a first degree contusion will cause little movement restriction and a second degree contusion will restrict some range of movement. A third degree injury usually severely restricts motion where the involved muscles become temporarily spastic, causing diminished motion at the joints they are responsible for moving. Such cases are typically signified by local swelling, tenderness and ecchymosis (tissue discoloration /bruising).

FIGURE 2.1: CLASSIFICATION OF SOFT-TISSUE TRAUMA

Tissue	**Type**	**Force**	**Condition**
Skin	Acute	Friction	Abrasion (scrape)
		Compression	Contusion (bruise)
		Tearing	Laceration (cut)
		Tearing	Avulsion (ripped)
		Penetration	Puncture (opening)
	Chronic	Friction	Blister
Muscle/ Tendon	Acute	Compression	Contusion
		Tension	Strain
	Chronic	Tension	Myositis
		Shearing	Fasciitis
		Tension	Tendinitis
		Tension	Tenosynovitis
		Compression/ Tension	Bursitis
		Compression/ Tension	Myositis ossificans & calcific tendin-itis

After Arnheim (1989)

Strains

A strain, often referred to as a pull or tear, is defined as an injury to any portion of the musculotendinous unit and may thus involve the muscle, the musculotendinous junction, the tendon or its osseous insertion. The cause of muscle strain is often obscure but essentially it is considered a stretch-induced injury (Garret,1990), implying that tensile forces are primarily responsible. In terms of the pathogenesis of muscle strains, it is of importance to note that as a muscle contracts, the muscle-tendon unit is subjected to increasing stress. With maximal muscle contraction high tensile stress which is within physiologic limits is reached. This stress can be increased further if rapid eccentric contraction of the muscle takes place, thus stretching the tendon-unit beyond its yield point in length (Cuillo & Zarins,1983). However, because tendons are usually twice the strength of the muscle they serve, these structures are extremely resilient to injury, and strains to the musculotendinous unit will commonly occur at the muscle belly, musculotendinous junction or bony attachment before tendons are strained or ruptured (Nordin & Frankel,1989).

A strain may range from a minute separation of connective tissue and muscle fibres to complete discontinuity of the musculotendinous unit. The resulting pathology is similar to that of a contusion, with capillary or blood vessel damage. A mild strain (first degree), involves stretching and a minimal amount of tearing of the tissues. Although there is some discomfort during function, there is generally little or no disability, normal or near normal range of motion and insignificant loss in strength, often allowing continued participation. A moderate strain (second degree) involves significant tearing of fibres although at least some continuity in the musculotendinous unit remains.

Signs and symptoms accompanying moderate strains include varying degrees of pain, swelling, ecchymosis, and loss of strength and range of motion with impaired muscle function. A severe strain (third degree) involves total disruption of the continuity of the musculotendinous unit, thus causing impaired muscle function and instant disability. Usually there will be an associated visible and/or palpable gap at the site of the injury.

CHRONIC MUSCLE INJURY

As discussed previously, chronic injuries usually have a slow progression over a period of time and are attributed to overuse microtraumas. Often, repeated acute injuries that are improperly managed or that allow the participant to resume activity before healing is complete, may lead to a chronic condition. Chronic musculotendinous injuries are representative of a low-grade inflammatory process, of which the following can be distinguished: i) Myositis - inflammation of muscles; ii) Fasciitis - inflammation of connective fascia; iii) Tendinitis - inflammation of tendons; iv) Tenosynovitis - inflammation of tendon sheaths; and iv) Myositis ossificans - the formation of bone within or around a muscle through ectopic calcification (abnormal sites of calcium deposit) as a complication of muscle contusions. The last mentioned injury occurs as a result of chronic irritation of the contused body part, usually occurring in the quadriceps/ femur or biceps brachii/humerus junction. Occasionally and in similar fashion, tendinitis can lead to a condition of calcific tendinitis.

2.4.2 SYNOVIAL JOINT TRAUMA

A joint of the human body is defined as the point where two bones join together, allowing forces to be transmitted between participating bones. Joints are classified as synarthroses (immovable), amphiarthroses (slightly movable) and diarthroses (freely movable). Diarthrodial joints, which are subdivided into six types (Figure 2.2), are synonymously termed synovial articulations and because of their ability to move freely they are more susceptible to trauma, thus being of major concern in sports-related injuries.

The anatomical characteristics of synovial joints structures and their functions are as follows: i) they have a capsule and/or ligaments which respectively hold the joint together and provide added joint protection to the primary support afforded by the dynamic aspect of muscles and tendons that serve the joint; ii) the capsule is lined with a synovial membrane which absorbs and secretes a small amount of lubricating synovial fluid into the joint cavity that it forms; and iii) the opposing articulating bone surfaces contain a thin yet resilient layer of hyaline cartilage which acts as a cushion for the bone ends and acts as a sponge in relation to the synovial fluid - absorbing and squeezing out the fluid as pressures vary between the joint surfaces during movement. In addition, some arthrodial joints are provided with tough fibrocartilagenous discs which vary in shape and are connected to the capsule. These discs are typically found in joints where two planes of motion exist and act as spreaders of the synovial fluid, while in the case of the knee menisci, they also distribute the shock experienced in the joint over a larger surface area and increase the concavity of the articular surface of the tibia.

Synovial joints can be traumatized by three major mechanical forces: tension (including torsional forces), shear stress and compression - causing acute and chronic types of injury (Figure 2.3).

FIGURE 2.2: CLASSIFICATION OF DIARTHRODIAL JOINTS

Common Name	Movement	Examples
Ball & socket	Multiaxial	Gleno-humeral
Condyloid	Biaxial	Radio-carpal
Gliding	Nonaxial	Inter-carpal
Hinge	Uniaxial	Tibio-femoral
Pivot	Uniaxial	Radio-ulnar
Saddle	Multiaxial	Carpo-metacarpal I

FIGURE 2.3: CLASSIFICATION OF SYNOVIAL JOINT TRAUMA

Tissue	Type	Force	Condition
Capsule & ligaments	Acute	Tension/ Compression	Sprains Dislocations Subluxations Synovial swelling
	Chronic	Tension/ Compression/ Shearing	Capsulitis Synovitis Bursitis
Cartilage discs	Acute	Compression/ Tension/ Torsion	Herniation/ Rupture
Articular cartilage	Chronic	Compression/ Shearing	Osteochondrosis Traumatic arthritis

After Arnheim (1989)

ACUTE JOINT INJURY

Sprains

A sprain is defined as an injury to some part of the ligamentous structure of a joint and occurs when a joint is forced beyond its anatomical limits. This typically leads to injury of the ligaments, the articular capsule and synovial membrane, and to the tendons crossing the joint.

As in muscle strains, sprains are graded in three categories according to the severity of the injury and resultant extent of joint instability. A mild sprain (first degree) involves minor stretching or tearing with minimal disruption in the continuity of the ligament. Although some pain may be experienced, a first degree sprain is characterized by a minimum loss of function and no joint instability when tested, often allowing continued participation without being aware of an injury. A moderate sprain (second degree) involves a tearing of ligament fibres and a partial break in its continuity. Moderate sprains show varying degrees of pain, swelling and instability - depending on the portion of fibres torn or ruptured. A severe sprain (third degree) involves a complete rupture and break in the continuity of the ligament. Injuries in this third category produce severe pain during the course of trauma, diminishing thereafter, major loss of function, marked instability, tenderness and swelling. An additional complication of sprains or contusions is an acute injury of the synovial membrane, where an irritation of the membrane known as acute synovitis occurs, causing an increase in fluid production and associated swelling.

Dislocations

A dislocation is the displacement of the connected surfaces of bones composing a joint. Dislocations result primarily from excessive or abnormally directed external forces which force the joint beyond its normal anatomical limits and may be divided into two classes viz.: subluxations; and luxations. Subluxations are partial dislocations in which an incomplete separation between two articulating bones occurs. Luxations are complete dislocations, presenting a total disunion of bone apposition between the articulating surfaces. A dislocation is recognized by the loss of limb function, definite deformity and swelling together with significant pain and immediate joint tenderness. First-time dislocations may result in a rupture of the stabilizing ligamentous and tendinous tissues surrounding the joint. Once a joint has been either subluxated or completely luxated, a loss of proprioception is experienced and the connective tissues that bind and hold it in its correct alignment are stretched to such an extent that they enter the plastic range, maintaining a certain amount of deformation and the joint is thus extremely vulnerable to subsequent dislocations. Chronic, recurring dislocations may then take place without severe pain because of the somewhat slack condition of the stabilizing tissues.

CHRONIC JOINT INJURY

As with other chronic problems occurring due to sports-related activity, chronic synovial joint injuries stem from repetitive microtrauma and overuse. The two major categories in which they fall are osteochondrosis and traumatic arthritis. The term osteochondrosis, derived from the roots osteo (bone) and chondral (cartilage), is a diseased state of bone and its articular cartilage and refers to a category of inflammatory conditions. The related causes are not well understood, but appear to be related to a disruption of epiphyseal circulation due to repeated trauma. Traumatic arthritis, in distinction from chronic osteoarthritic disease, is usually the result of microtraumas, occurring due to repeated trauma to the articular joint surfaces causing the bone and synovium to thicken, leading to pain, muscle spasm and articular crepitus (grating) with movement. In addition to the above, soft-tissue structures such as bursae, capsules and synovial membranes, which are an integral part of diarthrodial joints may also develop chronic conditions. Bursae which serve to provide protection between overlaying structures where there is friction, can over a period of time become chronically inflamed, causing bursitis. Similarly, after repeated joint sprains, chronic inflammatory conditions of capsulitis and associated synovitis may occur. Chronic synovitis leads to joint swelling and movement restriction while crepitis may be audible.

2.4.3 BONE TRAUMA

Bones of the human body are classified according to their various shapes and mechanical functions, into short (strength and stability), flat (protection), irregular (protection, support and leverage) and long bones (rigid movement levers). Although the long bones are most commonly injured in sports-related activities, bones in general can be traumatized by the complete range of injurious mechanical forces or combinations thereof - most often leading to acute fractures, stress fractures, tibial stress-syndrome and epiphyseal conditions.

ACUTE FRACTURES

A fracture is defined as a disruption in the continuity of a bone and can range in severity from a simple crack to the severe shattering of a bone with multiple fragments. Fractures are divided into two major classifications according to the involvement of the overlying skin. In the absence of external exposure of bone through the skin, a closed fracture is sustained, whereas fractures that are associated with a tear in the skin are termed open or compound fractures. Compound fractures are generally the more serious type because of the additional damage to the surrounding soft-tissues, possibilities of infection and external bleeding. Fractures can be recognized primarily by pain at the site that remains consistent with manipulation of the part, a reported snapping sound or sensation, crepitation during movement and possible deformity of the involved area. Bones can be fractured in several ways and fractures are also described by the manner in which the bone is broken (Figure 2.4).

FIGURE 2.4: MECHANISM AND DESCRIPTION OF ACUTE FRACTURES

Mechanism	Pattern	Description
Bending	Transverse	90 degrees to bone shaft
Torsion	Spiral	S-shaped bone separation
Compression, bending & torsion	Oblique	Oblique angle to the shaft
Variable	Comminuted	Three or more fragments

After Arnheim (1989)

In young bones that have not ossified completely, fractures commonly occur as incomplete breaks in the bone. This is the result of bending applied at each end of the bone with tension forces being concentrated on the shaft. Bone failure thus most frequently takes place in the convex bone surface, with the concave surface remaining intact. Such injuries are termed Greenstick fractures, the name being derived from the similarity of the fracture to the break in a green twig taken from a tree, and their occurrence are specific to youths (Wilkins,1980).

STRESS FRACTURES

Stress fractures of bones have synonymously been called march-, fatigue- and spontaneous fractures, although stress fracture is the most commonly used term (Black,1982). Stress fractures are defined as a partial or complete fracture of bone due to its inability to withstand non-violent stress that is applied in a rhythmic, repeated subthreshold manner (Mc Bryde,1982). These types of fractures occur over a considerable period of time without a history of an acute traumatic episode and are thus considered chronic overuse syndromes with the following typical symptoms (Micheli,1982; Devereaux et al.,1984; Goodman et al.,1985; Van Velden,1987):

i) localized pain at the specific site, with occasional referred pain;

ii) localized tenderness on palpation of the area;

iii) localized swelling in the area of the stress fracture;

iv) localized elevated skin temperature over the area of the suspected stress fracture; and

v) relief of all of the above symptoms with rest and a reversed aggravation thereof with repeated stress.

Two basic suggestions have been proposed as possible causes of this injury - the exhaustion theory (Baker & Frankel, 1972; Belkin,1980; Norfray,1980) and the overload theory (Stanitski et al.,1978; Harvey-Smith,1979; Van Velden, 1987), both of which centre around the role of muscle activity. The exhaustion theory maintains that stress fractures occur due to repeated stress of the bone structure associated with increased loading once the supporting structures have been exhausted. This process takes place when the endurance limits of the muscles have been surpassed during prolonged repetitive activity such as running. As a result, the muscles are no longer able to support the skeleton and the impact generated during heelstrike is carried over directly to the bone structure. The overload theory in contrast, advocates that the muscle tension imposed on and across the area of attachment gives rise to a stress fracture. In this case, the rhythmic muscle activity that takes place in a subtle fashion over a period of time, eventually causes the stress carrying capacity of the bone to be surpassed, resulting in a stress fracture.

Irrespective of the manner in which stress is transferred to the bone, the eventual pathology of stress fractures lies in the accompanying process of accelerated bone remodelling in response to increased loading - where the rate of osteoclastic resorption is greater than the rate of osteoblastic formation or repair. This leads to insufficient bone strength and support, causing a crack in the cortex of the bone which manifests in a stress fracture (Stanitski et al.,1978; Tver & Hunt,1986). The anatomical distribution of stress fractures, as in most overuse injuries, are largely limited in the lower extremity. There are exceptions, however, which include the first and fifth ribs, humerus, humero-ulnar joint and lumbar vertebrae (Roy & Irvin,1983; Sperryn,1985a).

The majority of stress fractures of the skeleton are encountered from the pelvis to the calcaneus with the most common sites being : i) the tibia, followed by ii) the pubic arch of the pelvis; iii) femoral neck and shaft; iv) distal two thirds of the fibula; v) metatarsal bones; and finally vi) the calcaneus, making up the remaining anatomical locations (Peterson & Renstrom,1986; Van Velden, 1987).

TIBIAL STRESS-SYNDROME

Another prevalent yet poorly understood form of potential overuse trauma to the lower leg which has similar symptoms to stress fractures, is a condition generally referred to as shin splints among sportsmen and uninformed coaches. The term shin splints has become known as a so-called "waste-basket" diagnosis, used to denote general pain in the shin or lower leg apparently caused by a change in training habits, such as an excessive and premature increase in intensity and training on unyielding surfaces without adequate shock absorbent footwear (Milgrom et al.,1986).

Sperryn (1985a), comments that surprisingly there are no nationally or internationally agreed definitions of the expressions "shin splints" or "shin soreness". Morris (1984), contends that for an accurate evaluation of the cause of pain associated with this injury it must be determined whether the source of pain is of vascular, soft tissue or bony origin. Consequently it is necessary to view the symptomatic pain anatomically in relation to the tibia, the fibula and the respective anterior or posterior compartments of soft tissue in front or behind these bones. In view of these various considerations associated with evaluating shin splints, Schwellnus (1991) maintains that describing this overuse injury as a tibial stress-syndrome (Clement,1974), has currently gained acceptance.

If the pain is from a vascular origin this condition is not indicative of bone stress but belongs to a classification of painful compartment syndrome caused by increased pressure inside the different muscle compartments (Peterson & Renstrom,1986; Soffer et al.,1991). This may occur in an acute or chronic manner to the anterior and posterior compartments of the lower leg. Acute anterior and deep posterior compartment syndrome is rare but can occur as a result of sudden or repeated external impact or acute overuse of the muscles following a single intense session at the initial stages of a training programme, in each case causing soft tissue injury with bleeding inside the compartment. In the anterior compartment in particular, such acute bleeding and the associated swelling can lead to greatly increased pressure which in turn impairs the blood flow in blood vessels that pass through the muscle compartment causing numbness in the anterior dorsum of the foot. Such a condition entails a dangerous complication often requiring an emergency surgical fasciotomy to release the pressure within the compartment (Peterson & Renstrom, 1986; Kulund,1988).

A more common compartment problem in runners is chronic compartment ischemia, in which the tight and relatively inelastic fascia that surrounds the muscles is unable to accommodate the increased muscle bulk induced by prolonged training. As a result the fluid pressure in the compartment rises, compromising the blood circulation to the nerves and muscles within that compartment thus producing swelling, which adds to the compartmental pressure while causing an ischemic pain due to the relative lack of oxygen (Soffer et al.,1991). Chronic compartmental ischemia may affect any of the compartments and the onset of pain is usually gradual over one year or more, eventually also being treated successfully by fasciotomy if persistent (Kulund,1988).

Alternatively, if the "shin soreness" is from a soft tissue origin, it may be the result of inflammation of the muscle, tendons or fascia of the lower leg. Examples of such soft tissue related shin pain are an inflammation of the tibialis anterior muscle tendon sheath or the interosseous membrane joining the tibia and fibula which also serves as a point of muscle attachment in the lower leg. Such irritation is usually caused by repetitive running and jarring of the lower limbs and thus rest has been advocated as the primary form of treatment (Morris,1984).

Finally, if the "shin soreness" is from a bony origin the pain will usually manifest as stress on the anterior aspect of the tibia, either along the lateral or medial border or situated posteromedial to the tibia (Mubarak et al.,1982). Anterior tibial stress is signalled by pain, tenderness and tightness along the lateral border of the tibia and at the distal third of the tibia along the medial crest associated with inflammation of the dense fibrous periosteal covering of the outer surface of the tibia. Posteromedial tibial stress syndrome is specific to the posteromedial compartment, 10-15 cm proximal to the tip of the medial malleolus where the soleus fascia inserts onto the tibia. It is believed that constant pulls of this fascia due to over pronation may also produce a periostitis reaction (Peterson & Renstrom,1986; Kulund,1988). The common denominator in the treatment of tibial stress of bony origin has been suggested as rest followed by a resumption of activity in a graduated fashion (Mubarak et al.,1982). In the treatment of medial tibial stress syndrome in particular, Clement (1974) recommended a two phase approach, namely, rest (including crutches) and anti-inflammatory medication, followed by a graduated rehabilitation programme using isometric and isotonic exercises. In the case of posteromedial tibial pain associated with the soleus fascia, a fasciotomy of the deep posterior compartment may be indicated (Puranen & Alavaikko,1981; Kulund,1988).

The common types of sports-related injuries of the musculoskeletal system described thus far can generally be sustained by adults as well as youths. The final category of bone trauma, namely physeal or growth plate conditions, are specific to children and adolescents and will be reviewed under musculoskeletal injuries unique to youths.

2.5 MUSCULOSKELETAL IMPAIRMENT AMONG YOUTHS

As illustrated earlier, the basic mechanism of injury during sports-related activity is the relationship between the type of load incurred and the ability of the musculoskeletal system to resist these loads. In the latter instance, from early childhood through to old age, different tissues of the body are more liable to overloading at various ages. The general rule in this respect is that the weakest link in the musculoskeletal chain is age-dependent (Noble,1989). Among youths the immature skeletal system is susceptible to overload and this linked to the process of physiological growth, development and maturation, results in musculoskeletal injuries unique to the young participant (Shaffer,1980; Cantu,1982; Andrish & Gurd,1983).

2.5.1 GROWTH, DEVELOPMENT AND MATURATION

The early childhood ages of two to five years, represent a period of rapid growth and development, especially in the nervous system. The late childhood phase begins at age six and continues to the age of ten to twelve years. During this developmental period, most of the bodies' systems show slow and steady growth (Sinclair,1989), with boys and girls being closely matched in size and physical ability (Sharkey,1986). Next, the onset of puberty marks the beginning of adolescence which typically occurs between ages ten to twelve or thirteen years in girls and twelve to fourteen or fifteen years in boys. More than at any other stage, adolescence is a time of dramatic growth and maturation (Beunen et al.,1988). Elevated levels of circulating hormones - particularly testosterone in boys and progesterone in girls, promote major changes in secondary sexual characteristics, muscular development and bone growth (Tanner,1962), the last mentioned continuing until as late as nineteen or twenty years (Luttgens & Wells,1982). According to Larson (1973a), the skeleton and growth plates are most susceptible to injury during the adolescent growth spurt when the discrepancy between skeletal and muscular growth is greatest.

2.5.2 BONE GROWTH AND RELATED INJURY

The growing bone has a complex architecture defined in part by the three sites of growth cartilage, namely : i) at the ends of the long bones underlying the joint surface, i.e. the pressure epiphyses; ii) at the growth plate or physis, which is responsible for the majority of skeletal growth; and iii) at the sites of major muscle-tendon insertions, i.e. the traction apophyses (Solomon & Davis,1978). The epiphysis has as its base the physis or growth plate where most linear bone growth occurs (Micheli,1989).

EPIPHYSEAL INJURIES

The epiphyseal growth plate has perhaps been implicated more than any other site as an area of potential injury in young sportsmen (Larson,1973a; Brighton,1978; Micheli,1984; Caine & Lindner,1985; Watkins,1986; Renstrom & Roux,1988; Ruggles et al.,1991). The main risk posed to the growth plate is that because it comprises cartilage, which is softer and thus weaker than fully developed bone, it is more likely to be damaged if an external force is applied to the bone. It has been reported that 6-18% of sports-related injuries in children involve the physeal area (Pappas,1983; Speer & Braun,1985). Physeal injuries associated with sports-related activity in youths can occur from both violent acute forces or chronic stresses. In skeletally immature children ligaments are reported to be relatively stronger than the epiphyseal plate (Collins & Evarts,1971). In joints were the ligaments attach to the epiphysis per se, injuries that normally result in ligament damage in the adult often result in fractures of the epiphyseal plate among twelve to thirteen year old youths, in particular (Peterson & Peterson,1972).

It follows therefore that the physis has been identified as the weak link in the musculoskeletal system of adolescents (Benton,1982). A common location for such injuries to occur is at the knee, where the tibial collateral ligament arises from the distal femoral epiphysis but inserts on the metaphysis of the tibia. Thus, a sudden powerful valgus force may result in a fracture of the distal femoral epiphyses rather than a sprain or rupture of the ligament or fracture of the proximal tibial epiphysis (Wilkins,1980). Other areas where this may occur include: i) the ankle - where a fracture of the distal fibular epiphysis may take place in stead of a collateral ligament injury; and ii) the elbow - on experiencing a varus stress while extended, resulting in a fracture of the growth plate of the lateral epicondyle or vice versa (Micheli,1986). As described in these examples, violent mechanical forces that produce predictable injuries in adults, tend to result in very different and unique musculoskeletal injury in the young participant.

As stated previously, it is not always a single violent force that overcomes the integrity of the physis. On the contrary, some authors believe that repetitive activity that causes overloading of immature tissue and inadequate rest are the primary causes of epiphyseal damage (Rarick,1973; Micheli,1979; Lopez & Pruett,1981). For example, Micheli (1979) attributes the prevalence of back injuries in gymnasts to recurrent microtrauma, of which growth plate injuries are typical (Jackson,1979). Similarly, the role of mechanical factors in predisposing the physis region to disruption through recurrent use is also proposed by Speer & Braun (1985). They contend that recurrent stress may cause an inclination in the plane of the proximal femoral epiphysis, as apposed to the normal situation in which the physes are perpendicular to the axial loads placed on them. This process thus becomes the pathogenic mechanism in a slipped capitofemoral epiphysis, being the displacement of the femoral head on its neck characterized by complaints of hip or medial knee pain and participation in a repetitive sports-related activity (Speer & Braun,1985).

A further example of recurrent microtrauma causing growth plate injury is cited by Godshall et al.(1981), who reported two cases of stress fracture through the distal femoral epiphysis in American football players. In each case no obvious mechanism of injury could be identified but they were precipitated by training periods that emphasized running. According to the American Academy of Paediatrics (1982) they consider running as the single mode of exercise that best exemplifies stressful, long-duration, repetitive activity and as more children and adolescents engaged in long-distance running, their concern about growth plate injuries also increased. Nevertheless, Caine and Lindner (1984), in their subsequent examination of the threat of growth plate injuries to young distance runners reported that evidence is lacking to unequivocally support or condemn the effect of long-distance running on musculoskeletally immature children and adolescents.

The potential for growth plate injury in the young participant has clearly been documented. Pappas (1983), also reported, however, that the incidence of physeal injuries does not appear to be escalating and that most injuries are not severe, stating that growth disturbances subsequent to epiphyseal injury are estimated to occur in fewer than 5% of all cases sustained during sport and free-play situations. Nevertheless, Zito (1990) reiterates that it is precisely this potential for growth disturbance that has resulted in the attention to the physis in the literature - where complete or partial cessation of growth due to premature closure of the growth plate can ultimately result in limb-length inequality or angular deformity (Pappas,1983).

The outcome or prognosis of growth plate damage is largely based on its potential for growth disturbance and is usually predicted by evaluating epiphyseal fractures according to the Salter-Harris classification (Salter & Harris,1963 in Micheli,1989). With this classification, these injuries are categorized from type I to V, based on the site of fracture; the extent of adjacent epiphysis and metaphysis involvement; the hypothesized mechanism of injury; and the potential for subsequent growth arrest. Types I and II are horizontal fractures and in general are caused by direct violent trauma; are less severe; are managed non-surgically; and are less inclined toward growth disruption. Types III, IV, and V on the other hand are fairly rare vertical fractures which are difficult to detect; more likely to cause growth arrest; and require urgent, often surgical treatment (Salter,1983).

APOPHYSEAL INJURIES

The apophysis, or tendon insertion, is another important area of musculoskeletal breakdown in young participants. Apophyseal growth centres present as protuberences, such as tubercles and eminences, which serve as growth areas where cartilage is interposed between tendon and bone and as such, are viewed as areas of weakness (Williams,1979). Skeletal growth at the apophysis occurs through the process of endochondral ossification much in the same manner as at epiphyseal plates (Riegger,1990). However, the apophysis receives its stimulus from muscular attachments that exert tensile forces and is often therefore referred to as a traction epiphysis (Larson,1973b; Micheli,1988a).

When large muscle forces are imparted to immature apophyseal centres during sports-related activities two primary forms of injury can result. Firstly, the apophyses can separate partially or completely from the bone, predominantly due to the superior strength of tendons and ligaments during adolescence as opposed to weakness in the apophyseal physis, although a loss of flexibility during the adolescent growth spurt may also contribute (Malina,1974; Micheli,1989). Thus, a violent muscular contraction while the muscle is stretched will likely lead to an apophyseal avulsion in the adolescent and a muscle strain in the adult (Singer,1984). Separations or avulsions commonly occur at muscular attachments on the front of the pelvis and the ischium, as well as but less commonly in the proximal trochanters of the femur (Stanitski,1982). For example, Wilkins (1980), asserts that whereas hamstring tears (e.g. semitendinosus) will occur in adults with hyperflexion of the hip combined with an extended knee - in the skeletally immature posterior ischial apophysis of youths, an avulsion of this apophysis may result. Other specific apophyses that may incur a similar injury at the points where major muscle tendons originate or insert are: i) the anterior-superior illiac spine (origin of sartorius) and anterior-inferior illiac spine (origin of rectus femoris) - due to overloading during flexion of the thigh; ii) the lesser trochanter of the femur (insertion of illiopsoas tendon) during trunk flexion or during adduction of the thigh (adductor muscle group insertion at lesser trochanter / linea aspera of the femur); and iii) the greater trochanter of the femur (insertion of the abductor group) during abduction of the thigh (Godshall & Hansen,1973; Metzmaker & Pappas,1985; Noble,1989; Micheli, 1990). Apophyseal injury, if not recognized and treated may result in significant physical impairment (Hamsa,1972; Cantu,1982). Such avulsions are according to Renstrom and Roux (1988), considered to be true fractures and should be examined by X-ray, where in the event that the bony attachments have been torn away and displaced to such an extent that healing is doubtful, surgery should be considered.

The second way in which apophysis breakdown occurs is through repetitive overload or overuse (Stanish,1984; O'Niell & Micheli,1988; Clain & Hershman,1989). The mechanism of injury differs from an apophyseal avulsion as described above, in that instead of separating the apophysis from the bone as with a sudden violent force, the tendon, if chronically stressed, may sustain micro tears at its attachment to the apophysis (Wilkins,1980). Common sites at which such injuries occur are the knee, manifesting as Osgood-Schlatters disease / tibial tubercle apophysitis and Sinding-Larsen-Johansson syndrome / inferior patellar tendinitis, or at the heel as Severs disease / os calcis apophysitis (Micheli,1983;1986). In explaining the origin of the nomenclature of certain of these entities, Micheli (1987;1989;1990) emphasizes that they have been labelled diseases having previously been classed as osteochondroses or developmental disorders (diseases) of cartilagenous growth. Subsequent to understanding their injury mechanism, these conditions have been termed apophysites - indicating the inflammatory response that usually accompanies these tiny avulsion injuries of the apophyses.

More specifically, Severs disease which may frequently be bilateral, commonly presents as heel pain with tenderness where the Achilles tendon attaches to the apophysis of the calcaneus (Micheli & Ireland,1987). In respect of the knee, both Sinding-Larsen-Johansson syndrome and Osgood Schlatters' disease are associated with the patellar tendon, the former occurring as tenderness where it attaches to the inferior pole of the patella (Medler & Lyne,1978). Sometimes this injury may when x-rayed demonstrate a small avulsion fracture at the distal pole of the patella anteriorly, being similar to jumpers' knee in the skeletally mature person (O'Niell & Micheli,1988). Osgood Schlatters' on the other hand is the best known form of apophysitis as it occurs most often, and thus merits further consideration. Pain is localized to the insertion of the patella tendon at the tibial tubercle, i.e. the knee extensor mechanism (Clain & Hershman,1989).

Tibial tubercle apophysitis is a condition unique to the knees of adolescents (Antich & Clive,1985). It occurs in 10-15% of youths aged eleven to fifteen years, usually with the onset of the growth spurt (Ogden & Southwick,1976; Ogden et al.,1980). In addition, Antich and Clive (1985) report that boys are affected by Osgood Schlatters' disease more often than girls, and that unilateral involvement occurs more frequently than bilateral. Although many youths continue to participate despite the presence of symptoms, those individuals with moderate to severe pain and impaired performance should refrain from sports-related activity and follow a rehabilitation programme (Clain & Hershman,1989). Such a programme would firstly consist of conservative treatment with rest and ice to reduce swelling and ease discomfort, followed by initial stretching and subsequent strengthening of the quadriceps muscles (Kujala et al., 1980; Strizak & Stroberg,1986).

SECTION THREE

RISK FACTORS AND INJURY PREVENTION

Injuries in sport and related activity result from the interaction of numerous identifiable risk factors at a given point in time, thus constituting a complex multifactorial problem. Consequently assessing their aetiology and developing preventive measures requires an epidemiological approach that studies the relationship of global factors that influence the frequency and distribution of injury (Walter & Hart,1990). In an attempt to predict the occurrence of injury, researchers have identified key factors involved in the pathogenesis of injuries. There is general agreement about the classification of these risk factors into two categories: i) extrinsic risk factors (Figure 2.5) - which are related to the type of activity, the manner in which it is practised, the environmental conditions and equipment involved; and ii) intrinsic risk factors - which refer to individual physical characteristics and psychological traits (Lysens et al.,1984; Nigg,1985;1988; Jones et al., 1988; Brown,1988).

FIGURE 2.5: EXTRINSIC RISK FACTORS IN SPORTS INJURIES

EXPOSURE	TRAINING PROGRAMME
- Type of activity	- Frequency
- Position/event	- Intensity
- Participation time	- Duration
- Competitive level	- Type
ENVIRONMENT	**EQUIPMENT**
- Type and surface condition	- Protective equipment
- Weather conditions	- Footwear
- Time of day	
- Time of season	

After Lysens et al.(1984) and Arnheim (1989)

3.1 EXTRINSIC RISK FACTORS AND PROPHYLAXIS

Of the identified extrinsic risk factors in sports-related injury (Figure 2.5), training programmes, environmental factors and equipment usage can be interpreted to be as much part of the preventive cure as the cause of injury, and will thus be considered as part of prophylactic measures. Exposure to an injury situation can, however, be distinguished as an unambiguous extrinsic aetiological risk factor.

3.1.1 EXPOSURE TO INJURY

Nature of Activity

By their very nature sports activities invite injury. As such the characteristic "all-out" exertion, the degree of body contact required, speed of play and situations that involve the striking and throwing of missiles all contribute to establish hazards. These hazards are directly related to the unique risks of the playing position or specialist event within the selected sports activity. According to Cantu (1982) the inherent hazardous nature of the chosen activity is the primary causative factor in the incidence of sports-related injuries among youths.

In this respect the American Academy of Paediatrics' Committee on Sports Medicine (1988) have updated (Figure 2.6) their original sports classification system, which is based on the degree of strenuousness and the probability of collision. This committee acknowledges that certain of these activities classified as "contact sports" are not inherently body contact activities. They contend, however, that when competitors fall and collide with the ground, they are as much at risk as participants in the more traditional collision/contact sports and hence have included such activities in a group called "limited contact/impact".

In accordance with this classification system, sports-related activities labelled as "collision" types generally have a higher risk potential for fatalities, catastrophic neck injuries and severe acute musculoskeletal injuries such as fractures, dislocations, contusions, strains, sprains and lacerations. By comparison, sports categorized as "limited contact/impact" or "non-contact", place participants at greater risk for chronic injuries like stress fractures, tendinitis, fasciitis and bursitis (Arnheim,1989). The point emphasized is that specific sports activities are generally linked to a predictable injury type.

FIGURE 2.6: CLASSIFICATION OF SPORTS ACTIVITIES

CONTACT		**NON-CONTACT**		
	Limited Contact		**Moderately**	**Non-**
Collision	**Impact**	**Strenuous**	**Strenuous**	**Strenuous**
Boxing	Baseball	Aerobics	Badminton	Archery
Field hockey	Basketball	Discus	Tabletennis	Golf
Ice hockey	Bicycling	Fencing		Riflery
Martial arts	Cricket*	Javelin		
Rugby*	Diving	Rowing		
Soccer	Equestry	Running		
Wrestling	Gymnastics	- Cross country		
	High jump	- Road		
	Pole vault	Shot put		
	Skating	Swimming		
	- Ice	Tennis		
	- Roller	Track events		
	Skiing	Weight lifting		
	- Downhill	Waterpolo		
	- Water			
	Softball			
	Squash			
	Volleyball			

After the American Academy of Paediatrics (1988), Committee on Sports Medicine. * Added by the author

Competitive Level and Participation Time

Level of competition and participation time are two further potential exposure-related extrinsic aetiological risk factors. As regards the level of competition, the identified pattern of injury is an increased incidence of sports-related injury among older (adolescent) children and adults. This has proven particularly true for collision type sports such as youth football in the USA (Robey et al.,1971; Goldberg et al.,1984). In the South African context Roux et al.(1987) have documented similar results among schoolboy rugby players while (Clark et al.,1990) found that adult players sustain an even higher incidence and increased severity of injury. According to Garrick (1990) one explanation for this tendency may be the increased time at risk, in that with older age groups games last longer and practices are more frequent, thus giving the participant more opportunities to be injured.

The observed increasing incidence of sports-related injury with increasing age may also be explained by anatomical and skill-based factors such as the larger size, increased speed of play and greater skill of older players competing at higher competitive levels. These factors of mass and speed have critical biomechanical implications in creating the injurious forces that typically produce acute injuries occurring as a result of collision or from rapid acceleration and deceleration (Peterson & Renstrom,1986). Two formulas from basic physics dealing with linear kinetics are useful in this regard (Rice,1989) viz.:

$$F = ma \qquad \text{and} \qquad K = \tfrac{1}{2} mv^2$$

Where:	F = Force	K = Kinetic Energy
	m = Mass	m = mass
	a = Acceleration	v = velocity

The first equation: $\boldsymbol{F = ma}$ originating from Newtons' Second Law, viz. *force is equivalent to the product of the mass and the acceleration of the body* is applicable in understanding the effect of the collision that results when two players make contact. Additionally, sudden acceleration and deceleration, often mentioned in terms of explosive power, is directly proportional to the force generated; thus the action of rapid initiation or termination of movement places considerable stress on the body. Acceleration is also important when considering projectiles such as balls or an errant discus, hammer etc. striking participants or spectators. The acceleration caused by gravity increases the velocity of the falling object with time; the farther the object falls, the greater the velocity and kinetic energy at the time of collision.

The second equation: $\boldsymbol{K = \frac{1}{2} mv^2}$ viz. *the linear kinetic energy of a body being equivalent to the product of one-half its mass and its velocity squared* once again demonstrates the significance of the speed (velocity) and mass of the player in determining the amount of energy transferred during a collision. As kinetic energy is directly proportional to the mass or weight involved, the larger the objects colliding, the more force or energy is thus transferred. As participants grow older, larger and faster, injuries in contact sports tend to become more severe, as the forces associated with kinetic energy of impact become far greater than when smaller and slower participants collide (Goldberg et al.,1988).

These mechanical formulae thus help explain why injury rates increase as participants grow. Figure 2.7 reflects this theoretical relationship in a contact sport such as American football, which could probably also be applied to the game of rugby.

FIGURE 2.7: THEORETICAL KINETIC ENERGY OF COLLISION

Age	**Mass (kg)**	**Estimated relative velocity**	**Kinetic energy** ***(K = ½ mv*** ^{2}***)***
11	40	1,0*x*	20x^2
16	75	1,5*x*	84x^2
21	90	2,0*x*	180x^2
26	110	2,5*x*	344x^2

x = velocity After Rice (1989)

The level of competition has a further extrinsic aetiological implication in that as players increase in age and expertise, they also go through a more rigorous selection process to gain team membership. Team members are often selected on the basis of skills that include characteristics associated with an increased risk of injury, such as being good "tacklers", thus leading to an inadvertent fostering of injury to both defender and opponent (Garrick,1990).

3.2 EXTRINSIC RISK FACTORS AND MODIFICATION

The extent to which the previously identified extrinsic risk factors can be modified and controlled, is largely dependant on the following inter-related preventive measures.

3.2.1. OFFICIATING AND SUPERVISION

Capable officiating implies a cooperative process of appropriate rule modification by administrators who hold office in various sports governing bodies, followed by the strict, impartial interpretation and application of these rules by qualified referees/umpires and club officials (Sperryn,1988). Sports rules generally fall into two categories, namely those pertaining to the specific laws of the game and those dictating the use of protective and functional equipment and clothing for the particular sport. If in the evaluation of an injury, the official rules of a sport are thought to contribute to an increased risk to the sportsman, then they should be critically considered to eliminate unsafe practices (Rice,1989; Ryan & Stoner,1989). For instance, catastrophic injuries have been reduced by prohibiting dangerous techniques in wrestling (Estwanik & Rovere,1983) and outlawing defenders from performing a head-on "spearing" tackle with the aid of their helmets in American football (Torg et al.,1985; Mueller & Blyth,1986). Similarly, continued concern has been raised abroad (Hooker & Leighton,1979; O'Carroll et al.,1981; Silver,1984) and in South Africa (Noble,1988; Sher,1978;1982;1989;1990;1991) over the high incidence of spinal cord injuries among rugby players and the need for appropriate rule revision. As a result the International and South African Rugby Boards (SARB) are constantly introducing certain law changes at senior and school level to promote safer participation (Hugo,1990). Any salutary effects of changes like the penalization of the high-tackle and the implementation of new scrum laws need to be researched and observed in the long term to determine their efficacy. To this effect Kew et al.(1991) have in their retrospective analysis of spinal cord injuries among South African rugby players in the Cape province, indicated that since the implementation of these law changes there has been a decrease in such injuries for the period mid 1990-1991 among schoolboys but not at adult level, where these law changes have only been implemented in a selective manner. In a very recent related incident (Harrison,1996) a paralysed British rugby forward is claiming that his injuries were partly caused by the referees' failure to take the necessary action to stop scrums collapsing. This has raised the possibility of referees being held legally liable for the consequences of their decisions and their control of the game. The legal maxim of "volenti non fit injuria" - no legal wrong is done to one who consents - may, however, protect the referee provided that he adheres strictly to the rules of the game. In local study concerned with officiating and rule changes as a preventive measure in rugby, Potgieter et al.(1991) reported that experimentation with a system of dual refereeing led to a lowering in the number of penalties for foul play and contend that this approach could thus decrease the number of injuries that are the result of foul play.

The provision of adequate health/medical care such as the availability of qualified medical and paramedical attendants during participation to deal with the early diagnosis and emergency treatment of injuries (Hage & Moore ,1981; Glaun et al.,1984), is another prime consideration for officials. More specifically, the mandatory presence of a Medical Doctor and a certified first aid squad at contests or matches and ready availability during practice sessions can prevent a potentially serious sports injury from developing into a permanent disability or fatality (Ekstrand et al.,1983b; Noble,1988). In this respect also, the SARB have ruled that a referee has the right and obligation to postpone a rugby match if he is of the opinion that field-side medical care is inadequate. Officials in control of an accountable, organised physical activity or sports programme also have the implicit obligation of recruiting and providing competent coaching and leadership.

3.2.2 COACHING AND LEADERSHIP

The coach is in all probability the individual whose leadership and actions could do the most in attempting to modify the various extrinsic risk factors of sports-related injury. Unfortunately, many of those involved with coaching sport in schools and the community, have no formal training and the need to improve their knowledge of the sport specific and scientific aspects of coaching through certification has been recognized in the United States (Martens et al.,1981; Houseworth et al.,1990; Milne,1990) and in South Africa (Van der Walt,1986). As a result, the American Coaching Effectiveness Programme and the South African Association for Sport Sciences' National Certification Programme for Sports Coaches were developed and introduced. Of particular significance in the context of this review, is that coaches usually have first contact with an injured sportsman and should thus have a basic knowledge of the prevention, recognition and emergency treatment of sports injuries (Hage & Moore,1981; Rowe & Miller,1991). In addition Rice (1989), stresses that performance goals should be elevated above outcome or victory at all costs. This implies that coaches who inculcate sportsmanship and respect for the rules of the game, in letter and spirit, can help reduce the risk of injury.

3.2.3 EQUIPMENT AND FACILITIES

Williams (1973) states that most common sports injuries can be attributed to extrinsic forces where various external agents act on the body. Typically these forces have been known to originate from collision with another participant, being struck by sports implements such as bats, balls, an errant discus et cetera (Mueller & Cantu,1990), and environmental hazards like goal posts, hard or unstable surfaces and advertising boards. Gieck and Mc Cue (1980) maintain that the incidence of injury due to such external trauma, can be reduced to a large extent by using appropriate, correctly fitted personal protective equipment, while others (Mueller & Blyth,1974; La Cava, 1978) incorporate the role of well developed and maintained fields and facilities together with strict adherence to safety requirements.

Roy and Irvin (1983) voice the dual purpose of personal protective and supportive equipment as being prophylactic and functional, the former to protect the healthy participant from injury and the latter to protect an existing injury from additional trauma. According to Rice (1989), to be considered "acceptable", an article of protective sports equipment must meet four requirements: i) the equipment must function as designed or intended, demonstrating its efficacy; ii) the equipment must fit properly and maintain its position during participation; iii) the equipment must not predispose the participant to another injury; and iv) the equipment, when used correctly, must not be harmful to others.

In general footwear with adequate shock-absorbing capabilities, when used for running or jumping activities on unyielding surfaces plays a major role in reducing injuries, particularly in the lower legs and feet (Noakes,1985; Van Heerden,1988; Van Heerden et al.,1990; Schwellnus,1990; Van Heerden,1991). Similarly headgear such as helmets, face masks and mouth protectors are imperative to protect the brain, face and teeth in the event of trauma incurred during cycling (Burke,1988) or playing baseball (Wilkins,1990) and cricket (Stretch,1989). The use of gumguards in contact sport has been shown to decrease the incidence and severity of concussion and serious oral/dental injury (Chapman,1985; Garon et al.,1986). This encourages the recommended if not obligatory use of gumguards at all levels in rugby, of which the custom-made type is preferable due to a high compliance rate (Upson,1985).

The above mentioned items of protective sports equipment appear to have met the necessary critical requirements and demonstrated their prophylactic effect. Their functioning is based on the biomechanical principle of absorbing and reducing pressure at the point of application to the body by distributing the injury producing force over a larger surface area and thus reducing the chance of injury (Le Veau,1990).

There are also forms of prophylactic equipment which are often recommended because of their purported protective effect despite the fact that research concerning their effectiveness remains inconclusive. Decisions about the use of these specific preventive practices should be individualized, ensuring that limitations are understood prior to participation. These include the use of goggles or eye protection for squash and racquetball (Diamond et al.,1982; Easterbrook,1982) and the practice of routine ankle taping (Garrick & Requa,1973; Ferguson,1973; Glick et al.,1976). The fairly recent innovation of prophylactic knee bracing in particular, has also created much controversy (Hewson et al.,1986; Rovere & Bowen,1986; Johnston & Paulos,1991). Their intended effectiveness in protecting medial knee ligaments from injury due to valgus tackling forces during American football has been questioned (Paulos et al.,1986; Teitz et al.,1987; Garrick & Requa,1987) and indications are that they hamper performance (Prentice & Toriscelli,1986) while possibly increasing the incidence of ankle injury (Grace et al., 1988). The prospect of using such a device in rugby, where similar injurious tackling forces are experienced, thus seems unwarranted from a prophylactic point of view while they may also be potentially harmful to opponents in the set absence of shoulder padding.

Another application of functional prophylactic sports equipment, is to protect and support a past injury and/or joint instability or to allow safer participation during injury rehabilitation (Roy & Irvin,1983). Such equipment may include commercially available options such as elastic type guards for the ankle (Myburgh et al.,1983), knee, thigh and elbow while more recently neoprene thigh sleeves, which supposedly provide mild soft tissue support and to some extent retain heat in the limb, have become popular. Whereas the benefits of these items are debatable, alternative options which are more readily acceptable include customized orthopaedic options such as a prescribed ankle brace (Van Pelt,1989) or derotation knee brace designed to stabilize rotatory problems in the joint (Hunter,1985; Knutzen et al.,1987).

3.2.4 PROGRAMME DESIGN AND EXERCISE PRESCRIPTION

Training and conditioning can be seen in dual perspective, that is, firstly as an extrinsic risk factor if not performed correctly or as a result of poor programme design or secondly, as a method of preventing injuries. Aside from performance benefits, it is generally accepted that the acquisition of a high level of specific physical fitness prior to participation in a sport is of paramount importance in avoiding injury. The purported preventive value of conditioning originates from the basic training effect on the sportsman in achieving increased strength, muscular and aerobic endurance and flexibility (Fox & Mathews,1981; Brooks & Fahey,1984), thereby reducing the chance of injury associated with the inherent physical demands of the activity. As has been highlighted, however, virtually all sports-related physical activities, including vigorous training, carry some risk of injury (Rice,1989). Furthermore, a prime feature of organised sport is the use of systematic repetitive training to improve fitness or sport skills. In this practice, however, incorrect and/or excessive training, which may be termed maltraining, could constitute a potential extrinsic risk factor predisposing participants to injury. This may be evident, in so far as uninformed yet highly motivated enthusiasts being convinced that optimum physical training equals the maximum amount of training that can be endured (Copely,1985). This misconceived practice of excessive training (overtraining) in the hope of maximizing aerobic performance in particular, may result in injury rather than in superior conditioning, as suggested by James et al.(1978) and Koplan et al.(1982). These authors contend that the error of wanting to do too much, too soon is a major pitfall in the conditioning of cardiorespiratory endurance, leading to an enhanced risk of overuse injury.

The phenomenon of excessive training or maltraining in pursuit of superior aerobic conditioning poses a realistic problem among some uninformed coaches training youths at primary school level. In this particular respect it is significant, as emphasized by Bar-Or (1989), that research is still inconclusive regarding the apparent decreased aerobic trainability of prepubescent children in comparison to adolescents or adults (prepubescence being defined as the period up to approximately 12 years old, prior to the onset of secondary sex characteristics at puberty marking the beginning of the adolescent growth phase).

According to Bar-Or (1989) it is difficult to interpret studies of training induced physiological changes in prepubescents because the results are confounded by the effects of natural growth and development. One suggested reason for the low trainability of prepubescent children is that children are generally active even when not taking part in a regimented training programme and thus a training programme adds little to their fitness. In a comprehensive review of a number of studies in which maximal oxygen consumption of children did increase with training, Rowland (1985) did however, come to the conclusion that when the aerobic training regimen conformed to guidelines established for adults, prepubescents are trainable.

In cognizance of this review (Rowland,1985), Bar-Or (1988;1989) remained of the opinion that the final verdict regarding the relative aerobic trainability of different maturation groups is still pending and noted that, even when aerobic training fails to increase maximal oxygen uptake, the running performance of children can improve markedly. The same author, in providing a possible explanation for this apparent discrepancy, argued that training induces an improved style-related running economy (decreased oxygen uptake at any given submaximal running speed) and suggested that a programme based exclusively on the improvement of running style would in itself improve the running performance of children.

In contrast to the controversy regarding prepubescents, there is general consensus about the aerobic trainability of adolescents (Ekblom,1969; Hamilton & Andrew,1976; Bar-Or,1989). Increases in maximal oxygen uptake and stroke volume and decreased resting heart rate due to training have been shown. As such a number of authors (Copely,1985; Mc Keag,1986; Sharkey;1990) do, however, make the valid observation that unless the training programme is correct or appropriate for a given individual regarding technique, duration, intensity and frequency, there is very little chance that optimum results will be achieved.

In this respect Mc Keag (1986) offers the following guidelines in terms of frequency, intensity and duration of exercise for developing aerobic fitness among normal healthy adolescents:

* Frequency - 3 to 5 times / week - if intensity and duration are increased, 3 times a week is reasonable.

* Intensity - Training level maintained between 60 and 90% of maximum pulse rate (estimated at 200 beats / min for adolescents, irrespective of size).

* Duration - Minimum of 15 min at a frequency of 5 times a week but preferably 30 to 60 min of continuous exercise for an optimal aerobic training effect. A longer duration with low to moderate intensity for non-competitive participation will lead to better compliance and fewer injuries.

An additional and important part of the conditioning process should be related to acquiring and practising the skills and biomechanical techniques required in facets of contact-sports (Peterson & Renstrom,1986) in which there is an increased risk of acute injury. This is particularly applicable for rugby scrummaging in which major potentially injurious forces are involved (Milburn,1990). Similarly, if proper techniques associated with repetitive cyclic movement patterns such as running and throwing are taught initially, the chance of an overuse injury could be reduced and the need to correct a faulty pattern later will be negated (Albright et al.,1978; Goldberg,1989).

On the other hand, proper pre-season and in-season physical conditioning as a preventive measure to reduce the risk of injury and to meet the competitive demands of the sport, also carries substantial weight. In particular, the role of warm-up and cool-down, together with strength and flexibility training are generally advocated.

An adequate warm-up and cool-down are commonly recommended as an integral component of any training programme. Their purported respective value is to prevent muscle strains and ligament sprains and to clear metabolic by-products from the system and reduce stiffness and delayed muscle soreness (Hermansen & Stensvold,1972; Shellock,1983; Shellock & Prentice,1985). Additionally, the effectiveness of general pre-season conditioning (Cahill & Griffith,1978; Ekstrand et al.,1983a) and specific progressive resistance training (Abbott & Kress,1969; Henja,1982) in injury prevention among high school participants has been demonstrated. The need for caution and qualified guidance in the application of the latter practice among youths should, however, also be emphasized (Vrijens,1978; Micheli,1988b).

3.3 INTRINSIC RISK FACTORS AND PROPHYLAXIS

As mentioned previously, intrinsic risk factors in sports-related injury refer to the individual physical characteristics of the participant (Lysens et al.,1984). The gathering of information that is intrinsic to the participant has been referred to as "profiling" (Sapega et al.,1978; Nicholas,1984). The broad practical benefits of sport-specific profiling have been motivated as follows:

1. The identification of physical deficiencies in the participant during both pre- and post-season screening;

2. Providing objective criteria for determining when injured participants have recovered to the extent that safe participation can be resumed as well as defining rehabilitation goals for full recovery;

3. Increasing the efficiency and efficacy of training techniques; and

4. The prospective identification of superior performance potential among sportsmen at early competitive levels.

In particular, the potential role of such assessment as a means to prevent sports-related injuries has been emphasized (Hershman,1984). This reasoning is based on the intuitive belief that many sports-related injuries are preventable if the potential intrinsic aetiological risk factors could be identified and effectively addressed through preparticipation evaluation of the individual (Goldberg et al.,1980; Mc Keag,1985). Subsequently, intrinsic risk factors will be discussed in conjunction with a central theme of this study, being the preparticipation evaluation of youths for sport and related activity.

SECTION FOUR

PREPARTICIPATION EVALUATION

4.1 OBJECTIVES

As reflected in the Sports Medicine literature, the primary established objective of the preparticipation evaluation (PPE) has traditionally been to screen for safe participation in sports-related activity by uncovering any latent life-threatening medical conditions (Linder et al.,1981; Mc Keag,1985; Marks & Fisher,1987). This motivation for the PPE has its historical origins in a "Bill of Rights for the Athlete", which was drawn up in the late 1950's by the American Medical Associations' Committee on Medical Aspects of Sports (Blazina,1989). Emanating from this bill a second goal for conducting a PPE became established, namely to satisfy subsequent legal requirements as set by various governing bodies. This in turn has led to the PPE being considered mandatory in certain areas of the USA, particularly among youth participants (Feinstein et al.,1988).

The objectives of the PPE have been debated frequently in relation to their utility and cost effectiveness. Goldberg et al.(1980), in what is considered a landmark study, showed in their evaluation of 701 pupils from three high schools, that 15% of these youths had medical problems that merited further evaluation or excluded them from participation. Subsequently two out of 701 participants were excluded from participation for medical reasons, while an additional seven had orthopaedic problems that prohibited their participation. In addressing the cost effectiveness of the PPE, Risser et al.(1985) maintained that the cost-benefit ratio was unfavorable and concluded that if cost effectiveness was to be a significant consideration, the feasibility of the PPE might come into question. In opposition, Mc Keag (1989) countered this deduction and along with others (Anderson,1987; Kibler, 1990) have more recently contended that the justification of the PPE should be based on additional and more comprehensive objectives.

Anderson (1987) and Kibler (1990) maintain that the recent advances made in Sports Medicine has led to a call for an evaluation process which is more inclusive and specific in its objectives. This would allow for maximizing both the efficiency of the procedure and the return of valuable information to the participant and the examiner.

Anderson (1987) summarizes the broader objectives of the PPE procedure as follows:

1. Reduce life-threatening or disabling injuries by identifying predisposing risk factors;

2. Recommend preparatory, preventive and/or rehabilitative measures;

3. Assist in matching participants with an appropriate activity or specialist sports event/playing position;

4. Promote the role of exercise and physical fitness in the overall health maintenance and disease prevention;

5. Initiate the participants' entry into the local Sports Medicine System or referral network; and

6. Fulfill legal obligation, if required.

While the final objective of legal fulfillment is a sincere motivation in the USA, this would not yet appear to be a relevant issue in South Africa. The fundamental aim of injury prophylaxis, however, certainly does have universal application.

4.2 CONTENT, FORMAT AND IMPLEMENTATION

The above stated objectives of the PPE have defined a framework for implementing the procedure in two parts. The first part entails a health and medical screening typically consisting of a health history questionnaire and medical examination, with the latter being conducted by a Physician. The second part of the process typically comprises an evaluation of selected health-related physical fitness parameters, preferably conducted by, or in cooperation with, an allied health professional (Murray, 1981; Allman,1989).

In this light, some have considered the PPE as a valuable opportunity to provide a full health screening (Shaffer, 1978; Micheli & Yost,1984; Beasley,1986). According to this point of view, adolescents as a group have infrequent contact with the medical care system and the examining Physician should thus take advantage of the prospective participants' visit for a comprehensive history and physical examination. Others disagree, arguing that the purpose of the PPE should be limited to specifically identify those conditions that have an influence on participation in the prospective sports-related activity (Rowland,1986; Marks & Fisher,1987; O'Brien,1991). It is evident that the second argument reflects current trends of a sport-specific approach to the medical examination and physical fitness evaluation portions of the PPE (Rowland, 1986).

As regards the particular format of the PPE, the literature reflects (Du Rant et al.,1985; Arnheim,1989) that as practiced abroad, three types of evaluations are conducted: i) the "locker room" evaluation; ii) an "office-based" evaluation; and iii) a "station" evaluation. The locker room evaluation refers to a mass evaluation, where groups of participants are examined by a team or volunteer Physician/s in a cursory manner to satisfy the legal requirements of the particular sport. The office-based evaluation involves an examination by a personal Physician in a consulting room setting. The station evaluation is similar to the locker room format in being conducted at a central venue for groups of participants, but involves a team of various specialists including Physicians, allied health professionals and sports coaches - each manning a station and evaluating those aspects which fall into their area of expertise.

The cursory locker room evaluation has fallen out of favour being decried as impersonal and superficial, because of their "line-up" format and customary sole aim of evaluating as many participants in as short a space of time in fulfillment of an imposed legal requirement (Runyan,1983; Du Rant et al.,1985). Controversy also surrounds the effectiveness of consulting-room based versus multi-station evaluations. Although the personal Physician in the office setting has the advantage of continuity and a better knowledge of the participants' past medical history, such evaluations generally vary in content and are often not sport-orientated nor directed towards the detection of sport-specific risk factors. Multi-station evaluations, on the other hand, have the expedient benefit of being more comprehensive whilst also being sport-specific in nature (Linder et al.,1981; Strong & Linder,1982). In this respect, Du Rant et al.(1985) compared history and physical examination findings during a PPE by individual consulting-room based Physicians with those of multiple evaluators with an eight-station protocol and found that greater frequencies of orthopaedic/musculoskeletal abnormalities were detected with the multi-station evaluation. Such data and other supportive recommendations has lead to increasing favour for multi-station evaluations which are specifically designed for the proposed sport or activity and make use of allied health professionals to assist in a focussed evaluation of relevant orthopaedic components and related musculoskeletal physical fitness parameters (Smilkstein ,1981; Du Rant et al.,1985; Kibler et al.,1989; Murray, 1989).

While the objectives and format of the PPE have been debated the remaining issues, which will be addressed subsequently, are: i) the identification of predisposing intrinsic risks factors for injury; and ii) the role of the health history, medical examination and musculoskeletal evaluation in the identification of these potential risk factors. In this regard Kibler (1990) maintains that the general purpose of the initial two steps of the evaluation (history and medical examination) is to delineate any "negative" information about the participant, that is, information which may be used to decrease the chance of catastrophic problems and define exclusion from or modification of participation.

4.3 HEALTH HISTORY

The health history questionnaire is considered to be the single most important screening portion in the PPE of youths (Micheli & Yost,1984; Linder,1989). In the landmark study of Goldberg et al.(1980), seven of the nine youths disqualified from participation due to medical reasons and/or orthopaedic abnormalities, were excluded on the basis of the history alone. Despite an expressed need for standardization of PPE procedures (Smilkstein,1981), a wide variety of questionnaires varying in content and length are used. Linder (1989) proposes that a possible reason for this lack in uniformity, is that most history questionnaires have been designed to meet the needs of a particular programme. Various authors (Roy & Irvin,1983; Anderson,1987) do, however, agree that the health history should focus on the following aspects:

1. Previous injuries;
2. Acute and chronic medical illness;
3. Cardiovascular disease; and
4. Previous exercise intolerance.

4.4 MEDICAL EXAMINATION

There appears to be general agreement concerning the core content and diagnostic utility of the medical examination portion of the PPE (Harvey,1982; Runyan,1983; Fields & Delaney,1990). These authors maintain that essentially a cardiovascular and orthopaedic examination should comprise the critical parts thereof. A positive response to any of the questions posed in the foregoing history and/or considerations for specific sports may, however, necessitate additional areas of examination.

The content priorities and suggested sport-specific considerations of the PPE medical examination are presented in Figures 2.8 and 2.9, respectively.

4.4.1 CARDIOVASCULAR EXAMINATION

The major thrust of the cardiovascular examination of the prospective youth participant is the discovery of conditions that might predispose to sudden death with competition (Galioto,1982). Although sudden death among the physically active population is uncommon (Drory et al.,1991), when it does occur the primary mechanism involves the cardiovascular system (Luckstead,1982; Northcote & Ballantyne,1984; Epstein & Maron,1986).

Cardiovascular Disease

According to Noakes (1991a) the major cause of sudden death in the exercising population can be identified as serious underlying cardiovascular disease. In the separate categories of young and older participants, this disease is most often identified as hypertrophic cardiomyopathy and atherosclerotic coronary artery disease, respectively (Epstein & Maron,1986). In debate of the value of preventive screening for these conditions Northcote and Ballantyne (1984) contend that a simple history and physical examination should suffice to reveal some of these

FIGURE 2.8: CONTENTS PRIORITY OF A PPE MEDICAL EXAMINATION

AREA OF EXAMINATION	ALWAYS	IF INDICATED	RARELY
Vital signs (Ht, Wt, HR, BP)	X		
General inspection	X		
Cardiovascular	X		
Orthopaedic	X		
HEENT*		X	
Respiratory		X	
Abdominal/lymphatic		X	
Skin		X	
Neurologic		X	
Genitalia			X

* HEENT - Head, Eyes, Ears, Nose, and Throat
After Anderson (1987)

FIGURE 2.9: AREAS OF EXAMINATION / SPORT-SPECIFIC EMPHASIS

SPORT	PHYSICAL EXAMINATION EMPHASIS
Football/Rugby*	Neck, head, back, shoulder, knee, ankle
Basketball	Ankle, knee
Baseball	Shoulder, elbow, arm
Swimming	Ears, nose, throat, rotator-cuff
Wrestling	Body fat, neck, shoulder, skin
Gymnastics/Ballet	Wrist, shoulder, spine, ankle, foot
Running	Back, hip, knee, ankle, foot, alignment
Soccer (goalie)	Hand, eye
Soccer (other)	Hip, pelvis, foot
Raquet sports	Wrist, elbow, shoulder, eye

After Myers & Garrick (1984); Anderson (1987) & Mc Keag (1989).
* Added by the author.

potentially serious pathologies and emphasize that expense should not negate the value of such sophisticated procedures. This is, however, a major concern for Epstein and Maron (1986) who claim that the costs of a community screening programme designed to detect all forms cardiac diseases that have the potential to cause sudden death during exercise will almost undoubtedly be prohibitive, particularly when considering the low incidence of exercise-related sudden death in young healthy individuals.

The sports-related sudden death of a participant is always viewed as a catastrophic tragedy, particulary if the victim is a child or adolescent. Such an incident typically captures the attention of the media - hence the frequency of such an event is usually falsley exaggerated. Therefore, Braden and Strong (1988) maintain that a thorough preparticipation history and physical examination of the cardiovascular system based on traditional inspection, palpation and stethoscopic auscultation can either detect the most frequent cardiac causes of exercise-related sudden death in young participants, or raise sufficient suspicion to perform more extensive assessments when indicated to be appropriate. Additional cardiovascular screening of vital signs such as blood pressure as well as pulse rate and rhythm are also considered to be of value in the PPE medical examination of youths (Blum,1985).

Blood Pressure

Since adolescents generally don’t undergo regular blood pressure determinations, Rowland (1986) contends that its not surprising that hypertension may first be detected during a PPE. Hypertension is the most significant risk factor for developing cardiovascular disease and early treatment of hypertension modifies long-term risks and lessens end organ damage (Hulse & Strong,1987). Hypertension has also been suspected of playing a role in left ventricular hypertrophy and possibly other forms of hypertrophic cardiomyopathies (Epstein & Marron,1986).

Participants with hypertension are a source of concern since the normal rise in blood pressure with exercise is exaggerated in adolescents with resting systemic hypertension. As such, dynamic aerobic activities such as running are associated with an acute isolated elevation of systolic pressure (Rowland,1990). On the other hand, regardless of age, sustained static activities such as weight lifting or heavy resistance training causes marked and sometimes prolonged elevations in both systolic and diastolic pressures. For this reason isometric type exercises have traditionally been considered to pose a greater risk for those with high blood pressure and are thus discouraged in individuals with borderline hyper-tension (Mc Keag,1985).

Weight training often forms part of the pre-season conditioning for numerous sports. A real risk thus exists in the sense that in some instances those participants already on such programmes may exhibit higher than normal blood pressure measurements (Mc Keag,1989). In practice, moderate or severe elevations in blood pressure can thus limit safe participation, but the participant with good levels of control or mild elevation may participate without restriction (American Academy of Paediatrics,1988). Moreover, as in adults, regular endurance exercise may therapeutically lower resting and exercise blood pressure in hypertensive adolescents (Hagberg et al.,1983).

Measurement of blood pressure in youths is, however, considered to be problematic. Questions frequently arise regarding the upper limits of normal blood pressure and the accuracy of measurement technique (Mitchell et al.,1975). Because blood pressure rises continually from birth to adolescence, normal upper limits cannot be arbitrarily assigned (Strong,1980). Furthermore, growing youths invariably differ in body and limb size. This poses particular equipment requirements to ensure that there is even compression of the brachial artery against the humerus during measurement (Jewell,1988). In this respect, Purcell (1985) emphasizes that when measuring blood pressure in youths the examiner should ensure that the cuff: i) comfortably encircles the girth of the arm; ii) leaves sufficient access to the antecubital space for placement of the stethoscope; and iii) the width is two-thirds or more of the arm length.

The generally accepted criterion for hypertension is a blood pressure exceeding two standard deviations above the mean for the individuals' age (Strong,1980). In this respect, exact upper-limit norms for youths tend to vary among sources but Myers and Garrick (1984) indicate that seated blood pressure values measured on the right arm are abnormal if greater than 130/80 mm Hg for ages 6-11 years, and greater than 140/90 mm Hg for 12 years and older.

Heart Rate and Rhythm

Additional cardiac evaluation of pulse rate and rhythm are also suggested to be of value in the PPE medical examination of youths (Blum,1985). It should be noted though, that bradycardia is more common among conditioned participants than in non-participants while tachycardia may be observed among some prospective participants due to anxiety (Runyan,1983). Arrhythmias among children and youths tend to be ectopic beats of atrial, junctional or ventricular origin but according to Blum (1985), these are usually benign and of no serious consequence. The same author does emphasize, however, that signs of premature ventricular contractions should be assessed further by electrocardiographic evaluation.

4.4.2 ORTHOPAEDIC EXAMINATION

During the PPE orthopaedic examination, it has been recommended by various authors that the following inter-related aspects be focussed upon:

1. Range of motion of major paired joints, particularly those which may be at risk during the intended competitive activity, and the bilateral gross strength of major muscle groups (Mc Keag,1989);

2. Careful examination of any previous injury sites to determine residual deficits (Dyment,1986);

3. Assessment of ligamentous laxity in joints, particularly the knees and ankles (Runyan,1983; Marron & Tucker,1984) ; and

4. Screening for postural musculoskeletal malalignment (Fields & Delaney,1990).

A generally accepted approach to evaluating the above factors is by carrying out an established "two-minute" orthopaedic examination proposed by the American Academy of Paediatrics and the American Orthopaedic Society for Sports Medicine as is described (Dyment,1986) in the following Figure 2.10.

FIGURE 2.10: ORTHOPAEDIC SCREENING EXAMINATION

INSTRUCTION	OBSERVATION
1. Stand facing examiner	*Acromioclavicular joints, general habitus.*
2. Look at ceiling; floor; over both shoulders; and touch ears to shoulders.	*Cervical spine motion.*
3. Shrug shoulders - (examiner resists)	*Trapezius strength.*
4. Abduct upper-arm to 90° (examiner resists @ 90°)	*Deltoid strength.*
5. Full external rotation of arms	*Shoulder motion.*
6. Flex and extend elbows	*Elbow motion.*
7. Arms at sides, elbows flexed to 90°; pronate and supinate wrists	*Elbow and wrist motion.*
8. Spread fingers; make a fist	*Hand or finger motion and deformities.*
9. Tighten (contract) quads; relax quadriceps	*Symmetry, knee and ankle effusion.*
10. "Duck walk" four steps (away from examiner)	*Hip, knee and ankle motion.*
11. Back to examiner	*Shoulder symmetry; scoliosis.*
12. Knees straight, touch toes	*Scoliosis, hip motion, hamstring tightness.*
13. Raise the toes and then raise heels	*Calf symmetry, leg length.*

After Dyment (1986)

A more detailed general description, as provided by Harvey (1982), of the instructions and salient features reflecting any significant and readily apparent problems when conducting this "two-minute" orthopaedic screening follows. In conducting the examination, the subject is minimally clothed and stands facing the examiner who, if necessary to facilitate the understanding of the instructions, demonstrates and/or calls out the commands.

Instruction 1.

The subject stands erect with arms at the sides. The examiner looks for symmetry of the upper and lower extremities and trunk. Common abnormalities include enlarged acromioclavicular and/or sternoclavicular joints, asymmetrical hips (leg length difference or scoliosis), swollen knees and ankles.

Instruction 2.

The subject is told to look at the ceiling; look at the floor; touch the right (left) ear to shoulder; look over the right (left) shoulder. The subject should be able to touch the chin to the chest, ears to the shoulders and look equally over shoulders. Common abnormalities, which may indicate previous neck injury, may include loss of flexion, loss of lateral flexion or a loss of rotation.

Instruction 3.

The subject shrugs the shoulders while the examiner holds them down. The trapezius muscle should appear symmetrical and the left and right sides should be of equal strength. Common abnormalities, which may indicate a neck or shoulder problem, include loss of strength or loss of muscle bulk.

Instruction 4.

The subject lifts the arms horizontally from the sides while the examiner holds them down. Strength should be equal and the deltoid muscles should be equal in size. Common abnormalities are loss of strength or wasting of the deltoid muscle.

Instruction 5.

The subject holds the arms out horizontally from the sides with the elbows bent at 90 degrees, then raises the hands back vertically as far as they will go. The hands should go back equally and at least to the upright vertical position. A common abnormality, which may indicate a shoulder problem or old dislocation, is a loss of external rotation.

Instruction 6.

The subject holds the arms out from the sides, palms up, then straightens elbows completely and bends elbows completely. Motion should be equal on the left and right. Common abnormalities, which may indicate an elbow injury, old dislocation or fracture, include loss of extension or loss of flexion.

Instruction 7.

The subject holds the arms down at the sides with the elbows bent to 90 degrees; the palms are supinated then pronated. The palms should go from facing the ceiling to facing the floor. Common abnormalities, which may indicate an old forearm, wrist or elbow injury, are lack of full supination or lack of full pronation.

Instruction 8.

The subject makes a fist, then opens the hands and spreads the fingers. The fist should be tight and the fingers straight when spread. Common abnormalities, which may indicate old finger fractures or sprains, may include a knuckle protruding from the fist or a swollen or crooked finger.

Instruction 9.

The subject contracts and relaxes the quadriceps while the examiner observes any sign of atrophy.

Instruction 10.

The subject squats on the heels, "duck walks" four steps, then stands up. The maneuver should be painless, heel-to-buttock distance should be equal on the right and left, knee flexion should be equal during walking and the subject should rise without undue effort. Common abnormalities include an inability to flex one knee or an inability to stand up without twisting or bending to one side.

Instruction 11.

The subject stands erect with back to the examiner. The observer looks for symmetry of the shoulders, waist, thighs and calves. Common abnormalities are a high shoulder (scoliosis) or low shoulder (muscle loss); prominent rib cage (scoliosis); high hip or asymmetrical waist (leg length difference or scoliosis); or a small calf or thigh girth (weakness from an old injury).

Instruction 12.

The subject bends forward slowly as to touch the toes. The bending should be straight and smooth. Common abnormalities are twisting to one side (low back pain) or asymmetrical back (scoliosis).

Instruction 13.

The subject stands on the heels and then on the toes. The examiner looks for equal elevation on the right and left and symmetry of calf muscles. A common abnormality is the wasting of calf muscles, which indicates an Achilles tendon injury or an old ankle injury.

4.4.3 ADDITIONAL AREAS OF EXAMINATION

As stated previously, a cardiovascular and orthopaedic examination should essentially comprise the critical parts of the PPE medical examination of youths (Harvey,1982; Runyan,1983; Fields & Delaney,1990). A positive response to any of the questions posed in the foregoing history, and/or considerations for specific sports may, however, necessitate additional areas of examination. The following are considered applicable in this respect.

Physical Maturity

A characteristic of the adolescent population is the variation in normal physical development. At any given chronological age during the teenage years a wide range of physiological maturation is represented, from prepubescent to full maturity. Because participation in contact/ collision sports in particular, may entail a risk for immature individuals in relation to their more physically developed peers of the same age, an assessment of physical maturity is considered to be of value in the PPE medical examination of youths (Blum,1985; Rowland,1986; Mc Keag, 1989; Fields & Delaney,1990).

The most authentic method of assessing maturation is by skeletal radiography, where an x-ray of the left hand is compared to standards established in the Greulich-Pyle (1959) radiographic atlas (Haywood,1986). The most practical method of determining physical maturation is by making use of sexual maturity ratings as originally proposed by Tanner (1962). Such Tanner staging assesses breast development and pubic hair growth in girls and genital development and pubic hair growth in boys. On the other hand, Myers and Garrick (1984) argue that physical maturation assessment by means of evaluating sexual development adds an unnecessary and embarrassing dimension to the PPE medical examination. In sympathy with the last mentioned sentiment Allman (1989) suggests retaining the Tanner classification for boys but assessing the axilla (Appendix D) rather than the pubic area as related to hair growth. Similarly Roy and Irvin (1983) suggest an alternative method for girls, based on a system of evaluating sexual maturity in relation to the time lapsed since first menarche.

Mc Keag (1989) further makes the point that in observing an unusual variation in height or weight or unnatural deviation from normal physiologic maturity, the examiner may be directed to suspect hormonal imbalance possibly associated with the prevalent ingestion of anabolic ergogenic aids for increased muscular strength and power.

Neurologic Disease

An individual with a seizure disorder or previous concussion should generally be identified by the health history. In this respect Marron and Tucker (1984) maintain that persons with poorly controlled seizure disorders (defining good control as a period of one year free of any form of seizure) should be limited to low risk recreational activity. The American Academy of Paediatrics (1983) recommends that given proper medical management, good seizure control and adequate supervision, the youth with epilepsy should be allowed to participate in all forms of sport activity, including contact sports. In the same light Rowland (1986) contends that fears of trauma-induced convulsions or seizures from hyper-ventilation have not proven to be a realistic problem and the general contention is that the risk of injury from recurrence of seizures is often outweighed by the advantages of leading a normal life.

An alternative recurrent neurological problem, namely that of concussion does, however, require serious consideration in the PPE medical examination. Since the effects of repeated head trauma are accumulative, the individual who has suffered multiple concussions should be restricted to some extent. The general consensus is that three or more second to third degree concussions should exclude the candidate from contact sports, including boxing and martial arts (Marron & Tucker,1984). As a further guide Cantu (1986), has compiled a method of classifying and determining readiness for return to contact sports following cerebral concussion (Figure 2.11).

Chronic Disease

According to Strong (1980) major progress has been made in understanding the mechanisms that limit exercise in youths with chronic diseases such as asthma and diabetes mellitus. As a result therapeutic measures based on this information should allow most of these individuals to participate fully. Neither should the respective prophylactic use of bronchodilators nor manipulation of diet and insulin dose prior to exercise, preclude competitive performance (Murray ,1981; Spack,1984; Rowland,1986).

FIGURE 2.11: CONCUSSION CLASSIFICATION AND GUIDELINES

GRADE	1st EVENT	2nd EVENT	3rd EVENT
1. MILD (No LOC; PTA < 30 min)	RTP if ASYM for 1 wk	RTP in 2 wks ASYM for 1 wk	Terminate season; RTP next season if ASYM
2. MODERATE (LOC < 5 min; PTA > 30 min)	RTP if ASYM for 1 wk	Rest min. of 1 month; RTP if ASYM; consider terminating season	Terminate season; RTP next season if ASYM
3. SEVERE (LOC > 5 min; PTA > 24 hrs)	Rest min. of 1 month; RTP if ASYM for 1 wk	Terminate season; RTP next season if ASYM	

KEY: LOC = Loss of consciousness
PTA = Post-traumatic amnesia
RTP = Return to play
ASYM = Asymptomatic (no headache; dizziness, or impaired orientation, concentration; or memory during rest or exertion)

After Cantu (1986)

Dermatologic Disease

Skin infections are easily transmittable in crowded changing rooms and among adolescents who may be disinclined toward frequent laundering of exercise clothing (Rowland,1986). Early detection of these conditions, particularly herpes (Blum,1985), during the PPE medical examination are important for contact sports such as wrestling and rugby (Anderson,1987) - where body and skin contact is characteristic of the activity.

Paired Organs

The presence of only one of paired organs, particularly of the genitourinary system (genital and urinary organs) wether congenital or surgical, is an important consideration in the PPE medical examination. The absence of a kidney or testicle will usually be apparent from the medical history (Marron & Tucker,1984). Traditionally these individuals have been restricted from contact sports because of the risk of traumatic damage to the remaining organ. In addition Dyment (1986) and Mc Keag (1989) make the link to assessing maturity whilst evaluating the integrity of the testes.

Further consideration of the eyes as paired organs and evaluation of defective vision is also encouraged (Blum,1985; Rowland,1986). For individuals with unilateral vision the risk of participating in contact sport may be far in excess of the benefits. Visual acuity can also be assessed rapidly and easily with a Snellen chart. Vision less than 20/40 in either eye while wearing glasses should prompt referral to an ophthalmologist before approving participation.

Abdominal Organmegaly

The unprotected abdominal viscera are generally vulnerable to trauma. Screening for and the detection of organmegaly or abnormal enlargement of the liver or spleen during the PPE medical examination may thus expose an absolute contra-indication to participation in both endurance and contact sports (Marron & Tucker,1984; Rowland,1986; Mc Keag,1989). In addition Dyment (1986) emphasizes the simultaneous examination for the presence of inguinal hernias.

Dental Screening

Allman (1989) motivates that dental evaluation should be part of the PPE. Involving a dentist may also be helpful in making arrangements for emergency dental treatment and the provision of mouth protectors as generally required in contact sports.

4.4.4 DISPOSITION AFTER EXAMINATION

In the final instance, Garrick and Myers (1984) emphasize that the PPE medical examination should not consist of, nor replace, a routine annual medical examination, but should be focussed and sport-specific in nature. Following a review of the health history and completion of the PPE medical examination, the examiner is typically required to assess the individuals risk for participation and thus determine the disposition (Fields & Delaney,1990). In this respect a decision must be made along the following lines or options available:

1. No participation;
2. Limited participation - only in specified activities;

3. Clearance withheld - subject to further evaluation or rehabilitation; or
4. Unlimited participation.

In making such a decision, Harvey (1982) reiterates the generally held opinion that the goal of the PPE medical examination per se, is not to disqualify youths from participating but to ensure that individuals are medically fit for the sports-related activity in which they wish to take part. Should this not be the case, participants should be directed to other more suitable activities.

The most widely used guidelines in deciding upon the disposition of an individual after the PPE medical examination are those of the American Medical Association which were initially proposed in 1966 and subsequently updated in 1976 (Dyment,1986). These guidelines have since been redeveloped for current use as published by the American Academy for Paediatrics (1988) Committee on Sports Medicine (Figure 2.12). These guidelines are interpreted in conjunction with their sports classification system (Figure 2.6).

The foregoing section has essentially reviewed the role of the Physician in examining medical or pathologic conditions that may comprise intrinsic risk factors for sports-related injury among youths. Henceforth, those aspects of the PPE which may be conducted in conjunction with the expertise of allied professionals such as a Biokineticist, Human Movement Scientist, Physical Educator or trained sports coach are discussed. In this respect, the evaluation of morphological status and variables of musculoskeletal function which may be considered intrinsic risk factors, are reviewed under the heading of musculoskeletal evaluation.

FIGURE 2.6: CLASSIFICATION OF SPORTS ACTIVITIES

CONTACT		**NON-CONTACT**		
	Limited Contact		**Moderately**	**Non-**
Collision	**Impact**	**Strenuous**	**Strenuous**	**Strenuous**
Boxing	Baseball	Aerobics	Badminton	Archery
Field hockey	Basketball	Discus	Tabletennis	Golf
Ice hockey	Bicycling	Fencing		Riflery
Martial arts	Cricket*	Javelin		
Rugby*	Diving	Rowing		
Soccer	Equestry	Running		
Wrestling	Gymnastics	- Cross country		
	High jump	- Road		
	Pole vault	Shot put		
	Skating	Swimming		
	- Ice	Tennis		
	- Roller	Track events		
	Skiing	Weight lifting		
	- Downhill	Waterpolo		
	- Water			
	Softball			
	Squash			
	Volleyball			

After the American Academy of Paediatrics (1988), Committee on Sports Medicine. * Added by the author.

FIGURE 2.12: RECOMMENDATIONS FOR PARTICIPATION IN COMPETITIVE SPORTS

CONDITION	CONTACT		NON-CONTACT		
	CC	LCI	STR	MSTR	NSTR
ATLANTOAXIAL INSTABILITY	N	N	Y*	Y	Y
* Swimming - no butterfly, breast stroke or diving starts					
ACUTE ILLNESS	*	*	*	*	*
* Needs individual assessment					
ACQUIRED IMMUNODEFICIENCY SYNDROME	*	*	Y	Y	Y
* Private decision between the player and his physician.[1]					
CARDIOVASCULAR					
Carditis	N	N	N	N	N
Hypertension : Mild	Y	Y	Y	Y	Y
Moderate	*	*	*	*	*
Severe	*	*	*	*	*
Congenital heart disease	+	+	+	+	+
* Needs individual assessment					
+ Patients with mild forms can be allowed a full range of physical activities; patients with moderate or severe forms, or who are post-operative, should be evaluated by a cardiologist before participation.					
EYES					
Absence or loss of function in one eye	*	*	*	*	*
Detached retina	+	+	+	+	+
* Approved eye guards may allow participation in most sports, but must be judged on an individual basis.					
+ Consult ophthalmologist					
INGUINAL HERNIA	Y	Y	Y	Y	Y
KIDNEY : ABSENCE OF ONE	N	Y	Y	Y	Y
LIVER : ENLARGED	N	N	Y	Y	Y

[1] After the American Academy of Paediatrics (1991), Committee on Sports Medicine and Fitness

FIGURE: 2.12 CONTINUED

CONDITION	CONTACT		NON-CONTACT		
	CC	LCI	STR	MSTR	NSTR
ORTHOPAEDIC DISORDERS	*	*	*	*	*
* Needs individual assessment					
NEUROLOGIC					
History of serious head or spine trauma, repeated concussions or craniotomy	*	*	Y	Y	Y
Convulsive disorder: Controlled	Y	Y	Y	Y	Y
Uncontrolled	N	N	Y+	Y	Y++
* Needs individual assessment + No swimming or weightlifting ++ No archery or riflery					
OVARY : ABSENCE OF ONE	Y	Y	Y	Y	Y
RESPIRATORY					
Pulmonary insufficiency	*	*	*	*	Y
Asthma	Y	Y	Y	Y	Y
* May be allowed to compete if oxygenation remains satisfactory during a graded stress test					
SICKLE CELL TRAIT	Y	Y	Y	Y	Y
SKIN					
Boils, herpes, impetigo, scabies	*	*	Y	Y	Y
* No gymnastics with mats, martial arts, wrestling, or contact sports until not contagious					
SPLEEN : ENLARGED	N	N	N	Y	Y
TESTICLE : ABSENCE OR UNDESCENDED	Y*	Y*	Y	Y	Y
* Certain sports may require protective cup					

KEY : CC = Contact/collision LCI = Limited contact/impact
STR = Strenuous MSTR = Moderately strenuous
NSTR = Non - strenuous Y = Yes N = No

After the American Academy of Paediatrics (1988), Committee on Sports Medicine.

4.5 MUSCULOSKELETAL EVALUATION

A number of authors have indicated various morphological components and variables of musculoskeletal function intrinsic to the individual that are thought to be risks for sports-related injury (Lysens et al.,1984; Renstrom & Johnson, 1985; Lysens,1987; Lysholm & Wiklander,1987; Brown,1988; Jones et al.,1988; Lorenzton,1988; Arnheim, 1989; Moskwa & Nicholas,1989). Potential intrinsic risk factors for sports-related injury are summarized in Figure 2.13.

In developing a PPE musculoskeletal profile, Nicholas (1984) emphasizes that the content thereof should embrace the specificity principle. This implies that essentially two components should be integrated in compiling an appropriate musculoskeletal evaluation profile, namely: i) the performance demands of the specific activity; and ii) the risk factors for injury - as derived from epidemiological studies of the particular sport together with conditions generally suspected of predisposing an individual to injury (Hershman,1984). The decision of which variables to evaluate is thus based on what typically happens in the particular sports-related activity (Anderson,1987).

In this regard, Figure 2.13 reflects those morphological components and musculoskeletal variables generally thought to contribute to injury in the majority of sports-related activities. Figure 2.14 additionally summarizes various forms of anatomical malalignment and anomalies altering the normal biomechanics of the lower extremity and thus predisposing to overuse injury during strenuous and stereotypical non-contact sport such as running (James et al.,1978; Smart et al.,1980; Clement et al.,1981; Stanish, 1984; Renstrom & Johnson,1985). It should be noted,

FIGURE 2.13: POTENTIAL INTRINSIC MORPHOLOGICAL AND MUSCULO-SKELETAL RISK FACTORS IN SPORTS-RELATED INJURY

* Stature	* Strength
* Mass	* Endurance
* Body Composition	* Power
* Somatotype	* Agility
* Physical Maturation	* Flexibility
* Previous Injury	* Lower-leg Malalignment [1]

[1] cf Figure 2.14 below.

FIGURE 2.14: LOWER-LIMB ANATOMICAL MALALIGNMENT/ANOMALIES AS INTRINSIC RISK FACTORS FOR OVERUSE INJURY

Hyper-pronation (subtalar eversion)
Hyper-supination (subtalar inversion)

Pes planus (flat foot - low medial longitudinal arch)
Pes cavus (clunk foot - high medial longitudinal arch)

Fore-foot varus [1] (metatarsal-plane inversion)
Fore-foot valgus [2] (metatarsal-plane eversion)

Hind-foot varus (calcaneal inversion)
Hind-foot valgus (calcaneal eversion)

Genu varus (bowed legs)
Genu valgus (knocked knees - "Q" angle > 20 degrees) [3]
Genu recurvatum (hyperextended knees)

Tibia vara (heel and lower-leg inversion)

Patella alta (high-riding patellas)
Patella squinting (medially-facing patellas)

Femoral anteversion (anteromedial rotation of femoral neck)

Leg-length variation (and/or pelvic tilt; lumbar scoliosis)

After Lorenzton (1988); [1] varus = outward angulation away from midline; [2] valgus = inward angulation toward midline; [3] Q-angle = angle formed by the intersection of a line from the superior illiac spine to another at mid - patella drawn perpendicular from the tibial tubercle.

however, that although these general (Figure 2.13) and overuse-specific (Figure 2.14) potential intrinsic musculoskeletal risk factors for injury are based on various plausible hypotheses, in many cases, controlled substantiating and supportive research evidence is still absent (Lorenzton,1988; Schwellnus,1991).

As this study is primarily directed towards strenuous contact sport, the ensuing review is aimed at emphasizing those aspects of morphological status and musculoskeletal function that would appear applicable to schoolboy rugby players. As such, a particularly applicable point of departure, as indicated by Hershman (1984), would be an analysis of the nature and demands of the game. In this regard Gordon (1987) points out that rugby is not a single continuous endurance event but that a match may consist of an average of 140 sequences of action giving rise to a playing time of only 34% of the total duration of a match. In expanding on this view, Docherty et al.(1988) conducted a time-motion analysis related to the physiological demands of the game. They found that the total match-time was spent as follows: i) 38% - standing; ii) 47% - low intensity activity of walking and jogging; and iii) 15% - intense activity, of which 9% was non-running activity in tackling, pushing and competing for the ball with the remaining 6% comprising intense running and sprinting.

As such, among both youths and adults participating in characteristically dynamic and contact team activities involving jumping, tackling, kicking and sprinting etc., injuries to muscles typically take the form of contusions and strains of the thigh, while skeletal trauma predominates as joint injury, typically comprising ligamentous sprains of the knee (Di Stefano,1982; Bulstrode,1989; Garret,1990). With particular reference to rugby, Clark et al.(1990) indicate that a number of overseas studies (Weightman & Browne,1974; Durkin,1977; Davies & Gibson,1978) have consistently shown little variation between schoolboys and adults with regard to relative frequency and anatomical site of musculoskeletal injury. Similarly, a general epidemiological tendency of a predominance of muscular and ligamentous injury to the lower extremities has also been documented locally (Nathan et al.,1983; Roux et al.,1987; Malan & Strydom,1987; Clark et al.,1990; Van Heerden,1991). These findings emphasize the primary need for a functional morphology and an optimal musculoskeletal base for the prevention of potential musculoskeletal injuries.

4.5.1 MORPHOLOGICAL STATUS

The association between human morphology and injury has not been given as much attention in the literature as has the relationship between morphology and sports performance. Allman (1989) asserts that the PPE of youths should not neglect this aspect. In his opinion, the evaluation of structural anthropometric variables such as the stature/ mass relationship, body composition and somatotype can yield important information on an individuals' physical preparedness and suitability for sports participation.

Somatotype and Injury Risk

Identified with age, height and weight, the somatotype of an individual provides the best single description for the classification of human shape or external somatic appearance. Somatotyping, as originally developed by Sheldon and subsequently refined by Heath and Carter (1967), is a valuable tool for classifying variations in human physique according to a three-component rating indicating the relative dominance of the following:

* Endomorphy - relative adiposity;
* Mesomorphy - relative musculoskeletal robustness; and
* Ectomorphy - relative linearity or "stretched-outness".

From the perspective of somatotype being a potential intrinsic risk factor for sports-related injury, Ross et al.(1988) suggest that due to the variety in human physique, some activities and sports are more suited to some individuals than to others. The same authors further contend that, regardless of the age of the individual or level of commitment to any sports-related activity, there are structural constraints which may affect performance or relate to health and well-being. Allman (1989) argues that an individuals' physique reflects physical fitness from the perspective of both heredity and existing physical condition.

Although data is inconclusive, variations in general body build and injury among youths have been associated. In American youth football, Goldberg et al.(1984) found that heavier players have an increased rate of injury. Another report pertaining to high school football players (Brooks & Young,1976), suggested that individuals with long, thin necks and relatively weak musculature should be actively discouraged from participating in the sport, particularly in defensive positions. With reference to youths participating in rugby, as a comparable form of collision sport holding risks for neck injury, similar sentiments have been raised (Noble,1988; Noakes,1990). In commenting on the issue of safety and the correct positional selection of young rugby players, Noble (1988) maintains that in addition to reporting any previous neck injury or congenital abnormality, players should be of suitable build and adequately prepared for the position for which they are selected. He expresses the opinion that a player should, for example, not be put into the front row of the scrum untrained and with "a neck like a chicken", evidently referring to an individual with a dominant ectomorphic physique. In the same light, Noakes (1990) has voiced concern for rugby injuries among youths in general and for catastrophic spinal injuries in particular. In terms of the relationship between somatotype and injury in rugby, Noakes (1990) shares the opinion of Ross et al. (1988), that certain physiques are more suited for a particular sports, by arguing that it is irresponsible to compel a thin, linear ectomorphic schoolboy to play the game of rugby.

Notably, however, a study by Reilly and Hardiker (1981), relating somatotype to injuries in adult student rugby players, did not indicate any significant correlation between individual components of somatotype and injury incidences. In critical appraisal of the previous opinions referring to American football, Runyan (1983) concedes that while limited range of motion and small muscle bulk in the neck should provoke concern, he points out that there are no definite reports that addressed the empiric prediction of neck injury from physical evaluation findings. In addition the same author adds that epidemiological surveys suggest that more senior football players have a higher incidence of neck injury despite a more robust physique associated with maturation. This latter tendency has also been reported for the South African situation by Kew et al. (1991), in their retrospective study of catastrophic spinal injuries to rugby players.

From another perspective, one study has reported the influence of a specific somatotype on injury in womens gymnastics. Steel and White (1986) were able to predict with 79% accuracy a "low risk status" by assessing the age, weight, mesomorphy and standing lumbar curvature of individual female gymnasts.

Somatotype Assessment

Several systems of somatotyping have been proposed in the past (Sheldon et al.,1940; Cureton,1947; Parnell,1954; Heath & Carter,1967). Sheldon is credited with the original conceptualization of the three component somatotype classification system with the publication of the photographic atlas entitled - *The Varieties of Human Physique*. In contemporary somatotype appraisal and guidance, however, the refined Heath-Carter method is used most extensively, primarily due to its versatility.

As such, the Heath-Carter method provides for three approaches to obtaining a somatotype namely, the anthropometric, photoscopic and anthroposcopic technique (Carter,1990). The direct measurement-based anthropometric somatotyping technique is widely used in the research laboratory setting, often in conjunction with available micro-computer technology and software programmes being utilized for derivation plotting and analyses. Alternatively, the anthroposcopic estimate, based on the subjective visual inspection of the body, is a useful quick method of assessing an individuals' somatotype and may thus serve as an appropriate field method of screening in the PPE of participants (Allman,1989).

Body Composition and Injury Risk

In its simplest form body composition analysis divides the body mass into fat mass and lean body mass (LBM). The amount of fat has relevance to both general health and sports performance. Thus, body composition assessment has become an important component in the comprehensive evaluation of health and fitness. It is well recognized (Boileau & Lohman,1977), that physical performance can be strongly influenced by the relative amounts of fat and fat-free components of body composition in both the adult and young participant.

Roy and Irvin (1983) suggest that there are essentially no sports-related activities in which a large amount of subcutaneous fat is an advantage and that activities where a large body mass is of benefit in the application of force against external objects, such body mass should preferably be in the form of lean muscle mass as opposed to fat. In support of this view Boileau et al.(1988), contend that past research has shown that tasks requiring either vertical or horizontal translocation of body weight are generally performed poorly by overweight and obese individuals.

Although it is conceded that an ideal relative body fat percentage for performance in various sports-related activities is an individualized matter, depending on both the participant and the sport, Eisenman and Johnson (1982) provide some guidelines for youths (Figure 2.15) and Wilmore (1983) for adults (Figure 2.16). Within the context of South African youth sport, similar reference values are not readily available. A comparison of schoolboy rugby players with these values for American football as a corresponding contact sport may be an alternative. It should be noted, however, that successful and safe participation and related body composition values may not necessarily be synonymous.

FIGURE 2.15: IDEAL PERCENT FAT VALUES FOR YOUTHS IN VARIOUS SPORT-RELATED ACTIVITIES

SPORT	MALES	FEMALES
Baseball & Softball	8 - 10 %	10 - 12 %
Basketball	7 - 9 %	7 - 11 %
Distance running	5 - 7 %	5 - 9 %
Sprinters	6 - 10 %	7 - 11 %
Field events	10 - 14 %	10 - 16 %
Football		
Defensive back	6 - 8 %	
Offensive back	6 - 8 %	
Linebacker	13 - 15 %	
Offensive lineman	13 - 15 %	
Defensive lineman	13 - 15 %	
Tight ends	13 - 15 %	
Gymnastics	5 - 7 %	5 - 10 %
Soccer & Field hockey	7 - 9 %	7 - 11 %
Swimming	6 - 10 %	6 - 12 %
Volleyball	7 - 9 %	7 - 11 %
Wrestling	5 - 7 %	7 - 9 %

After Eisenman and Johnson (1982)

FIGURE 2.16: IDEAL BODY FAT VALUES FOR ADULTS IN VARIOUS SPORT-RELATED ACTIVITIES [1]

SPORT	MALES	FEMALES
Baseball	11 - 14 %	-
Basketball	7 - 11 %	20 - 27 %
Canoeing	12 %	-
Football	9 - 19 %	-
Gymnastics	5 %	9 - 24 %
Pentathlon	-	11 %
Rugby [2]	9 - 15 %	-
Soccer	10 %	-
Swimming	5 - 9 %	14 - 26 %
Tennis	15 %	20 %
Track Events	4 - 16 %	15 - 20 %
Field Events	16 - 19 %	20 - 28 %
Volleyball	-	21 - 25 %
Wrestling	4 - 14 %	-

Values are the range of means published in the literature:
[1] Wilmore (1983); [2] Van der Walt & Oosthuizen (1980); Lübbert et al.(1984) and Barnard & Coetzee (1991).

From a health perspective, body fat evaluation as part of the PPE of youths conforms to one of the essential objectives of the procedure namely, the promotion of exercise and physical fitness in overall health maintenance and disease prevention. As such, obesity - defined as the presence of excessive body fat (Kirkendall et al.,1987), is considered an undesirable state of body composition. A related problem is determining the cut-off point for obesity in individuals of different body types and various ages. This is not only problematic in adults where a number of variations exist in the literature regarding criterias of obesity but probably more so for youths due to constant growth-related variations in body composition (Rowland, 1990). Under normal conditions relative body fat remains fairly constant at between 15 and 20% during early childhood for both boys and girls and with the advent of adolescent sexual maturation, body fat increases in girls to between 20 and 25% and decreases in boys to between 10 and 15% (Goldberg & Boiardo,1984). Significant variation from these general norms may be indicative of obesity although Goldberg and Boiardo (1984) and Rowland (1990) respectively specify a relative body fat greater than 20% for adolescent boys and greater than 25% for adolescent girls as being indicative of obesity.

Although the degree of obesity among the South African youth is not clear, it must be emphasized that childhood obesity has been established as a significant risk factor in such entities as coronary artery disease, hypertension and diabetes (Rowland,1990). During an appropriate mode of sports-participation, youths have the opportunity to exercise and when combined with proper dietary intervention, the potential for required weight reduction is established (Goldberg & Boiardo,1984).

The possibility of being overweight as a result of excessive body fat and thus being susceptible for specific sports-related injury may be plausible. Such a situation may be a risk factor for injury by causing greater physiologic and biomechanical stress during weight-bearing exercise (Jones et al.,1988). As such, Murray (1989) contends that young participants who have been overweight or who have weak musculature may be at risk during contact/collision sports, especially those requiring movement against resistance. Montoye (1978) highlights the associated problem of poor agility and hence greater proneness to injury. Additionally Hershman (1984), maintains that an obvious problem encountered is that an overweight individual will impart more force across a joint and thus be more likely to abnormally load a musculoskeletal structure.

In the same light it may be mentioned that two authors (Gelberman et al.,1986; Galbraith et al.,1987) have noted an association among youths between obesity, together with decreased femoral anteversion, and slippage of the capital femoral epiphysis. They did not infer causality but agreed that in heavier individuals the capital femoral epiphysis may be more likely to slip because the forces generated across the hip joint increase proportionally as body weight increases.

On the other end of the spectrum, an assessment of body composition has become useful in evaluating individuals in whom there is an excessive weight reduction related to those activities in which a minimal body fat is desirable. Consequently there is growing concern about participants who become too lean, particularly for two reasons (Wilmore,1988a). Firstly, once weight drops below a certain critical level, generally recognized to be between 2 - 5% and 12 - 14% "essential" body fat for adult reference males and females respectively, performance and health, including normal growth and maturation of young participants, could be compromised. Secondly, eating and/or weight disorders such as bulimia and anorexia nervosa may develop (Wilmore,1988a). Among male youths, an example of the above problem that has raised serious concern in the USA is the practice of "making weight" as seen in the sport of competitive high school wrestling (Boileau et al.,1988; Thorland et al.,1991). In this respect the ACSM has recommended that pre-season assessment of body composition be used to determine an appropriate minimal wrestling weight and that medical clearance be obtained for any individual whose relative body fat is below 5% (Thorland et al.,1991).

Alternatively, excess weight reduction and/or eating disorders such as bulimia and anorexia nervosa may be particularly prevalent during female adolescence, when a preoccupation with low body weight is fairly common. Furthermore, among female participants, secondary amenorrhea - where normal menstrual cycles suddenly cease for intervals of three months or longer, and oligomenorrhea - where menses are infrequent, are possible consequences of low body weight and body fat (Shangold,1985; Wilmore, 1988b). In young female participants an associated condition is that of delayed menarche (Wilmore,1988b; Dyment,1989).

Secondary amenorrhea in distance runners has been closely linked to serious bone mineral disturbances such as osteoporosis (Drinkwater et al.,1984). This phenomenon has also been recognized in ballet dancers, swimmers, cyclists, divers and gymnasts (Wilmore,1988b). It has been suggested, although not generally accepted, that a level of 17% body fat among females is necessary for menarche and that 22% is necessary to maintain normal menstrual function (Wilmore, 1988b). This may, however, be refuted by the observation that many active females who are below 17% body fat still have normal menstrual cycles whilst maintaining a high level of physiologic and performance capacity (Mc Ardle et al.,1986). With respect to the above mentioned problems and dangers, Sharp (1986) suggests that female participants in their teenage years to early twenties should maintain a "reasonable" body fat level of at least 18%.

Body Composition Assessment

The two-compartment model of body composition viz. fat and fat-free body weight - the latter consisting collectively of muscle, bone and vital organs, provides the basis for various current methods of body composition assessment. Because the direct analysis of body composition is restricted to cadaver dissection, all practically viable methods of assessment are necessarily defined as indirect prediction techniques.

Densitometry

Of all the methods of estimating body composition in vivo, underwater weighing is generally accepted as the "gold standard". Methodically (Brooks & Fahey,1984), the body density (D) of an individual is determined hydrostatically using the Archimedes principle (Density = Mass/ Volume; Volume = weight in air - weight in water) making appropriate corrections for entrapped air and water temperature. This value may then be converted to an estimate of percentage body fat by using either of two formulas, based on known constant values (as derived from original cadaver analyses) for fat (0,90 g/ml) and lean tissue (1,10 g/ml) densities: viz. % fat = (4,950/D - 4,500) x 100 (Siri,1956) or % fat = (4,570/D - 4,142) x 100 (Brozek et al.,1963).

In more recent literature a critical analysis has led to some concern being expressed with regard to the validity of the densitometric approach to the evaluation of body composition. Ross et al.(1988) argue that the implicit two-compartemental - constant density assumption, with the fat compartment having a density of 0,90 g/ml and the lean body mass a density of 1,10 g/ml, may be prone to error. While they concede that the density of human body fat is relatively constant within and among individuals regardless of age or gender, they do take issue with the assumption of a constant density of the LBM for individual assessment. As such, for this to be true, they contend that one would expect two conditions to be true as well: i) that the constituent tissues of bone, muscle and organs are in fixed proportions; and ii) that each of these constituent tissues have constant densities.

As regards the first condition, Ross et al. (1988) maintain that more recent cadaver analyses (Martin et al.,1986) showed otherwise, with dissected proportions of muscle ranging from 41,9 - 59,4%, bone from 16,3 - 25,7% and the remainder from 24,0 - 32,4%. The second condition of assumed constant densities of the constituent tissues of the LBM, was also refuted by the cadaver evidence. Considering the above deviations from the usual assumptions made, it has been estimated that a 2% variation in the LBM density of 1,10 g/ml may exist (Ross et al.,1988).

In addition to the above illustration of inconstant proportions and densities of the constituent tissues of the LBM, Lohman et al.(1984;1986) and Boileau et al.(1988) have also highlighted that the LBM density may vary from and is less than the assumed constant of 1,10 g/ml among both older and younger populations. This variation, primarily in bone mineral and total body water content among these groups, is ascribed to the osteoporosis process in the aging and to skeletal growth in the young. These authors

(Lohman et al.,1984;1986; Boileau et al.,1988) emphasize that fundamental changes are taking place in the LBM density of the growing youth and that this chemical immaturity can be related to a decreasing LBM water content and increasing LBM bone mineral content. The conceptual basis of standard densitometric computations of using total body density to estimate relative body fat via the Siri or Brozek equations, may thus lead to an overestimation of relative body fat in these populations. Within context, this view constitutes an important factor to consider when studying the principles of body composition assessment in the child and adolescent.

Notwithstanding the foregoing critical appraisal, Golding et al.(1989) are of the opinion that an estimated 2,5% potential error associated with underwater weighing, can be considered minimal, and this approach thus remains the gold standard for estimating body fat. This technique thus remains the prime choice employed for research in numerous laboratory settings.

Anthropometric Fractionation of Body Mass

Early research into body composition conducted by Matiegka (1921) differed from the above described two-compartemental approach. He proposed a method for the anthropometric fractionation of body mass into four main components, viz.: skeletal mass; fat mass; muscle mass; and a residual vital organ/visceral mass. This technique required that three types of anthropometric measurements be made, viz.: skeletal diameters; girth circumferences; and skinfolds and that these values be substituted into four appropriate formulas to calculate the corresponding skeletal, fat, muscle and residual mass. Matiegkas' model was subsequently modified by Drinkwater and Ross (1980), who interpreted any measurement relating to the four particular types of tissue, according to its departure from that of the Ross and Wilson (1974) unisex reference human or metaphorical phantom (stature of 170,18 cm; mass of 64,58 kg). Despite the suggested greater precision of this discriminate four-component model, an evaluation thereof in comparison to densitometry (Withers et al.,1991), judged it to be an unnecessary complication of matters and emphasized the approach of using skinfold thicknesses, body mass and body density as being preferable in the evaluation of body composition.

Anthropometry

Densitometry is clearly not suitable for widespread usage (Nelson & Johnson,1979). In this light, alternative anthropometric methods which are technically less demanding, less expensive and which can generally be applied expeditiously lend themselves to more extensive use such as in the PPE of youths and adults. In essence these anthropometric techniques also entail measuring skinfolds, skeletal diameters and girths or combinations of these three and then using these values in formulated regression equations to predict body volume and/or body density and thus relative body fat based on the two-compartment model of body composition. Conceptually, these equations function to predict the body density or percent body fat that would have been obtained using the hydrostatic method, and are thus generally validated by the same procedure. In this manner numerous such regression equations have been developed and proven valid, although population specific, implying that their greatest accuracy is obtained only when applied to samples very similar to those from which the original equations were formulated (Nelson & Johnson,1979).

Girths and Diameters

Initially Behnke and Wilmore (1974) developed an equation for predicting the body density and thus relative body fat of adult males and females from circumferences in combination with skeletal diameters. Other researchers (Weltman & Katch,1975; Mc Ardle et al.,1986) subsequently developed prediction equations based on measuring circumferences only. These equations are considered useful in the absence of laboratory facilities or skinfold calipers, or alternatively for use among the obese in whom skinfold measurements are at times difficult to carry out (Bray & Gray,1988). Thus far their development and application has, however, been limited to adults and excluded youths.

Skinfolds

Of all the anthropometric approaches to body composition assessment, the measurement of subcutaneous fat using skinfold calipers is evidently the most preferable and "scientific" method (Brooks & Fahey,1984; Gettman,1988). As such skinfolds are used in most clinical settings, making skinfold measurement as much a laboratory technique as a field method of evaluating body composition. To acquire accurate results from the skinfold technique of measuring body composition generally implies that some potential for error be realized and overcome. The first requirement is securing a caliper that is reliable and designed to provide a constant jaw pressure of 10 g/mm» over prolonged periods of use. In this regard the Harpenden and Lange models, although expensive, are generally recognized to be the most accurate (Whitehead,1990). It is, however, probably their expense which has precluded widespread use of the skinfold technique in the field-setting. Recently cheaper plastic spring loaded calipers such as the Slimguide model have proven relatively accurate substitutes (Schmidt & Carter,1990). This development should increase the accessibility of the skinfold technique in the field-setting. A second requirement for accurate skinfold measurement is conforming to standardized procedures and extensive practice on the part of the anthropometrist. Provided both of the above practical requirements and challenges can be met, the skinfold technique may enjoy a justified and accurate utilization in the PPE of youths.

Skinfold assessment of body composition has, however, also required that the evaluator critically discern the validity, with respect to population applicability, of the numerous prediction equations being offered in the literature (Baumgartner & Jackson,1987). As such early researchers developed relatively homogeneous "population-specific" equations, while a later trend has been to develop "generalized" equations for application among heterogeneous samples. A few of these early population specific equations were applicable to youths, viz.: Parizkova (1961) developed equations for boys and girls from 9-16 years with useful nomograms for assessing body density or percent body fat from the tricep and subscapular skinfolds. Durnin and Rahaman (1967) developed equations for 12-15 year old-boys and 13-16 year-old girls. Durnin and Womersley (1974) developed equations for 17-19 year-old boys and 16-19 year-old girls.

Later developed generalized equations, though still gender-specific, allowed for one equation to be used in stead of several population-specific equations and proved valid for adults varying greatly in age and body fatness, viz.: Jackson and Pollock (1978) - developed equations for 18-61 year-old males. Jackson et al.(1980) - developed equations for 18-55 year-old females. Pollock et al.(1980) - developed equations for 18-61 year-old males and females. Concern has, however, been raised with respect to the accuracy of using the generalized equations for individuals outside the development sample age range of 18-61 year-old males and females (Lohman,1981). As indicated earlier, the extreme age groups of youths and the aged would thus fall into this category, where due to a variation in body water and bone density, the accuracy of these generalized equations may be affected. Thorland et al.(1984), nonetheless did manage to cross validate these generalized equations with high school participants of 15-19 years of age.

In the interim, after five years of development, the 1980 Health Related Physical Fitness Test (HRFT) for Youths designed by the American Alliance for Health, Physical Education, Recreation and Dance (AAHPERD) utilized the tricep skinfold alone or summed with that of the subscapula as a raw score for evaluating the body composition of school children aged 6-17 years. At times this value was used to estimate body fatness from equations developed on adult samples. In order to circumvent the problem of overestimating body fat among youths using the adult generalized equations, the 1985/86 Texas Youth Fitness Test proposed a new approach and used the sum of the tricep and calf skinfolds as a raw score for body composition. In addition corresponding relative body fat percentages were provided, as calculated from a newly developed regression equation (Lohman,1987). Subsequently, after revision of the AAHPERD HRFT in 1988, the above approach was incorporated into "Physical Best" - the new fitness education and assessment programme of AAHPERD (Petray,1990; Riley,1990; Going & Lohman,1990) thus becoming the most recent method of evaluating body composition among youths.

There is little doubt that the skinfold technique presents the Human Movement Scientist in the laboratory and the Physical Educator and coach in the field-setting with an undeniably useful tool for estimating body fat. However, having said that, it may be noted that purists in the field of kinanthropometry, have once again cautioned proponents of the skinfold technique to be aware of its potential conceptual deficiencies. Ross et al.(1988) assert that a primary realisation in this regard is that, because skinfold caliper formulas for the prediction of body fat are generally based on densitometry as the method of validation, they are essentially doubly indirect. In addition to the same assumptions as those for the densitometric model, as described earlier, the authors reiterate that the skinfold technique relies on a number of further assumptions, viz.: i) constant compressibility of the skinfolds; ii) skin thickness being negligible or a constant fraction of the skinfold; iii) fixed adipose tissue patterning; and iv) fixed proportion of internal to external fat.

In a concluding comment, Ross et al.(1988) express the view that skinfolds not be used in converted form to predict percent body fat among individuals, but rather that a trend be maintained of skinfolds being used in their own right in a summed form for individual comparative purposes. Notably, Seltzer and Mayer (1965) were early proponents of this approach and suggested using a minimum triceps skinfold thickness as being indicative of obesity for individuals ranging from 5-50 years of age (Figure 2.17).

FIGURE 2.17: MINIMUM TRICEP SKINFOLD INDICATIVE OF OBESITY

AGE (Yrs) :	**12**	**13**	**14**	**15**	**16**	**17**	**18**
BOYS (mm) :	18	18	17	16	15	14	15
GIRLS (mm) :	22	23	23	24	25	26	27

After Seltzer & Mayer (1965)

Alternative Anthropometric Indices

In the absence of laboratory facilities or anthropometric equipment, as may often be the case in field-settings, various alternative anthropometric indices may have to suffice as methods of body composition assessment. Such methods, which according to Rowland (1990) can essentially be applied to youths in the same manner as adults, include: i) body mass; ii) stature/mass ratios; and iii) direct observation.

Body mass is an easy precise measure but is inherently flawed in that by using standards obtained from age-height-weight tables in conjunction with rough classifications of body frame size, the extra weight for height could be either lean body mass or fat. This problem thus also questions the suitability of age-height-weight tables for use during the PPE. Stature/mass ratios are generally calculated as: i) the Ponderal Index (cube root of the mass divided by the stature); ii) the Reciprocal Ponderal Index (stature divided by the cube root of the mass); and iii) the Body Mass Index (BMI - body mass divided by the square of the stature). Intrinsically, the flaw of using stature/mass ratios to evaluate body composition remains an inability to distinguish between muscle and fat mass comprising the body mass of an individual (Ross & Marfell-Jones,1991). However, both the AAHPERD Physical Best Test for Youths (Petray,1990) and the Fitnessgram Test for Youths developed by the Cooper Institute for Aerobics Research (Howden,1990), incorporate the BMI as an alternative substitute for skinfold body composition assessment. Thus, provided the evaluator ensures that the individual being assessed is not overtly muscular, the BMI would appear to be a useful supplementary tool in the PPE. Direct observation can according to Rowland (1990), serve as a simple yet fairly accurate subjective estimate of fatness, indicating that positive skinfold correlates have been documented when an individual "looks fat".

In conclusion of this topic, based on the foregoing review of an individuals potential morphological predisposition to sports-related injury, kinanthropometric assessment as part of the PPE of youths would thus appear to be a necessary procedure. Henceforth, the review focuses on muscular function as a potential intrinsic risk factor for injury and on corresponding methods of assessment.

4.5.2 MUSCULAR FUNCTION

It is generally acknowledged, and as defined in broad terms according to Wallace et al.(1990), that muscular function can be expressed in terms of the variables of muscular strength (the amount of force a muscle-tendon unit can generate or resist); muscular power (the amount of force that can be generated per unit of time); specific muscular endurance (the ability of the muscle-tendon unit to repeatedly reproduce strength and power); and muscle flexibility or extensibility (the ability of the muscle-tendon unit to lengthen sufficiently in response to being stretched). As such, in terms of assessing intrinsic muscular risk factors for injury, an individual may manifest asymmetry or a differential deficit in muscular strength, power, endurance or flexibility when comparing extremities within in the same subject or between agonist-antagonist muscle groups within the same extremity (Nicholas,1976; Wallace et al.,1990; Herring,1990).

That there is a relationship between functional muscular imbalance and injury has always been a logical assumption. It is known that participants with previous joint injuries and those whose injuries have required surgery have persistent muscle weakness, imbalance and a high rate of reinjury in the affected limb (Campbell & Glen,1979; Grimby et al.,1980; Arvidsson et al.,1981). The generally proposed association between muscle imbalance and injury or reinjury hinges on the view that the weaker or more imbalanced (compared to normal) an extremity muscle group is, the more prone it is to soft tissue (muscle) or joint injury (Slagle,1979; Knight,1980; Grace,1985).

Muscular Performance Variables and Injury Risk

Muscle strength itself has been proposed to be a primary protective mechanism considered important for averting injury. As such, stronger tissue is expected to withstand the normal trauma such as forceful bumps and blows that typically accompany contact or collision sports and usually result in contusions. Furthermore, it has been suggested that a related increased muscularity due to hypertrophied muscle mass forthcoming from improved strength, may provide greater protection to the internal deep structures against external sources of trauma (fracture) by presenting an intervening fleshy shield on impact (Reilly & Hardiker, 1981; Rooks & Micheli,1988).

In addition it has been proposed that stronger contractile (muscle) and non-contractile (ligament and tendon) tissue may resist strain and sprain type injuries better than weak tissue (Rooks & Micheli,1988; Stone,1990). In particular, meniscus injury and sprain type injuries of the cruciate and medial knee ligaments, are largely related to respective forced extension and/or torsion and valgus forces produced by tackles from the side (Bulstrode,1989). The development of sufficient muscle strength around the knee joint is thus considered important for preventing and alleviating pathological conditions and knee instability due to ligamentous damage. This is achieved by increasing the tensile strength of the ligaments and the ligament-bone interface as well as the musculotendinous sleeve surrounding the knee (Moskwa & Nicholas,1989; Wallace et al.,1990).

While muscle contusions and knee ligamentous sprains/ meniscal injury incurred during rugby are essentially directly related to the characteristic extrinsic risk of the tackle and collision nature of contact sport, the mechanism and aetiology of muscle strains on the other hand is essentially intrinsic, although also typically occurring as a sudden macrotraumatic event (Davies & Wallace,1980). In terms of the mechanism of injury, Garret (1990) maintains that it is generally believed that muscle strain injuries are stretch-induced, occurring in response to forcibly stretching a muscle. Certain muscles are more prone to strain injury than others. Anatomically, the muscles of the thigh, in particular, which function to propel the body through space and aid in kicking, jumping and running at various speeds, are under considerable stress and thus prone to strains. The most commonly strained muscles of the thigh are the adductor longus, illiopsoas, rectus femoris and hamstring group (Saudek,1990). Most muscle strain injuries tend to occur in biarticulate muscles that cross two or more joints and are therefore subject to stretch at more than one joint (Alter,1988). It is in this respect that a lack of extensibility in the injured muscle or flexibility / range of motion at a joint, can be considered a risk for injury. During dynamic activity circumstances placing an excessive (over) stretch on a joint with a restricted range of motion possibly due to tight or inextensible muscle(s) crossing that joint, may be responsible for injury, such as the hamstrings limiting knee extension when the hip is flexed (Rooks & Micheli,1988; Alter,1988).

Among youths in particular, a lack of flexibility is very realistic risk factor for injury. During the period of rapid growth accompanying the onset of sexual maturity, bone and musculotendinous tissue may grow at different rates (Leard,1984). At this stage, growth typically occurs primarily in the long bones while the soft tissues and muscle tendon units spanning these bones lengthen secondarily in response to the stretching forces applied as bony growth takes place. As a consequence soft-tissue lengthening lags behind skeletal growth. This process can result in a dramatic loss of flexibility in the rapidly growing youth, and this imbalance may commonly result in sprain and strain injuries (Micheli,1988a).

Another characteristic of muscles at risk for injury, is that muscles often function in an eccentric (lengthening) manner when being injured during sports-related activity, as is the case with running or sprinting (Garret,1990). For instance the hamstrings act not only concentrically to flex the knee, but also eccentrically to decelerate knee extension during running. Similarly, the quadriceps act as much to prevent knee flexion as to power knee extension during running. These muscles thus act to control joint motion or to decelerate the particular joint and are therefore acting eccentrically. In this manner, muscle strain injuries frequently involve a powerful eccentric muscle contraction, causing the stretching of the active (muscle) and passive (tendon) components of the muscle-tendon unit (Malone,1988).

An observation has also been made that muscle strain injuries, particularly of the hamstrings, occur most often among sprinters (Lysholm & Wiklander,1987) or "speed athletes". Accordingly Garret (1990), confirms that muscle strains are more common in sports and events or positions requiring bursts of speed or rapid acceleration such as

American football, basketball, rugby and soccer. Finally, in close relation to the previous observation, Malone (1988) has indicated that muscles with a relatively high percentage of Type II or fast twitch muscle fibres are susceptible to injury. Thus while superior agility and higher speeds of contraction or high degrees of muscle power would be necessary to rapidly escape a potentially injurious situation (Wallace et al.,1990) it may also be a factor predisposing to injury (Lysens,1987).

Muscular Imbalance and Injury Risk

In returning again to the broad category of functional muscular imbalance - such a condition literally implies that either an asymmetry exists between extremities (contralateral) or a reciprocal differential exists within a limb (ipsilateral) when compared to an anticipated normal value (Grace,1985). The actual magnitude of what constitutes balance and imbalance has not yet been accurately defined. A 10% discrepancy has been mentioned in the literature (Gilliam et al.,1979a; Mira et al.,1980) and a 7 to 20% discrepancy is utilized in practice as a guideline for resuming varying degrees of specific sports-related activity or participation after knee injury (Grace,1985; Prinsloo,1986). In essence what determines a significant discrepancy, probably depends on the anatomical region, the sport involved and the participants' size, age and gender. The crux of the question dealing with muscular imbalance should distinguish between what is "normal", what is "not normal" and finally what is "abnormal" or "pathological".

Normal limits are generally defined statistically as being those of the majority of the population. In this respect the work of a number of researchers has, via isokinetic dynamometry, dealt with developing and objectively quantifying norms with respect to age, sex, height, weight and other factors. Such norms have been compiled for children (Molnar & Alexander,1973;1974; Gilliam et al. ,1979b); high school and adult sportsman, particularly football players (Gilliam et al.,1979a; Parker et al.,1982;1983; Davies et al.,1981; Davies,1984;1987); adult middle/long distance runners and sprinters (Morris et al.,1983; Davimes & Levinrad,1990); and adult rugby players (Barnard & Coetzee,1991).

On the other hand, "not normal" - by implication applies to those subjects who have measurements that do not fall within the normal range. Grace (1985) emphasizes an important distinction at this point, between what is not normal and what is abnormal or pathological. As such he maintains that the two are commonly yet erroneously assumed to be synonymous. The significance of a given value should thus not be judged according to its relative frequency within a population, that is normal or not normal, but rather by its association with actual injury occurrence or decreased functional performance. The latter would thus be indicative of an abnormal or pathological muscle imbalance.

A limited number of studies have addressed the critical issue of muscle imbalance and injury by specifically relating actual muscle imbalance and injury incidence. Merrifield and Cowan (1973) studied ice-hockey players with groin strains and documented a relation between muscle imbalance of the adductor hip musculature with injury. The authors also found that all participants reinjured the weak side after resuming play. Similarly, the question of muscle imbalance and one of the most common muscle injuries, namely the hamstring strain, has been studied. Originally, research by Burkett (1970) indicated that a contralateral strength imbalance between the right and left hamstrings of 10% or more would likely result in a strain to the weaker hamstring. Later another more favoured postulate was put forward (Liemohn,1978) which maintained that an ipsilateral hamstring-to-quadricep muscle strength ratio of less than 60% may predispose to hamstring injuries. In support of this, Heiser et al.(1984) showed a major reduction in hamstring injuries among university American football players using a specially designed prophylactic rehabilitation programme which included correcting the hamstring/quadriceps ratio to 60%.

In contrast to the above positive findings, Grace et al.(1984), could not specifically relate varying degrees of imbalance for thigh musculature with knee joint injuries among high school football players. Grace (1985) did comment, however, that their finding should not be interpreted to imply that muscle weakness and imbalance have no relationship to joint injury. Stafford and Grana (1984) emphasize that the problematic association between muscle imbalance and injury is further confounded by the potential latent differences existing between dominant and non-dominant limbs.

Concerning an imbalance in varying degrees of flexibility being related to injury, evidence to this effect appears to be more circumstantial than experimentally documented. Micheli (1979) has indicated that adolescents who have tight lumbosacral fascia and hamstrings in conjunction with weak abdominal musculature, tend to develop functional hyperlordosis and subsequent low back pain. In an eight-year study of high school football players, Cahill and Griffith (1978) found that a pre-season conditioning programme decreased both the number and severity of knee injuries and attributed this finding to increased flexibility and total body conditioning. Millar (1979) indicated that calf stretching and strengthening could prevent strains of the posterior calf muscles, in so far as only a 0,7% incidence of recurrent injury was observed after a stretching programme. In a well controlled prospective study Ekstrand and Gillquist (1982) did document that muscle strains were more common in soccer players with muscle tightness of the hip adductors, but that no significant difference in the range of motion was found between players incurring hamstring strains and those that did not.

In conclusion of this topic, Shambaugh et al.(1990) reaffirm the generally held opinion (Merrifield & Cowan, 1973; Grace,1985; Lorenzton,1988), that the relationship between muscle imbalance and injury essentially remains open. A challenge thus exists for future research to further quantify and delineate this relationship and its relevance to injury prevention.

Muscular Function Assessment

It is apparent that the detection of deficient muscular function should comprise a critical part of the PPE of individuals wanting to participate in sports-related activity. Nicholas (1984) and Hershman (1984) reflect the dominant view that since the PPE is primarily aimed at preventing injury, those related aspects of musculoskeletal function which are modifiable by conditioning and rehabilitation should be emphasised. Various techniques can be employed to assess these pertinent aspects of muscle strength, endurance, power, agility and flexibility.

Muscle Strength, Power and Endurance Evaluation

Although muscle function has been studied extensively its assessment remains problematic. Because the variables of muscular strength, power and endurance are highly related (Howley & Franks,1986; Sanders & Sanders,1990), they have at times been used interchangeably in an indiscriminate manner. As such the salient differences between these variables, as defined by Huesner and Van Huss (1978), need to be emphasized: Strength is the maximum effective force that a muscle or group of muscles can exert once. Power implies the maximum strength that can be exerted once at a maximum rate of movement. Endurance denotes the duration or the number of repetitions that a given contraction can be performed.

Muscular strength may thus be seen as the force utilized in the creation or prevention of movement (Bosco & Gustafson,1983). Various methods of assessing muscular strength exist, ranging from practical field tests using little or no equipment to expensive sophisticated mechanical dynamometry found in the laboratory setting. An appreciation of these methods requires cognizance of isometric vs isotonic mechanisms of muscle contraction in creating the force being measured.

Malone (1988) distinguishes as follows between the acknowledged types of muscle contraction. During an isometric (static) contraction, neither muscle length nor joint position change and the mechanical work performed is zero. In an isometric contraction, the function of the contraction is thus fixation. On the other hand, isotonic (dynamic) contraction entails a concentric and eccentric phase and the joint moves through a range of motion. During a concentric muscle contraction, the muscle shortens, the work is positive and the function of the contraction is acceleration. In an eccentric contraction, the muscle lengthens, the work is negative and the function of the contraction is deceleration.

Conforming to the above variations in muscle contraction, muscular function and assessment thereof has been correspondingly described (Safrit,1981) as an evaluation of: i) static strength (isometric muscle strength/

endurance); ii) dynamic strength (isotonic muscle strength/ endurance); and iii) explosive strength (isotonic muscle power).

The design of field tests using little or no apparatus, such as those popularized by and commonly employed in the batteries of AAHPERD and its Canadian equivalent (CAHPER) to assess the variables of muscle function of isolated muscle groups, have intrinsic limitations. Nelson and Johnson (1979) relate that in most of these traditional calisthenic performance tests (executed against ones' own body weight) used for this purpose, the distinction between muscle strength, endurance and power cannot always be made. For example, push-ups, pull-ups and the flexed-arm hang are usually designated as both strength and endurance measures, requiring that the given maneuver be performed as dynamic repetitions either with or without a specified time limit, or that the given maneuver be maintained statically for a period of time. Yet if the subject cannot perform any (or only one or two repetitions) of such a test or does not have the strength to hang for more than an instant from the bar in a flexed-arm position, then the tests are by definition not measuring endurance, since endurance involves repeated or continuous exertion, which by implication thus also requires a degree of strength.

Similarly, whereas muscular power defined implies the release of maximum force in the shortest period of time, muscle power is relatively difficult to measure in the field despite the apparent simplicity of its definition (Nelson & Johnson,1979). As such, field tests that are generally used for this purpose include the vertical jump, standing broad jump and medicine ball throw. In all these tests the criterion measure is the height/distance achieved - and yet, although none employs a time measurement, they are required to suffice as measures of explosive strength/ power.

The problematic nature of assessing muscle function, is further illustrated by the fact that the established non-invasive methodologies cannot provide direct readings of muscle strength, but in essence rely on measurement through muscular action on the skeletal system (Malone,1988). By the same token, strength tests amenable to general use do not measure the strength of a single muscle but of groups of muscles. Additionally, isometric (static) and traditional isometric (dynamic) strength testing have certain underlying mechanical constraints with respect to the validity of the values being attained (Howley & Franks,1986; Pitman & Peterson,1989; Sale,1991).

The criticism of isometric testing is that, because there is no limb movement, values obtained are specific to the joint angle at which the test is conducted and may differ from values at other points in the range of motion (Howley & Franks,1986). Similarly, although isotonic testing entails movement through a range of motion, this type of testing is dependant on leverage effects at the joint. That is, because the muscle force moment arm changes throughout the range of joint motion, the muscle tension also changes. Thus some points in the range of motion will be overcome more easily than others with the involved muscles not being forced to contract to their maximum and thus causing a variation in the applied force (Hay & Reid,1982; Pitman & Peterson,1989; Sale,1991).

Since the pioneering work on isokinetic dynamometry in the 1960's (Hislop & Perrine,1967; Thistle et al.,1967; Perrine ,1968; Moffroid et al.,1969) and with the advent of isokinetic dynamometers currently being utilized in most modern laboratory settings, accurate assessment of muscle function has become greatly enhanced. Isokinetic assessment requires that work be performed against a device which provides a constant preset-velocity of joint motion and maximal accommodating external resistance throughout the range of motion of the involved joint, thereby requiring maximal muscle torque (Pitman & Peterson,1989). Technically, because of the adjustable speed controlling mechanism of the isokinetic device, the set velocity of a limb being evaluated cannot be increased (Osternig,1986). Instead as more force is exerted against the lever arm of the apparatus the energy of the moving limb is absorbed or accommodated and converted to a proportionately increased resistance encountered by the limb - thus a maximal load can be applied at all points throughout the arc of motion (De Lee et al.,1989).

Isokinetic devices thus provide an accurate diagnostic tool for assessing muscular imbalances and/or deficiencies in strength, power and endurance (Davies,1987; Sanders & Sanders,1990). The following specific parameters can be determined via isokinetic dynamometry for the muscle group being evaluated (Wallace et al.,1990):

1. Peak bilateral torque (absolute strength);
2. Peak bilateral torque with respect to time (power and endurance);
3. Right versus left (contralateral) ratios;
4. Relationship of agonist and antagonist (ipsilateral) ratios;
5. Strength of the muscle group versus body mass (relative strength); and
6. Variations of the above relationships with different speeds of testing (velocity spectrum).

Finally, from a safety perspective isokinetic devices can adjust the resistance to protect various anatomical or pathological deficiencies present at certain points in the joint range. This occurs as the dynamometer accommodates the decreased force at the point of pain and thus reduces the resistance (Osternig,1986).

Agility Evaluation

Agility is broadly defined as the ability to change the direction of the body or parts of the body rapidly. In a more specific sense agility is, however, considered a multifactorial attribute. It is apparent that to be agile one must also possess dynamic balance and be well coordinated (Bosco & Gustafson,1983). It should also be obvious that agility includes factors such as strength, flexibility, reaction time and speed (Kirkendall et al.,1987; Baumgartner & Jackson,1987).

Tests of agility are generally conducted in the field-setting and essentially evaluate two main types of agility: i) running agility - which is the most representative of sports-related activity and requires the subject to turn, stop or start at speed; and ii) whole body agility - which does not involve running but still requires changes of body position and/or the direction of body parts (Kirkendall et al.,1987).

Flexibility Evaluation

From a functional anatomical perspective, Sigerseth (1978) points out that the term "flex" refers to the motion of a joint or bony segment by the action of muscles. Flexibility thus pertains to the moving of articulating segments of the body about a joint. From this, flexibility has generally been defined as the range of motion about a joint (Safrit,1981).

As concerns the assessment of this variable, the factors limiting flexibility are of obvious concern. As such, specificity plays a primary role, in that each joint has its own range of motion related to the unique structural features of the joint and its surrounding tissue. With respect to the relative importance of the different types of tissue in inhibiting joint mobility, it is generally accepted that the muscles and ligaments are most inhibiting and tendons considerably less inhibiting (Fox & Mathews, 1981). For this reason, the varying degrees of elasticity and extensibility of muscle and connective tissue, indicate that flexibility can definitively be considered a variable of muscle function. Therefore, flexibility is best described as a measure of the range of motion of body parts about their joints, attainable without undue strain to those joints and their muscular attachments (Bosco & Gustafson,1983).

In addition to the definitions already provided, further descriptions are of discriminate value when evaluating flexibility. As such there are two general categories of flexibility, namely static and dynamic. Static flexibility, sometimes referred to as passive or extent flexibility, refers to the range of joint movement without taking the speed of movement into consideration. Dynamic flexibility on the other hand, involves the ability to make repeated flexing or stretching movements and thus requires the rapid use of the full range of motion (Corbin,1984).

There are various approaches and devices that can be used to assess flexibility. Original approaches to flexibility testing consisted of single-joint evaluation in which some form of goniometry was used (cf. Greek: gonia = angle; metron = measure). According to Bosco and Gustafson (1983), manual goniometry has consistently been the preferred form of accurately measuring static flexibility by making use of a protractor. Methodically, the centre point of the protractor is placed over the fulcrum of the joint being measured and the two body segments about the joint form the two legs of the angle recorded on the protractor (Norkin & White,1985). Other more technical, though generally less utilized, devices have been developed to provide measurements of dynamic flexibility by recording the range of joint motion during various body movements. In particular, these are the flexometer and the electrogoniometer (ELGON). The first mentioned device was an early development of Leighton (1955) while the ELGON was developed in the 1960's (Sigerseth,1978). As the development and maintenance of general body flexibility became accepted as a health-related goal, practical tests of gross flexibility of various body parts, rather than tests for individual joints, have received attention. The prime benefits of such tests are their general expedience and relative inexpense while trained expertise is not a prerequisite. Conceptually, quantifiable values of flexibility are acquired by subjectively judging or measuring the linear distance between anatomical structures or from one body segment to another body segment or standardized object (Rooks & Micheli,1988).

One such test that deserves particular mention is the trunk flexion test in its various forms. Although it is recognized that no single general flexibility test exists that is representative of total body flexibility, the trunk flexion test is nonetheless often purported to be the best overall test of gross flexibility (Golding et al.,1989). It is believed that Cureton (1941) first introduced the test as the trunk forward flexion test - which required that subjects attempt to keep their knees completely extended while bending forward from a standing position and then attempt to touch their toes with their fingers. This version of the trunk flexion test was followed by the Scott and French (1950) bobbing test - which involved a bench and an attached scale so that subjects could reach further than their toes. Later Wells and Dillon (1952) again modified the test because it was felt that subjects experienced feelings of insecurity and apprehension when bending forward while standing on an elevated surface. Subsequently, they changed the trunk flexion test to the sit-and-reach - with a horizontal, elevated scale that provided scores in negative and positive linear units. Essentially the Wells and Dillon sit-and-reach form of the trunk flexion flexibility test is the format currently utilized widely in practice to assess lower-back and/or hamstring flexibility. In effect, however, the trunk flexion test includes the extensibility or tightness of the gastrocnemius, hamstrings, gluteus, lower-back, upper-back and shoulder musculature (Gettman,1988).

Direct (angular) measurements of isolated joint flexibility are preferred with regard to the accuracy of measurement. Indirect tests of linear segmental approximation or subjective bilateral comparison of isolated joint flexibility are, however, useful approaches due to their widespread practical application. Their use remains popular in the field for evaluating large numbers and as a quick subjective estimate in the clinical setting (Rooks & Micheli,1988).

4.6 THE PREPARTICIPATION EVALUATION - A SYNTHESIS

A systematic preparticipation evaluation (PPE) is an important and worthwhile preventive procedure in Sports Medicine. Having thus far presented a detailed analysis of the PPE and its component parts (health history, medical examination and musculoskeletal function evaluation), a brief synthesis is provided in conclusion.

Objectives

The primary objective of the preparticipation evaluation (PPE) is to prevent and manage injury by exposing various potential intrinsic risk factors for injury prior to participation in sports-related activity, in the following manner:

1. Determining the general health of the participant;

2. Screening for any condition that may limit participation (congenital or developmental problems; untreated illness or injuries; lack of physical fitness for the specific proposed activity - particularly regarding morphological and musculoskeletal status); and

3. Establishing comprehensive baseline data to serve as reference values for pre-season conditioning or rehabilitation in the event of an injury.

Timing and Frequency

The ideal time to conduct the PPE is approximately six weeks before the season or period of participation begins. This should allow enough time to detect, correct and/or rehabilitate any problems (Lombardo,1984; Mc Keag,1985). Although there may be variations in policy, annual evaluations are performed in most cases (Feinstein et al.,1988). Young participants are generally healthy - PPE studies showed that relatively few (3,2% to 13,5%) subjects required rehabilitation and that only 0,3% to 1,3% were completely disqualified from participation (Goldberg et al.,1980; Linder et al.,1981; Tennant et al.,1981; Thompson et al.,1982). Since 63% to 74% of problems can be identified through the medical history (Goldberg et al. ,1980; Risser et al.,1985), current opinion is that an entry-level history and thorough medical examination and physical evaluation followed thereafter by an annual history and limited physical examination / evaluation should be sufficient (Lombardo,1990).

Format

The PPE has traditionally been conducted on an individual basis in the primary-care Physicians' consulting room or on a group basis through a station-type mass examination. Both offer distinct advantages. The consulting room format emphasizes the patient familiarity aspect with respect to the health history and continuity of care. The multidisciplinary station-type evaluation on the other hand, delineates the approach of involving more specialized professionals (Sports Physicians, Biokineticists, coaches etc.) and thus additional musculoskeletal function testing can be done. The advantages of both approaches can be obtained if the primary-care Physician is provided with specific guidelines and incorporated as a member of a multidisciplinary sports medicine team.

Health History

The health history is an integral part of the PPE and will serve to identify the majority of health problems experienced by participants. Important subjects to explore in the history are hospitalizations; medication usage; allergies; the cardiovascular system and familial history of cardiovascular problems; the musculoskeletal system; the neurologic system; and other chronic medical conditions.

Medical Examination

During the medical examination the areas indicated to be of greatest concern and those identified as problems in the history are emphasized and examined. These essentially include a cardiovascular examination; blood pressure; heart rate and rhythm; the orthopaedic system; the abdominal system; skin; genitalia and maturity staging. Based on the results of the examination the Physician is required to determine the subjects' disposition with respect to participation with the aid of the American Academy of Paediatrics' (1988) recommendations for participation in competitive sport.

Musculoskeletal Function Evaluation

This portion of the PPE essentially falls into the realm of the Human Movement Scientist as Biokineticist, Physical Educator or trained coach and should concentrate on the morphological and muscular system. Evaluation should preferably be sport-specific in nature, to provide a profile of the participants' morphological status and muscular function to respond to the stresses that the prospective activity may impose. Methods of evaluation may include kinanthropometric assessment of body composition and somatotype; agility testing; flexibility testing (gross flexibility tests or goniometry); and assessment of muscular function variables of strength, endurance and power (isometric, isotonic or isokinetic evaluation).

The general health and medical screening are the areas of the PPE in which life-threatening and functional abnormalities may be discovered. The musculoskeletal function evaluation on the other hand, may provide more practical data in generating information about physical deficiencies which, on correction, could decrease potential predisposition to injury by providing an optimum musculoskeletal base for participation.

CHAPTER 3

METHODS AND PROCEDURES

1. PRELIMINARY STUDY

The preliminary study investigated the epidemiology of sports injuries during an annual primary schools tournament. Boys participating in soccer, rugby and tennis, and girls participating in hockey, netball and tennis respectively, were monitored prospectively for the duration of the tournament. The specific aims, procedures, data analysis and results of the study are presented in the form of journal articles, either published or prepared for publication, as provided in Appendix A.

2. PRIMARY STUDY

2.1 AIMS AND DESIGN

To place the methodological approaches and design employed in the primary study in perspective the aims and phases thereof are again delineated, namely:

1. The initiation and implementation of an appropriate multidisciplinary preparticipation physical evaluation procedure to assess potential intrinsic risk factors for injury among high school rugby players; and

2. An injury surveillance study was conducted in order to re-assess extrinsic risk factors and examine the role of potential intrinsic risk factors, identified at baseline evaluation, in the aetiology of injuries occurring among the cohort of subjects during a subsequent season of participation.

A cross-sectional and prospective analytical epidemiological design were thus adopted for the two respective phases of the primary study.

2.2. CHOICE OF SUBJECTS

In their study on the epidemiology of injuries among high school rugby players participating in the Cape Province, Roux et al.(1987) found that in a large number of schools monitored by correspondence, there had been substantial under-reporting of injuries. This led to their recommendation and subsequent confirmation (Noakes,1991b), that the most accurate method of data collection appears to be direct personal contact between the researcher and the injured player and that intensive monitoring of a single school, would identify the overall injury trends of a larger number of schools.

In cognizance of these motivations, it was decided to confine the present study to the rugby teams of one local high school in the Natal Province, which constituted a well-defined population at risk for injury. The cohort comprised all prospective players, including reserves, from seven teams. According to age group division, the cohort consisted of three senior teams in the open age group (i.e. 1st, 2nd & 3rd XV - made up of under-16 and under-17 age group players) and four junior teams (i.e. under-15 "A" & "B" and under-14 "A" & "B" teams). The entire cohort studied thus totalled 125 subjects (Table I).

2.2.1 INFORMED CONSENT

Prior to the study a covering letter was sent to parents of the subjects. This letter explained the nature and procedures of the study and procured parental and subject approval in an informed consent document (Appendix B).

TABLE I: COMPOSITION OF THE STUDY COHORT

TEAMS / AGE GROUP*	NUMBER OF SUBJECTS	AGE OF SUBJECTS X ± SD	(Years) Range
Open 1st Team	n = 15	16,9 ± 0,5	16 - 18
Open 2nd Team	n = 15	16,5 ± 0,7	16 - 18
Open 3rd Team**	n = 25	16,1 ± 0,7	15 - 17
Under-15 A Team	n = 15	14,8 ± 0,4	14 - 15
Under-15 B Team**	n = 23	14,9 ± 0,4	14 - 15
Under-14 A Team	n = 15	13,7 ± 0,5	13 - 14
Under-14 B Team**	n = 17	13,3 ± 0,5	13 - 14
TOTAL	N = 125	15,2 ± 1,4	13 - 18

* Determined according to chronological age at the 30th of June. e.g. If a player turned 13 yrs old after the 30th of June he would participate in the under-13 age group. If the player turned 13 yrs old on or proir to the 30th of June he would be required to participate in the under -14 age group.

** Denotes that teams included reserves.

3. PREPARTICIPATION EVALUATION PROTOCOL

The preparticipation evaluation (PPE) procedure consisted of a multidisciplinary protocol and involved various professionals from the community. The procedure was initiated by the investigator, who served as Biokineticist / Human Movement Scientist and coordinated the cooperative efforts of parents, a panel of General Medical Practitioners and the school rugby coaches.

The procedures for this phase of the study consisted of the following, with each stage described in detail thereafter:

1. The initial administering of a health history questionnaire; and

2. A subsequent process of evaluating the players medical and physical status to participate in sport by:

i) a sports-related medical examination; and

ii) a subsequent evaluation of morphological status and muscular function.

3.1 HEALTH HISTORY QUESTIONNAIRE

3.1.1 QUESTIONNAIRE DEVELOPMENT

The items selected for inclusion in the health history questionnaire (Appendix C) were based on examples and recommendations found in the relevant literature. In this respect, an appraisal of the various approaches to conducting the PPE among youths reflected that although the health history is of primary importance, a limited number of questions should suffice to screen the critical areas of concern, namely:

1. Cardiovascular risks;
2. Previous musculoskeletal injury;
3. Previous neurological injury;
4. Heat-related illness; and
5. General health screening.

Particular care was taken in keeping the questionnaire as concise as possible and using a style relatively free of paramedical/medical terminology so as to make the questionnaire clear to youths and their parents.

3.2 MEDICAL EXAMINATION

All subjects had the opportunity to undergo a voluntary medical examination. The examination of the players' medical status to participate in rugby was conducted by a panel of Physicians from a local medical practice with an interest in Sports Medicine. It was emphasized that this medical examination should not be seen as an attempt to interfere with any established doctor-patient relationship.

On reviewing the health history which had been completed by the subject and his parents in advance, the Physician conducted a medical examination of the player. The examination was focussed and sports-related, examining aspects of the individuals' health that may predispose to injury during participation.

To ensure uniformity of examination the Physicians were provided with an outline of the aims of the study and guidelines and recommendations for participation and disqualifying conditions for competitive sport, as drawn up by the American Academy of Paediatrics (1988) Committee on Sports Medicine. Additionally, the examiners were provided with a specifically designed proforma, which they had reviewed and approved in advance (Appendix D). On this proforma the findings of the examination were recorded and the disposition of the individual was indicated with respect to:

1. No participation permitted;
2. Limited participation permitted i.e. only in specific activities;
3. Clearance withheld i.e. subject to undergo further evaluation and/or rehabilitation; or
4. Unlimited participation granted.

3.3 MORPHOLOGICAL STATUS AND MUSCULAR FUNCTION ASSESSMENT

The morphological status and muscular function assessment was directed at evaluating selected variables which may constitute potential intrinsic risk factors for injury among youths participating in rugby. The selection of these variables was based on:

1. Observations and experience with respect to the characteristic nature of the game; and

2. Deductions pertaining to the epidemiology of sports-related injury and the literature reviewed indicating potential intrinsic risks factors associated with the aetiology of injury in contact team sport.

The assessment of the selected morphological status and muscular function variables was conducted by the researcher in cooperation with the rugby coaches. Elementary field-testing as well as advanced laboratory-testing were used. Tests were selected with respect to their proven validity, ease of administration and/or availability of equipment. Coaches were provided with a manual which, inter alia, detailed the methodology of the tests and included examples of the applicable proforma (Appendix E).

The following potential intrinsic risk factor variables were evaluated through the morphological status and muscular function assessment:

MORPHOLOGICAL STATUS

* Stature
* Body Mass
* Relative Body Fat
* Lean Body Mass
* Somatotype

MUSCULAR FUNCTION

* Strength
* Endurance
* Power
* Agility
* Flexibility

3.3.1 MORPHOLOGICAL STATUS

All anthropometric measures taken to assess the morphological status of subjects were executed according to the directions of the *Anthropometric Standardization Reference Manual* (Lohman et al.,1988).

STATURE

Stature was measured to the nearest 0,1 cm, as the vertical distance from the vertex in the mid-sagittal plane to the floor using a wall-mounted tape measure. The subject stood barefoot or wearing only socks and without a shirt so that the positioning of the body could be observed. The weight of the subject was distributed evenly on both feet and the head positioned in the Frankfort Horizontal Plane. The arms hung freely at the sides of the trunk with the palms facing the thighs. The heels were placed together, with both heels touching the base of the wall. The gluteus, scapulae and posterior aspect of the cranium were in contact with the wall. The subject was asked to inhale deeply and maintain a fully erect position, whereupon the measurement was made taking care that sufficient pressure was applied to compress the hair.

BODY MASS

A Detecto beam balance scale was used to determine body mass to the nearest 0,1 kg. The subject, who was barefoot or wearing only socks with shorts, stood quietly over the centre of the platform with the body weight evenly distributed between both feet.

BODY COMPOSITION

Skinfold Measurements

Skinfold measurements at various sites were used to assess body composition. The following measurement technique was applied for all sites measured, using a Lange spring-loaded skinfold caliper and taking all measures on the right hand side of the subject.

The thumb and index finger of the left hand were used to elevate a double fold of skin and subcutaneous adipose tissue one centimetre proximal to the site at which the skinfold was to be measured. Caliper jaws were applied at right angles to the site, approximately midway between the general surface of the body near the site and crest of the skinfold, and the spring-loaded handles fully released. Once full pressure was applied and initial needle drift had stopped or a maximum period of four seconds had passed, the measurement was taken. Two measures were taken and recorded to the nearest 0,5 mm. If the difference was greater than 1 mm, then a third measure was taken and the mean of the closest two recorded.

Tricep Skinfold

The skinfold was measured in the midline of the posterior aspect of the arm, over the triceps muscle, at a point midway between the lateral projection of the acromion process of the scapula and the inferior margin of the olecranon process of the ulna. The skinfold was measured with the arm hanging pendant and comfortably at the subjects' side.

Sub-scapula Skinfold

The skinfold was measured just below the inferior angle of the scapula, on a diagonal inclined infero-laterally approximately 45 degrees to the horizontal plane, in the natural cleavage lines of the skin. The skinfold was measured with the subject standing comfortably erect and arms relaxed at the sides of the body. To locate the skinfold site, the scapula was palpated by running the fingers inferiorly and laterally along the vertebral border, until the inferior angle was identified.

Supra-illiac Skinfold

The skinfold was measured in the midaxillary line immediately superior to the illiac crest. The skinfold was measured with the subject standing feet together and the trunk in an erect position. The arms hung pendant at the sides or, if necessary, were abducted slightly to improve access to the site. An oblique skinfold was grasped just posterior to the midaxillary line following the natural cleavage line of the skin, aligned inferomedially at 45 degrees to the horizontal.

Medial-calf Skinfold

The subject stood with the involved foot on a chair so that the knee and hip were flexed at about 90 degrees. The skinfold was raised parallel to the long axis of the calf on its medial aspect, at a level slightly proximal to the specified measurement site of maximum calf circumference.

Percentage Body Fat

For subjects aged 13 to 16 years, percentage body fat was estimated according to the currently favoured skinfold method of Lohman (1987), developed specifically for assessing body composition among youths. As required, the sum of the tricep and medial-calf skinfolds were used to generate a percentage % body fat, utilizing the appropriate computerized programme of Lohman and Lohman (1987) based on the following regression equation for boys: **% body fat = (0,709*X) + 2,7**; X = sum tricep and medial-calf skinfolds.

For subjects aged 17 and 18 years, the skinfold procedure of Durnin and Womersley (1974) was employed to estimate percentage body fat. Accordingly, the sum of four skinfolds (bicep, tricep, subscapula and supra-illiac) was converted to a common logarithmic value (L) and substituted in the following regression formula to obtain a predicted body density (D) : D = 1,1620 - (0,0630*L). Relative body fat was then calculated from the Brozek et al.(1963) formula for converting body density to body fat, viz.: **% body fat = (4,570/D - 4,142)*100**.

Lean Body Mass

Lean body mass as a derived anthropometric variable of body composition was calculated as follows:

$$\mathbf{LBM = BM - ABF} \quad \text{and} \quad \mathbf{ABF = \frac{RBF \times BM}{100}}$$

where : LBM = lean body mass (kg)
BM = measured body mass (kg)
ABF = predicted absolute body fat (kg)
RBF = predicted body fat (%)

SOMATOTYPE

As required by the Heath-Carter somatotyping method (Carter & Heath,1990), a total of 14 anthropometric measurements were taken. The following measures were then used to obtain a computerized somatotype rating of subjects (Zeng,1985):

* Stature (cm);
* Mass (kg);
* Skinfolds (mm) - Tricep, sub-scapula, supra-illiac and medial-calf skinfolds (all on the right-hand side).
* Diameters (cm) - Bilateral bicondylar width of the humerus and femur (using the greater value).
* Circumferences (cm) - Bilateral contracted upper-arm girth (maximal bicep circumference) and calf girth (level of maximal circumference), using the greater value.

Stature, body mass and skinfolds were measured as described formerly. Diameters were measured using a Lafayette sliding anthropometer (Model-01291) and girths using an Enraf-Nonius plastic anthropometric tape measure with an automatic retraction mechanism.

Diameters were measured in centimetres to the nearest millimetre, ensuring that firm pressure was applied to the bony reference points before the readings were taken. Circumferences were measured in centimetres to the nearest millimetre, such that firm and continuous contact was applied but ensuring that the fleshy contour of the skin was not deformed by the tape.

Bi-epicondylar Diameter

The subject held his upper-arm horizontal to the floor and the elbow flexed to 90 degrees, with the distance between the outermost parts of the medial and lateral humeral epicondyles being measured.

Bicondylar Diameter

The subject was seated and the knee flexed at 90 degrees, with the distance between the outermost parts of the medial and lateral femoral condyles being measured.

Contracted Upper-arm Girth

The subjects' upper-arm was held horizontal, the fist clenched and the elbow fully flexed, with the maximal bicep girth being measured.

Calf Girth

The subject stood erect, the legs slightly parted and the body mass equally distributed on both feet, with the measurement being taken at the level of maximal circumference.

3.3.2 MUSCULAR FUNCTION

FIELD-TESTING

*** Prone Push-up Test**

Push-ups were applied as a test of dynamic strength / muscular endurance of the upper-body.

Equipment: Stopwatch

Description: The standard prone push-up movement was executed from the floor. A front lying position was taken with the hands at the sides of the chest. The body was raised to the starting position by extending the arms completely while keeping the body in a straight line. The chest was required to touch a partners' fist held on the ground each time on the down phase and arms were fully extended on the return (up) phase. The back was kept straight throughout the movement. No partial credit was allowed and the exercise was done continuously.

Scoring: The total number of valid push-ups completed in 60 seconds were recorded.

*** Bent-Knee Sit-up Test**

Bent-knee sit-ups were applied as a test of dynamic strength / muscular endurance of the abdominal and hip flexor musculature.

Equipment: Stopwatch & soft ground.

Description: The subject lay on the back with knees bent at 90 degrees or less, hands behind the neck with fingers interlaced, and elbows pointed inwards. The feet were placed flat on the surface, slightly separated, parallel to each other and were held in place by a partner. The abdominal muscles were tightened, the head and elbows brought forward, and the elbows touched to the knees. This action constituted one sit-up. The subject returned to the starting position and repeated the exercise. To be counted as a valid sit-up the subject was required to: i) keep the fingers clasped behind the neck; ii) bring both elbows forward in starting to sit-up without using the elbow to push off the floor; and iii) return to the starting position with the scapulae touching the surface, before sitting-up again.

Scoring: The total number of valid sit-ups completed in 60 seconds were recorded.

*** Vertical Jump Test**

The vertical jump test was applied as a test of dynamic strength / power.

Equipment: A mobile collapsible vertical jump board, tape measure, chalk powder and duster. Footwear was standardized.

Description: After dipping the fingertips of their dominant hand into the chalk powder the subjects' reach-height was determined: Standing sideways against the board with both feet flat on the floor and heels together, the subject reached as high as possible and made a mark on the board. To execute the jump, the knees were bent and then in a maximal vertical effort the subject jumped making a mark against the board with the hand of his outstretched arm at the highest point reached. Subjects were allowed to swing their arms in preparation for the jump but were not permitted to move their feet. The difference between the reach-height and jump-height was then measured to the nearest centimetre. After observing a demonstration of the test, subjects were allowed two jumps following in close succession.

Scoring: The greater distance achieved with the two attempts was recorded.

*** Zig-Zag Run Test**

The zig-zag run was applied as a test of running agility (Baumgartner & Jackson,1987).

Equipment: Stopwatch; Five cone markers outlining the test course.

Description: At the signal the subject began from behind the line and ran the outlined course once as fast as possible. Three trials were given. The first trial was carried-out at three-quarter speed to familiarize the subject with the procedure and to serve as a specific warm-up.

Scoring: The subjects' performance was measured as the elapsed time to the nearest tenth of a second. The score was recorded as the fastest of the last two trials.

GROSS-FLEXIBILITY MEASURES

*** Apley Scratch Test**

The Apley Scratch Test as described by Corbin (1984) was applied as a gross test of shoulder flexibility.

Description: The right elbow was raised and the right hand reached down between the shoulder blades. The left hand was placed in the small of the back with the palm facing away from the back. The subject attempted to overlap the fingers of the two hands. The test was then repeated, reversing the positions of the hands.

Scoring: The score was recorded by observing the distance between the hands according to discrete numerical scores ranging from 1 - 3, indicating the amount of finger overlap (Corbin,1984), where:

1 = Fingers not touching;
2 = Fingers touching; and
3 = Fingers overlapping.

*** Standing Trunk Flexion / Floor-Touch Test**

The standing floor-touch test as described by Allman (1989) was applied as a gross test of lower-back / hamstring flexibility.

Description: The subject assumed an erect standing position either barefoot or wearing socks and with feet together. The arms hung by the sides. Keeping the knees straight throughout the test, the subject slowly leant downward towards the toes, attempting to touch the floor with the palms of the hand.

Scoring: Discrete scores ranging from 0 - 5, were recorded according to the finger placement on the floor, where:

0 = Fingertips not in line with the malleoli (ankles);
1 = Fingertips in line with the malleoli (ankles);
2 = Fingertips touching the toes;
3 = All fingertips touching the ground;
4 = All fingers (but not palms) flat against the floor; and
5 = Palms flat against the floor.

ISOMETRIC DYNAMOMETRY

Bilateral grip strength was applied as a test of static strength of the upper-body. The evaluation was performed using an adjustable Grip Dynamometer (Takei Kiki - Model 1201).

Description: It was ensured that the subjects' hands and instrument were dry prior to testing. The handgrip size was adjusted for the subject in such a way that the third proximal interphalangeal joint could be flexed at an angle of 90 degrees. The pointer on the dial was set to zero and the dynamometer was placed in the subjects' hand with the dial facing away from the palm. The subject stood erect and looking straight forward with the involved arm pendant at the side and held slightly away from the body. The dynamometer was squeezed as hard as possible without moving the arm.

Scoring: The highest score of two attempts read from the dynamometer scale was recorded to the nearest 0,5 kg.

ISOKINETIC DYNAMOMETRY

An isokinetic knee extension / flexion test at an angular velocity of 60 degrees per second was applied to evaluate the strength of the quadriceps and hamstring muscle groups. The test was performed using an Akron Computerized Isokinetic Dynamometer (Therapy Products Limited - Suffolk, England) and conducted according to guidelines for a standardized isokinetic protocol in clinical usage (Davies,1987).

Protocol

Subjects were seated in the testing chair and appropriately positioned with respect to seat height, seat length, back-rest angle, pivot height and adjustment of the lever-arm just proximal to the malleoli. Each subject was secured with the hips and torso, and the involved thigh strapped to the testing chair, arms folded across the chest and the input axis of the dynamometer aligned with the central axis of the knee joint. Prior to testing, the subject was informed about the purpose and procedures of the test and, in lay terms, of the functioning of the isokinetic mechanism. Thereafter a warm-up period was provided to familiarize the subject with the testing equipment. The warm-up consisted of several submaximal (10-15) and at least one maximal trial at the specified testing speed. During the set-up and testing periods, verbal commands and encouragement were standardized and consistent for all subjects. During the test procedure, subjects performed as many consecutive maximal repetitions as possible (3-5) in a ten second period. Each subject was tested bilaterally with the first leg tested being randomly alternated, except in the case of an existing injury - in which case the uninvolved leg was tested first.

3.4 PILOT TESTING PHASE

Prior to the preparticipation evaluation protocol being implemented, a pilot test was conducted. A subgroup of subjects from the cohort on whom the study was to be conducted were exposed to the previously described preparticipation evaluation protocol.

3.4.1 PILOT TESTING PHASE - DATA ANALYSIS AND RESULTS

Health History Questionnaire

On receiving the health history questionnaire back from the subjects, the responses were studied. From this review no administrative problems or ambiguity of questions seemed readily apparent, and the health history questionnaire was thus left unaltered.

Morphological Status and Muscular Function Assessment

The entire range of field-tests were administered according to the protocol outlined previously. No procedural problems were experienced and the protocol was thus left unchanged. Similarly, the entire range of laboratory tests were administered according to the protocol described previously. By calculating correlation coefficients for duplicate (test-retest) measures and applying a dependent t-test for significant differences among their means (Thomas & Nelson,1990), intra-tester reliability of the investigator and system reliability of the laboratory apparatus and measuring techniques was evaluated (Tables II - IV).

As reflected (Tables II - IV), high correlations and no significant differences (p>0,05) were found for duplicate (test-retest) measures for all anthropometric variables and muscle strength dynamometry. Accordingly, intra-tester reliability of the investigator and system reliability of the laboratory apparatus and measuring techniques was accepted. Some methodological difficulties were, however, experienced with the goniometric assessment of range of motion. It was therefore decided to exclude measures making use of the digital goniometer from the final protocol and rely on the Apley scratch-test and standing trunk flexion (floor touch test), as gross measures of shoulder and lower-back / hamstring flexibility, respectively.

TABLE II: PILOT STUDY DATA - ANTHROPOMETRY

VARIABLE	Test X ± SD	Retest X ± SD	r	t	p level
DIAMETERS (cm)					
n=5					
R Humerus	7,2 ± 0,3	7,2 ± 0,3	0,99	0,1	p>0,05 NS
L Humerus	7,1 ± 0,3	7,2 ± 0,3	0,94	0,7	p>0,05 NS
R Femur	9,7 ± 0,2	9,7 ± 0,2	0,91	0,4	p>0,05 NS
L Femur	9,7 ± 0,2	9,8 ± 0,2	0,92	0,4	p>0,05 NS
GIRTHS (cm)					
n=8					
R Bicep	33,1 ± 2,8	32,9 ± 2,8	0,99	0,1	p>0,05 NS
L Bicep	33,3 ± 2,8	32,8 ± 2,9	0,99	0,3	p>0,05 NS
R Thigh	55,7 ± 4,6	55,4 ± 5,3	0,96	0,1	p>0,05 NS
L Thigh	55,3 ± 5,4	54,4 ± 5,1	0,98	0,3	p>0,05 NS
R Calf	37,9 ± 2,7	38,5 ± 2,3	0,97	0,5	p>0,05 NS
L Calf	38,1 ± 2,5	38,3 ± 2,5	0,98	0,1	p>0,05 NS
SKINFOLDS (mm)					
n=19					
Tricep	9,7 ± 3,2	9,5 ± 3,2	0,95	0,3	p>0,05 NS
Bicep	5,0 ± 2,1	4,8 ± 1,9	0,98	0,3	p>0,05 NS
Sub-scapula	7,4 ± 1,9	7,5 ± 2,1	0,98	0,1	p>0,05 NS
Supra-illiac	9,9 ± 4,3	10,1 ± 4,3	0,99	0,1	p>0,05 NS
Thigh	14,1 ± 3,3	13,8 ± 3,5	0,97	0,3	p>0,05 NS
Calf	10,2 ± 3,6	10,1 ± 3,6	0,99	0,1	p>0,05 NS

r = Correlation coefficient ; t = Observed t-value
p = Level of significance ; NS = Not significant

TABLE III: PILOT STUDY DATA - ISOMETRIC DYNAMOMETRY

GRIP STRENGTH (kg)	Test X ± SD	Retest X ± SD	r	t	p level
R Grip	53,5 ± 8,4	53,3 ± 8,7	0,89	0,1	p>0,05 NS
L Grip	52,7 ± 7,1	50,4 ± 7,2	0,86	1,0	p>0,05 NS

n=19; r = Correlation coefficient ; t = Observed t-value
p = Level of significance ; NS = Not significant

TABLE IV: PILOT STUDY DATA - ISOKINETIC DYNAMOMETRY

TORQUE* (Nm)	Test X ± SD	Retest X ± SD	r	t	p level
Extension[a]	190,0 ± 36,3	199,8 ± 35,5	0,90	0,8	p>0,05 NS
Flexion[a]	129,9 ± 27,8	136,5 ± 29,3	0,95	0,7	p>0,05 NS

r = Correlation coefficient ; t = Observed t-value
p = Level of significance ; NS = Not significant
* = Knee extension / flexion torque
a = Bilateral peak extension / flexion torque of 8 subjects (n=16 observations)

4. INJURY SURVEILLANCE PROTOCOL

The second phase of the study, namely the injury surveillance phase, consisted of monitoring the occurrence of injury prospectively among the identified cohort over the full duration (14 weeks) of the season.

4.1 DEFINITION OF INJURY

When sports injuries are studied for epidemiological purposes, the sensitivity of the definition of injury is an important consideration. Various methodological approaches define a reportable injury in different ways (Vinger & Hoerner,1981; Lysens et al.,1984; Noyes et al.,1988; Rice,1989). Some studies have considered the status of the participant directly after a practice/match or the need for first aid care at the field-side to determine whether a reportable injury has occurred (Nilsson & Roaas,1978; Schmidt-Olsen et al.,1985). Other methodological approaches seek to eliminate minor injuries from consideration (Vinger & Hoerner,1981; Noyes et al.,1988). Their definition of injury is based on a more stringent time-loss criteria, and accounts only for injuries which result in an inability to participate in an unrestricted manner during a subsequent practice session or match. In the pertinent studies referred to in the preceding chapters on the epidemiology of rugby injuries among South African schoolboys over a season of participation (Nathan et al.,1981; Roux et al.,1987) the researchers utilized the last mentioned approach, and reported only those injuries which prevented the player from participating for at least seven days. An additional common approach is to formulate a reportable injury as one for which treatment from a Physician or medical facility was requested (Lysens et al.,1991).

If injuries are recorded using stringent injury definitions, as described above, a fairly large proportion of serious injuries will be documented. However, a clear constraint of such an approach, referred to as the "ice-berg" phenomenon, is that numerous supposedly less serious injuries will pass unreported and as result their aetiology will remain unstudied (Walter et al.,1985).

To avoid the above problem and to provide a more comprehensive perspective of injury occurrence among South African high school rugby players, as compared to that offered by previous studies (Nathan et al.,1981; Roux et al.,1987; Malan & Strydom,1987), this study employed the following injury recording definition, viz.:

* Any traumatic condition resulting while competing that:

i) required first aid treatment during or after the match/ practice; and/or

ii) necessitated the complete cessation of participation in the match/practice.

In using this methodological approach the means was retained to compare corresponding results of the present study, that is, injuries of a more serious nature causing a loss of at least seven days participation, with that documented by the aforementioned studies (Nathan et al.,1981; Roux et al.,1987; Malan & Strydom,1987).

4.2 INJURY RECORDING PROCEDURES / TRIAGE PROTOCOL

To ensure the complete and accurate recording of injury data, the investigator acted as triage officer in the personal surveillance of injuries occurring throughout the season. This approach thus entailed personally monitoring daily training sessions and weekly match- fixtures in collaboration with team coaches and paramedical attendants on duty during matches.

4.2.1 INJURY RECORDING FORM

Injuries were recorded using a revised version of an injury recording form (Appendix F), which had been piloted during the preliminary study.

The injury recording form consisted of four sections and elicited the following information required for control purposes and subsequent data analysis:

Section 1 - Player Identification

- Name, age, playing position and competitive level.

Section 2 - Injury Description

- Anatomical site of the injury;
- Injury classification;
- Treatment rendered and injury disposition.

Section 3 - Aetiological Factors

- Injury status and injury onset;
- Position played when injured;
- Period of play and phase of play involved;
- How the injury occurred (mechanism);
- Condition of the playing surface;
- Footwear and protective equipment used; and
- Warm-up conditions before playing.

After completing this section of the injury recording form it was retained for filing or alternatively, if the injured player was referred to a Physician or hospital by the paramedical attendants, the injury recording form was left in the possession of the injured player or accompanying person (coach/parent) so that the examiners' report could be recorded on the reverse-side of the injury recording form (section 4).

Section 4 - Medical Report

- Specific diagnosis of the injury;
- Injury severity (expected return to participation); and
- Disposition and recommendations.

The injury recording form was then handed over to the coach or investigator by the player or accompanying person on their return to the competition venue/school.

In particular, the investigator and coaches took the following precautions in order to curtail the potential problem of under-reporting:

1. Players were informed of the injury recording procedure and the importance of reporting their injuries on the injury recording form was impressed upon them.

2. It was ensured that injuries were recorded in the following cases where injuries may easily be missed:

a) injuries sustained during practices;

b) injuries sustained during a practice or match which did not receive treatment at the time but were reported afterwards;

c) injuries sustained during competition which received treatment but the player returned to the competition thereafter.

3. It was ensured that injuries sustained during an away-match, during the last week of a term or at the end of the season, were recorded and forms handed in.

4.3 CONSIDERATION OF RULE-REVISIONS

The rules of a game play an integral part in regulating the nature and inherent risks of the particular sporting activity. It was therefore warranted to take cognizance of pertinent revisions to the rules of rugby which may have bearing on the safety-aspects of the game and which had been introduced in the interim since the original epidemiological studies (Nathan et al.,1983; Roux et al.,1987; Malan & Strydom,1987) of injuries among South African schoolboy rugby players and the period during which the present study was conducted. These revisions are detailed in Appendix G.

5. STATISTICAL ANALYSIS AND TREATMENT OF DATA

5.1 PREPARTICIPATION EVALUATION DATA

Nominal data resulting from the health history questionnaire and medical examination portions of the preparticipation evaluation were categorized into frequencies of abnormal findings. Where appropriate, significant differences between sets of nominal data were evaluated using a chi-square analysis. Where the data was of a ratio nature, standard descriptive statistics (means and standard deviations) were applied. Significant differences between sets of ratio data were evaluated using an independent t-test (Thomas & Nelson,1990).

5.2 INJURY SURVEILLANCE DATA

5.2.1 CALCULATION OF INJURY INCIDENCE

As recommended by the American Orthopaedic Society for Sports Medicine in their Manual on Sports Injury Research (Noyes et al.,1988), cognizance was taken of the participation-time that players were exposed to when determining the incidence of injury. Consequently the exposure-related injury incidence was calculated and expressed in the following two forms:

i) injuries per player-hours (i.e. number of player-hours as numerator and number of injuries as denominator); and/or

ii) injuries per 100 player-hours (i.e. number of injuries as numerator and number of player-hours as denominator multiplied by 100).

Consequently, injury incidence was calculated and expressed according to two categories of severity, namely an overall incidence and a major injury incidence.

OVERALL INJURY INCIDENCE

The overall injury incidence was derived using all injuries conforming to the adopted inclusive injury definition (as expressed in paragraph 4.1) as the denominator when expressed per player-hours and as the numerator when expressed per 100 player-hours.

MAJOR INJURY INCIDENCE

A major injury was considered as one of a more serious nature causing a loss of at least seven days participation. The major injury incidence was thus derived using only those injuries conforming to the above injury definition as the denominator when expressed per player-hours and as the numerator when expressed per 100 player-hours.

UNIT OF EXPOSURE

The unit of exposure (player-hours) in which injury incidence is expressed, was derived from the product of the number of participants involved per team and the number of hours spent participating in the activity. Thus, 15 players participating for 1 hour equals 15 player-hours.

The number of hours spent participating was calculated by combining the practice-time and the match-time. Table V presents a detailed summary of the exposure-record over the entire 14 weeks of the season for each individual team and a cumulative total for all teams.

TABLE V: INJURY SURVEILLANCE - EXPOSURE-RECORD SUMMARY

TEAM	PRACTICE HOURS+	MATCH HOURS++	PLAYER-HRS# PRACTICE	PLAYER-HRS MATCHES	PLAYER-HRS TOTAL
1st XV	46	15*	690	225	915
2nd XV	38	9	570	135	705
3rd XV	20	8	300	120	420
U/15 A	30	7	450	105	555
U/15 B	15	4	225	60	285
U/14 A	24	5	360	75	435
U/14 B	16	3	240	45	285
TOTAL	**189**	**51**	**2 835**	**765**	**3 600**

+ Practice-time recorded according to the specific frequency and duration of practice-sessions undertaken by the individual teams.

++ Match-time recorded according to the specific frequency and duration of matches played by the individual teams, with matches lasting: i) 60 min at the senior open age group (*5 matches played by the 1st XV during a tournament lasted 50 min; ii) 50 min at the U/15 age group; and iii) 40 min at the U/14 age group.

15 players participating for 1 hour equals 15 player-hours (e.g. 1st XV - where 15 players participated in 46 practice-hours results in 690 player-hours of practice).

5.2.2 IDENTIFICATION OF EXTRINSIC RISK FACTORS

The role of the following potential extrinsic risk factor variables in the aetiology of injury were evaluated:

* Match-play vs Practice
* Stage of the Season
* Playing Position
* Time of Day
* Anatomical Site
* Age Group & Competitive Level
* Phase of Play
* Period of Play
* Injury Type
* Injury Mechanism

Extrinsic risk factors were identified by comparing injury incidences among categories, expressed per 100 player-hrs or as a percentage of the injury incidence. Where appropriate, significant differences between categorical comparisons were evaluated using a chi-square analysis (Thomas & Nelson,1990).

5.2.3 IDENTIFICATION OF INTRINSIC RISK FACTORS

In the analysis of intrinsic risk factors an injury was defined as one either requiring medical referral or being severe enough to cause a loss of at least seven days from participation. On conclusion of the injury surveillance phase of the study, players incurring injuries conforming to the above definition were categorized as the exposed (injured) group while players who did not sustain such an injury were labelled as the non-injured controls. Potential intrinsic risk factors were subsequently identified by contrasting the preparticipation evaluation profiles in morphological status and muscular function of injured versus non-injured controls via independent t-tests (Thomas & Nelson,1990). The role of the following potential intrinsic risk factor variables in the aetiology of injury were evaluated:

* Stature
* Body Mass
* Relative Body Fat
* Lean Body Mass
* Somatotype
* Strength
* Endurance
* Power
* Agility
* Flexibility

5.3 CONFIDENCE LIMITS AND STATISTICAL SOFTWARE

In all statistical analyses the 95% level of confidence ($p \leq 0,05$) was applied as the minimum to interpret significant differences among sets of data (Thomas & Nelson, 1990). Computations to determine standard descriptive statistics (mean and standard deviation), analysis of variance (t-tests) and categorical analyses (chi-square) were performed using the STATGRAPHICS Software Programme Version 6.0 (1992).

CHAPTER 4

RESULTS AND DISCUSSION

1. PREPARTICIPATION EVALUATION DATA

1.1 HEALTH HISTORY / MEDICAL STATUS

A total of 78 subjects were screened by means of the health history questionnaire and voluntary medical examination. The findings from each of these screening components are presented in Tables VI-XII.

1.1.1 HEALTH HISTORY FINDINGS

As noted in Table VI, item 3 on the health history questionnaire indicated that the most frequent and significant ($p<0,05$) problem experienced by the subjects was previous musculoskeletal injury (61,5%). The second highest ranked response (55,1%) was linked to the first, namely having suffered a past injury or illness which required an x-ray; plaster-cast; sling or the use of crutches (item 10.4). Items 10.1 to 10.6 on the questionnaire essentially served to probe specific memorable events so as to obtain further information not elicited by the preceding items. As such, item 10.4 detected another eight responses indicative of previous musculoskeletal injury which, effectively, increased the latter finding to a 71,8% response.

Frequent medical consultation (37,2%), operations excluding common tonsillectomy (33,3%), previous hospitalization (28,2%) and illness or injury lasting longer than a week (23,1%) were items that generated a similar frequency of response. This finding was not unexpected as these conditions are generally inter-related.

TABLE VI: PROBLEMATIC HEALTH HISTORY FINDINGS

ITEM	AREAS PROBED / INVESTIGATED	n	%[1]
1.	Familial heart disease / sudden death	12	15,4
2.	Fainting / dizziness during exercise	1	1,3
3.	Musculoskeletal injury	48	61,5 *
4.	Loss of consciousness / concussion	17	21,8
5.	Heat-related illness	2	2,6
6.	Aerobic exercise tolerance	1	1,3
7.	Chronic illness	5	6,4
8.	Daily medication	2	2,6
9.	Problematic / loss of paired organs	8	10,3
10.1	Previous hospitalization	22	28,2
10.2	Frequent medical consultation	29	37,2
10.3	Operations (excluding tonsillectomy)	26	33,3
10.4	X-ray; cast; sling or crutches	43	55,1
10.5	Illness / injury lasting > 1 week	18	23,1
10.6	Prohibited from sports participation	1	1,3

[1] Percentage based on the number of responses recorded for each category as numerator and the total number of subjects evaluated (N=78) as denominator.

* Significance level p<0,05

Notably, previous concussion / loss of consciousness and a family history of heart disease was reported by 21,8% and 15,4% of subjects, respectively. Problems with, or the loss of one of paired organs (eyes, ears, kidneys and testicle) were reported by 10,3% of subjects, while 6,4% suffered from chronic allergy-related illness (asthma and hayfever). The remaining infrequent responses were: heat-related illness (2,6%); daily medication usage (2,6%); fainting / dizziness during exercise (1,3%) and aerobic exercise intolerance (1,3%). The single positive respondent to the last mentioned item was also grossly obese.

Finally, one subject reported a significant problem of previously being temporarily prohibited from sports participation (item 10.6) because of a diagnosed aortic stenosis. At the time of the current evaluation this condition had, however, been treated by a cardiologist and had been fully compensated for. Notably this condition was detected in the absence of a positive history of familial heart disease probed for in item 1 of the questionnaire. This suggests that in review of the questions posed on the health history, a rephrasing of item 1, in particular, to probe the subjects' cardiac history in addition to that of the family, would be prudent. The potential significance of the findings of the health history questionnaire (percentages indicated in parentheses), can be judged within the context of the following literature-based discussion of each item.

Cardiovascular Risks - Items 1 & 2 (Table VI)

A family history of cardiac problems or sudden death (15,4%), might suggest hypertrophic cardiomyopathy noted to be the most common cause of sudden death among athletes under the age of 35 years (Luckstead,1982; Maron et al., 1986). Similarly syncope or dizziness during exercise (1,3 %), is intended to screen for hypertrophic cardiomyopathy as well as various other conditions including congenital anomalies of the coronary arteries or arrhythmias (Strong & Steed,1982).

Musculoskeletal Injury - Item 3 (Table VI)

As is clear from Table VI, a history of musculoskeletal injury (61,5%) is the most common problem area detected in the PPE. A positive response to this question places the participant in a risk group that has the potential to suffer from recurrent injuries. In addition it should direct the evaluator to ask the participant as to what rehabilitation has been done and serves to direct the orthopaedic evaluation to determine residual effects of any previous musculoskeletal injury.

In particular, previous fractures and joint problems are a common finding in the PPE (Linder et al.,1981; Du Rant et al.,1985). This is confirmed by Table VII, which reflects that of the musculoskeletal injuries reported by the subjects on the health history, a significant collective proportion (65%;p<0,001) were fractures (44,8%) and joint problems (29,9%), respectively. Muscular injuries were responsible for 20,7% of all musculoskeletal injuries reported by the subjects.

It has been observed that knee and ankle injuries often recur and that, most commonly, new injuries may in fact be reinjury of a previously damaged joint or muscle (Runyan,1983; Hulse & Strong,1987). This is supported by the site-specific profile of previous musculoskeletal injuries reported by subjects (Table VIII). As such the ankle (42,3%) and knee (34,6%), were involved in a significant (p<0,01) proportion (76,9%) of all joint injuries. Previous muscle injuries occurred most frequently to the quadriceps and groin musculature (27,5% each), followed by the hamstring and calf muscles (16,7% each).

Finally, three subjects had previously suffered overuse injuries synonymous with maturing youths. These were calcaneal apophysitis (Severs' disease) and tibial tubercle apophysitis (Osgood Schlatters' disease).

TABLE VII: PREVIOUS MUSCULOSKELETAL INJURY / TYPE

INJURY TYPES (N=87)	n	%
Bone fractures	39	44,8] ***
Joint injuries	26	29,9]
Muscle injuries	18	20,7
Other	4	4,6

*** Significance level p<0,001

TABLE VIII: PREVIOUS MUSCULOSKELETAL INJURY / SITE

BONE FRACTURES (N=39)	n	%
Upper extremities	20	51,3
Lower extremities	9	23,0
Clavicle	6	15,4
Other	4	10,3
JOINT INJURIES (N=26)	**n**	**%**
Ankle	11	42,3] **
Knee	9	34,6]
Wrist	2	7,7
Neck	1	3,9
Other	3	11,5
MUSCLE INJURIES (N=18)	**n**	**%**
Quadriceps	5	27,5
Hamstrings	3	16,7
Groin	5	27,5
Calf	3	16,7
Other	2	11,0
OTHER INJURIES (N=4)	**n**	**%**
Severs' disease	2	50,0
Osgood Schlatters'	1	25,0
Back pain	1	25,0

** Significance level p<0,01

Neurological Injury - Item 4 (Table VI)

A history of traumatic neurological injury, such as concussion / loss of consciousness (21,8%), is of major importance in contact and collision sports. Gerberich (1983), using data from over 3000 high school American Football players, has emphasized that participants with a previous concussion have a four-fold greater risk of intracerebral haemorrhage. A positive response clearly indicates a need for more in-depth evaluation. The participant with a history of recurrent concussions falls into a special category in which clearance for participation requires a thorough evaluation beyond the PPE assessment (Fields & Delaney,1990).

Heat-related Illness - Items 5 & 6 (Table VI)

Heat-related illness (2,6%) poses a particular risk for participants in hot, humid conditions. It has been indicated that individuals who have suffered a bout of heat illness have an increased risk of recurrent problems (American College of Sports Medicine,1983). Whether this susceptibility relates to some intrinsic defect in their physiological ability to dissipate heat or to poor aerobic conditioning (1,3%), is evidently not always clear, but a possible positive response to item 5, motivates the inclusion of item 6 (Dyment,1986). Publicity regarding deaths of athletes with cardiovascular problems often overshadows the fact that heat-related illness may also be implicated in many cases of exercise-related sudden death - as heat stroke is a medical emergency with high mortality, unless prompt recognition and therapy are instituted (Fields & Delaney,1990).

General Health Screening - Items 7 - 9 (Table VI)

General health screening looks at acute and chronic illness/allergies (6,4%), regular medication use (2,6%) and problems with or the loss of one of paired organs (10,3%). Positive responses to these areas may alert the evaluator to specific restrictions that the participant should follow in terms of safe participation. Restriction of participation based on dysfunction or absence of paired organs and other medical illness is clarified by the recommendations of the American Academy of Paediatrics (1988) Committee on Sports Medicine (Appendix D).

1.1.2 MEDICAL EXAMINATION FINDINGS

A number of health problems were detected during the medical examination of subjects. For indicated medical abnormalities the subjects were advised to consult their primary physicians. The most frequently detected abnormalities / problems (Table IX) in ascending order, were those of the cardiovascular (7,7%), urinary (9,0%) and orthopaedic systems (33,3%).

Cardiovascular Findings

Problems of cardiovascular origin comprised common heart murmurs and arrhythmia, with none of the conditions being considered serious enough to warrant an electrocardiogram. Maximum blood pressure measurements recorded were 140/90 mm Hg. Using these values as respective systolic and diastolic upper limits, the examiners classified all subjects as normotensive. The mean resting heart rate and blood pressure values recorded are indicated in Table X.

TABLE IX: PROBLEMATIC MEDICAL EXAMINATION FINDINGS

AREA OF EXAMINATION	n	%[1]
Heart	6	7,7
Lungs	1	1,3
Eyes	2	2,3
Ears	1	1,3
Nose	3	3,9
Genitalia	1	1,3
Skin	5	6,4
Teeth	1	1,3
Urine	7	9,0
Orthopaedic	26	33,3

[1] Percentage based on the number of subjects with abnormalities for each category as numerator and the total number of subjects examined (N=78) as denominator.

TABLE X: CARDIOVASCULAR EXAMINATION PROFILE

VARIABLE	X	±	SD	RANGE
Resting HR (bpm)	68,9	±	6,9	54 - 82
Systolic BP (mm Hg)	119,9	±	10,6	95 - 140
Diastolic BP (mm Hg)	74,1	±	7,4	50 - 90
Age of subjects (Yrs)	15,6	±	1,3	13 - 18

N=78

TABLE XI: PROBLEMATIC ORTHOPAEDIC EXAMINATION FINDINGS

ORTHOPAEDIC PROBLEM	FREQUENCY
Patella pain and crepitus	11
Vastus medialis atrophy	3
Pes planus	6
Scoliosis	5
Tennis elbow	2
Inversion (talo-fibular) ankle sprain	2
Lateral collateral knee ligament laxity	1
Medial meniscus tear	1
Illio-tibial band syndrome	1
Genu valgus > 15°	1
Genu recurvatum	1
General ligamentous laxity	1
Osgood Schlatters' disease	1
TOTAL	**36**

Orthopaedic Problems

A total of 36 orthopaedic problems were detected among 26 subjects. Some subjects thus manifested more than one orthopaedic problem. The nature and frequency of these problems are reflected in Table XI. The most common problem detected was patella pain and crepitus (11) which was also accompanied by vastus medialis atrophy and patello-femoral tracking problems in three cases. Other frequent findings were pes planus (6) and scoliosis (5). One subject suspected of having a medial meniscus tear (positive Mc Murray sign) was referred to an orthopaedic surgeon, who confirmed the injury and suggested a subsequent diagnostic arthroscopy of the knee.

Urinary Findings

Results of the urine samples tested by dipstick for protein, blood and glucose yielded seven positive tests. One subject had proteinuria which was interpreted as indicative of possible abnormal kidney function. The remaining six subjects had haematuria and the examiners interpreted this as possible bilharzia infection, in view of the numerous rivers and dams in the geographic area frequently used for recreational pursuits.

Maturation Index

The degree of sexual maturation of the subjects, graded from 1 - 5 by Tanner Staging (Allman,1989) according to the extent of axial hair growth, is reflected in Table XII. In some circles the ability of the young sportsman to withstand injury is thought to be related to their physical development. Goldberg et al.(1980) has suggested that youths who are graded at stage II sexual maturation and below, are at risk for injury in collision sport when participating against more mature opponents. Although they do not consider this a contra-indication for participation, they do emphasize that such individuals should be warned of the related risk of injury. This view concurs with that of Runyan (1983), who suggests that youths who are graded below Tanner stage III should be discouraged from participating in contact sport against more developed peers.

TABLE XII: MATURATION INDEX EXAMINATION PROFILE

AGE GROUP	X	±	SD	RANGE
U / 14	2,0	±	0,7	1 - 3
U / 15	2,3	±	0,7	1 - 3
Senior	3,5	±	1,0	2 - 5

N=78

New Findings

The medical examination portion of the PPE detected a total of 50 abnormalities which were not reported on the prior health history, and as such were considered new findings. The areas of examination that detected these new findings were as follows: i) orthopaedic system (31/50 = 62%); ii) inspection and auscultation of the cardiovascular and respiratory system (6/50 = 12%); and iii) additional examination of the urine, skin and teeth (13/50 = 26%). It is clear that the orthopaedic component of the medical examination was the most valuable in yielding the majority of new findings. Although no follow-up was conducted to determine the results of further evaluation of abnormal urine samples in this study, Goldberg et al.(1980) found that none of the youths in their study had any urinary tract abnormality after referral and consultation. If those subjects with urine abnormalities in this study are excluded, then effectively the diagnostic utility of the orthopaedic evaluation in detecting new findings increases to 72%. This lends further support to the view that the orthopaedic component is the most productive portion of the PPE medical examination of prospective sports participants, although the cardiovascular examination has the potential for detecting more significant life-threatening abnormalities (Smilkstein et al.,1981; Du Rant et al.,1985; Murray,1989).

Review and Disposition

The disposition of subjects based on review of the health history and medical examination were as follows: i) unlimited participation was granted to the significant (p<0,001) majority (73 = 93,6%) of subjects screened; and ii) although none of the abnormalities detected were felt to merit immediate restriction from participation, clearance was withheld from five of the subjects on the recommendation of further evaluation for a case of proteinuria; haematuria (2 cases); an acute ankle sprain of the talo-fibular ligament; and a suspected medial meniscus injury of the knee.

In conclusion, the PPE health history and medical examination procedure demonstrated various health problems among the subjects studied. The procedure eventually led to 6,4% of the subjects evaluated, being referred for additional evaluation prior to sports participation. Whilst this figure may seem negligible, it is a similar yield to that of other PPE studies ranging from 3,2% - 6,5% (Linder et al.,1981); 6,4% (Du Rant et al.,1985) and 13,5% (Goldberg et al.,1980).

1.2 MORPHOLOGICAL STATUS AND MUSCULAR FUNCTION

The results of the morphological status and muscular function evaluation and comparative data of other researchers are presented in Tables XIII-XXXI and Figures 4.1-4.3. These results provide a range of descriptive data on morphological status and muscular function for high school rugby players.

1.2.1 MORPHOLOGICAL STATUS

Table XIII reflects the anthropometric profile of subjects evaluated with regard to stature, mass, relative body fat and lean body mass. As is evident from this table certain trends may be observed when comparing the various age groups: namely, under-17 and under-16 (open age group); under-15 and under-14 players, as a whole and in different playing positions (forwards versus backline players).

TABLE XIII: MEAN ANTHROPOMETRIC PROFILE OF SUBJECTS [1] / COMPETITIVE LEVEL AND PLAYING POSITION

TEAMS / POSITION		AGE (Yrs)	STATURE (cm)	MASS (kg)	FAT (%)	LBM (kg)
OPEN	1st	16,9	180,6	78,0 *	13,5	67,1 ***
	2nd & 3rd	16,3	176,5	69,6	15,8	58,3
	F	16,5	180,6 ***	77,0 ***	16,7	63,9 **
	B	16,4	174,0	65,8	13,4 **	56,9
U/15	-"A"	14,8	176,1 **	67,5 *	16,1 *	56,5 ***
	-"B"	14,9	169,4	61,3	19,8	48,9
	F	14,7	173,2	65,5	19,0	52,7
	B	14,9	170,6	61,8	17,5	50,8
U/14	-"A"	13,7	171,3 **	58,7	16,9	48,6 ***
	-"B"	13,3	161,7	52,0	20,2	40,8
	F	13,4	167,3	58,1	21,5	44,9
	B	13,6	164,9	51,8	15,3 *	43,9

[1] N = 125; LBM = Lean Body Mass; F = Forwards B = Backs

Significance levels * p<0,05 ** p<0,01 *** p<0,001

TABLE XIV: ANTHROPOMETRIC PROFILE [1] OF JUNIOR RUGBY PLAYERS / COMPETITIVE LEVEL AND PLAYING POSITION

LEVEL / SUBJECTS PLAYING POSITION			AGE (Yrs)	STATURE (cm)	MASS (kg)	FAT+ (%)	LBM (kg)
High School	N=10	F	17,6	180,4	82,0	12,8	71,5
Provincial		B	16,7	170,8	66,9	9,9	60,3
High School	N=32	F	17,0	176,4	78,0	13,9	67,2
1st Team		B	16,8	171,6	68,6	11,1	61,0
Prim. School	N=21	F	12,5	160,2	53,9	10,4	48,3
Provincial		B	12,5	156,6	48,5	10,3	43,5
Prim. School	N=38	F	12,3	156,5	48,1	13,7	41,5
1st Team		B	12,1	149,6	41,1	11,1	36,5

[1] Lübbert et al. (1984) F = Forwards B = Backs
+ Relative body fat derived as (Mass - LBM) ÷ Mass x 100

Stature, Mass and Lean Body Mass

A definite growth-related increase in stature, mass and lean body mass was observed with an increase in age. When comparing the competitive level, players representing the 1st team or an "A" team per age group, generally had a significantly greater stature, absolute mass and lean body mass than those in lower teams, although stature did not differ significantly (p>0,05) in the open age group. When contrasting playing position in the open age group, forwards were significantly taller and carried more absolute and lean body mass than backline players. This was also the case in the under-15 and under-14 age groups, although the differences were not significant (p>0,05). This observation concurs with that of Lübbert et al.(1984) who found the same overall tendency in an anthropometric study of schoolboys at 1st team and provincial level among both high school and primary school rugby players (Table XIV).

It would thus appear that even at school level, as is the case for senior rugby (Table XV), the typical selection policy of coaches to select those players with a superior morphological size to be forwards is well established. The logical motivation for such an approach would seem to be their potential ability to secure, retain and utilize possession of the ball. The fact that those players representing "A" teams were also generally superior in stature and mass as opposed to "B" team members, is probably also related to the above factor.

Relative Body Fat

The benefits of an increased body mass in a contact sport such as rugby is conceivable due to the associated increase in momentum. It is evident from the anthropometric profile of the present subjects (Table XIII) and from other studies (Tables XIV & XV) that among rugby players at all levels

TABLE XV: ANTHROPOMETRIC PROFILE OF SENIOR RUGBY PLAYERS / COMPETITIVE LEVEL AND PLAYING POSITION

LEVEL / POSITION	:	N	AGE (Yrs)	STATURE (cm)	MASS (kg)	FAT (%)	LBM (kg)	
National Trialists	F	27	26,5	188,0	96,2	·	·	1
	B	20	25,2	178,5	78,2	·	·	
National Team	F	·	27,0	190,1	102,6	14,6	87,6	2+
	B	·	24,6	177,7	81,1	10,7	72,4	
Provincial Finalists	F	54	23,9	188,8	101,2	15,0	86,0	3
	B	53	23,6	176,9	78,8	9,2	71,6	
Provincial Level	F	·	28,1	188,7	101,4	16,3	84,9	2+
	B	·	24,8	179,2	81,4	11,6	72,0	
Provincial/ 1st League	F	50	23,7	185,5	94,5	·	·	4++
	B	50	22,3	175,4	74,7	·	·	

[1] Smit et al.(1979); [2] Lübbert et al.(1984); [3] Barnard & Coetzee (1991); [4] Van der Walt & Oosthuizen (1980).

+ Relative body fat derived as (Mass - LBM) ÷ Mass x 100

++ Values derived from mean reported for all positions.

F = Forwards B = Backs · = Values not reported

TABLE XVI: RELATIVE BODY FAT (%) OF SUBJECTS PER AGE YEAR

AGE (Yrs)	:	X	±	SD	
13	:	22,0	±	9,7	* (13–14)
14	:	16,4	±	4,2	
15	:	18,0	±	5,7	
16	:	15,9	±	4,4	
17+	:	13,9	±	4,4	

* Significance $p<0,05$; N = 125

the greater body mass of forwards as opposed to backs, is in part due to the fact that they carry a larger amount of body fat than backline players. It may be hypothesized that, given the shock-absorbing capabilities of fat tissue, this could be advantageous as a protective mechanism against the characteristic robust and contact nature of forward play (Van der Walt & Oosthuizen,1980). It is also recognized in sport scientific circles, however, that dead weight in the form of adipose tissue is not desirable and that increased weight should preferably be in the form of lean body mass because fat does not contribute to the force production capabilities of the musculoskeletal system (Heyward,1991). In all probability the usually superior mobility and/or agility of backline players over forwards, may be directly linked to their lower levels of relative body fat, thus bearing evidence to support the latter point of view.

Obesity

It is generally believed that the advent of a mechanized society has led to a general decrease in physical activity patterns. This, together with altered nutritional habits, may have resulted in an increased prevalence of obesity among the youth. National surveys to ascertain the truth of such a concern are unfortunately lacking and thus specific norms for assessing fatness among South African youths have yet to be compiled. Concerns about the body composition of American children and youths and its association with adult obesity have, however, led to the development of standards for assessing optimal body fat content (Lohman,1987) thus providing some source of comparison. Lohman (1987) suggests the following norms for assessing relative body fat for boys aged between 6 and 17 years old:

< 6 %	-	Very Low
6 - 9 %	-	Low
10 - 20 %	-	Optimal
21 - 25 %	-	Moderately High
26 - 30 %	-	High (Mild Obesity)
> 30 %	-	Very High (Obese)

Lohman (1987) contends that although many boys increase in body fatness prior to pubescence and enter the 20-25% range, they naturally lose fat during pubescence and move into the optimal range (10-20%). This general trend is also evident among the subjects evaluated in the present study (Table XVI). Using the above norms, only the under-13 age group mean (22%) fell within the moderately high (21-25%) category with the means for the remaining age groups falling into the optimal 10-20% range of body fat.

At the same time, using 25% relative body fat as the cut-off point for obesity the significant ($p<0,001$) majority (92%) of the subjects evaluated would have been classified as normal and only 8% as mildly obese (26-30%) or obese (>30%). Being a physically active group of subjects, this figure is lower than the ± 14% prevalence of obesity suggested by Lohman (1987) to be typical of the general population of male youths. Fortunately 60% of those judged accordingly as mildly obese or obese, were in early pubescence, aged 13-14 years old. This augurs in their favour as it is generally believed that obese individuals who are nearing young adulthood, are the ones most at risk for developing heart disease, hypertension and diabetes (Rowland,1990). In the final judgement, the youths evaluated in this study appeared to have a fairly sound health and fitness status with respect to the prevalence of obesity.

Somatotype

The descriptors of physique associated with participation in particular sports has been an active field of study. Questions that may be raised in this regard, is whether rugby players have a characteristic somatotype and if differences exist between levels of play (senior versus junior) and playing position. Research conducted thus far among senior South African players (Table XVII) and foreign rugby playing countries (Table XVIII), has indicated that rugby players have physiques which are dominated by musculoskeletal robustness (mesomorphy) with varying degrees of relative fatness (endomorphy) or linearity (ectomorphy). Smit et al.(1979) found that among the Springbok trialists of 1976 both forwards (3.8-6.1-1.6) and backline players (2.6-5.7-2.0) were endo-mesomorphs. Van der Walt and Oosthuizen (1980) found the same somatotype categories (forwards: 4.6-4.8-1.9; backs: 3.1-4.6-2.1) among a combination of provincial and first league players. Overseas researchers (Bell,1973; Reilly & Hardiker,1981) have also reported a dominant endo-mesomorphic somatotype for Welsh and British students respectively, while Boennec et al.(1980) found that although French forwards were endo-mesomorphic, backline players were balanced mesomorphs.

A more disciplined approach in physical preparation and/or an adaptation to the dynamic running nature of the game since the introduction of increased points for scoring tries in the last decade may, however, be reflected in the somatotypes documented for rugby players in more recent studies. Withers et al.(1986) found a somatotype of 2.3-5.6-2.4 for provincial players in Australia and in South Africa, Barnard and Coetzee (1991) have reported a similar move away from endo-mesomorphy towards ecto-mesomorphy for both forwards (2.8-6.6-3.4) and backline players (2.1-6.0-2.3) participating at provincial level in the Currie Cup Final from 1981-1986.

TABLE XVII: SOMATOTYPE PROFILE OF SENIOR RUGBY PLAYERS / COMPETITIVE LEVEL AND PLAYING POSITION

LEVEL / POSITION	: :	N	AGE (Yrs)	ENDO - MORPHY	MESO - MORPHY	ECTO - MORPHY
SA National Trialists	F	27	26,5	3.8	6.1	1.6 [1]
	B	20	25,2	2.6	5.7	2.0
	C	47	25,9	3.2	5.9	1.8
Provincial Finalists	F	54	23,9	2.8	6.6	3.4 [2]
	B	53	23,6	2.1	6.0	2.3
	C	107	23,8	2.5	6.3	2.9
Provincial/ 1st League	F	50	23,7	4.6	4.8	1.9 [3+]
	B	50	22,3	3.1	4.6	2.1
	C	100	23,0	3.9	4.7	2.0

[1] Smit et al. (1979); [2] Barnard & Coetzee (1991); [3+] Van der Walt & Oosthuizen (1980) - values derived from mean for all positions.

F = Forwards B = Backs C = Combined F & B

TABLE XVIII: SOMATOTYPE PROFILE OF FOREIGN RUGBY PLAYERS / COMPETITIVE LEVEL AND PLAYING POSITION

LEVEL / POSITION	: :	N	AGE (Yrs)	ENDO - MORPHY	MESO - MORPHY	ECTO - MORPHY
South Australia Provincial	C	16	25,3	2.3	5.6	2.4 [1]
British Student Club Champions	C	28	18-22	3.6	5.4	2.1 [2]
Welsh Students 1st League	F	·	·	4.5	5.0	2.5 [3]
	B	·	·	4.0	5.0	2.5
French Players	F	·	·	3.0	6.0	1.0 [4]
	B	·	·	2.5	5.0	2.5

[1] Withers et al. (1986); [2] Reilly & Hardiker (1981); [3] Bell (1973); [4] Boennec et al. (1980). · = Not reported

F = Forwards B = Backs C = Combined F & B

With regard to junior South African rugby players, Desipres et al.(1982) have studied the somatotypes of two provincial high school teams (N=31). They found that the forwards were endo-mesomorphic and backline players rated as balanced mesomorphs. De Ridder (1993) conducted a comprehensive study comparing the morphology and somatotypes of elite South African primary and high school rugby players participating in the Craven Week. He found that elite primary school players were ecto-mesomorphic (forwards and backs) and high school forwards and backs were endo-mesomorphic and balanced mesomorphs, respectively. The present study contributes to somatotype research by providing data for a general population of high school rugby players.

When considering the somatotypes of all the subjects evaluated (Table XIX), the mean somatotype category in each age group, irrespective of playing position, was found to be ecto-mesomorphic (under-14 players: 2.7-4.9-3.7; under-15 players: 2.9-4.9-3.2; and open players: 2.7-5.0-3.0). Similarly, with the exception of the open age group where forwards were endo-mesomorphic (3.2-5.2-2.7), there was no further distinction between forwards and backline players across all age groups with regard to their overall somatotype classification as ecto-mesomorphs.

Table XX presents a detailed positional analysis of the anthropometric profile and somatotypes of the 1st XV rugby team only. Considering the somatotypes of the team as a whole, players were found to be balanced mesomorphs (2.6-4.8-2.6) but according to playing position, forwards were endo-mesomorphic (3.0-5.0-2.3) and backline players were ecto-mesomorphic (2.2-4.6-3.0). When taking the analysis further to distinguish between specific playing positions some notable results were found, with the forwards as a unit displaying some typically expected physical characteristics as opposed to the backline players.

TABLE XIX: SOMATOTYPE PROFILE OF SUBJECTS [1] / COMPETITIVE LEVEL AND PLAYING POSITION

TEAMS / POSITION		AGE (Yrs)	ENDO - MORPHY	MESO - MORPHY	ECTO - MORPHY
OPEN 1st	:	16,9	2.6	4.8	2.6
2nd	:	16,5	2.7	5.2	2.6
3rd	:	16,1	2.8	5.0	3.3
F	:	16,5	3.2	5.2	2.7
B	:	16,4	2.2	4.8	3.2
C	:	16,5	2.7	5.0	3.0
U/15 -"A"	:	14,8	2.4	4.9	3.2
-"B"	:	14,9	3.2	4.9	3.1
F	:	14,7	3.0	4.9	3.1
B	:	14,9	2.8	4.8	3.2
C	:	14,9	2.9	4.9	3.2
U/14 -"A"	:	13,7	2.5	4.7	3.8
-"B"	:	13,3	3.0	5.0	3.5
F	:	13,4	3.3	5.0	3.4
B	:	13,6	2.1	4.7	3.9
C	:	13,5	2.7	4.9	3.7

[1] N = 125 F = Forwards B = Backs C = Combined F & B

TABLE XX: MORPHOLOGICAL AND SOMATOTYPE PROFILE OF FIRST - XV TEAM SUBJECTS / PLAYING POSITION

PLAYING POSITION	STATURE (cm)	MASS (kg)	FAT (%)	SOMATOTYPE ENDO MESO ECTO
Forwards	**183,8**	**84,4**	**14,3**	**3.0 - 5.0 - 2.3**
Eighth-man	187,0	87,6	15,0	3.0 - 5.0 - 2.5
Flankers	184,0	81,0	10,5	1.8 - 5.0 - 2.8
Locks	190,5	80,0	12,9	2.8 - 3.5 - 4.0
Hooker	175,0	76,0	16,0	3.5 - 5.0 - 1.0
Props	179,5	94,7	18,3	4.3 - 6.5 - 0.8
Backline	**177,1**	**70,6**	**12,7**	**2.2 - 4.6 - 3.0**
Fullback	171,0	66,2	12,0	2.0 - 5.5 - 2.5
Wingers	185,5	78,8	11,5	2.0 - 4.0 - 3.3
Centres	172,8	68,4	14,2	2.5 - 5.3 - 2.5
Fly-half	177,0	61,0	10,9	1.5 - 2.5 - 4.5
Scrum-half	175,5	72.5	14,5	3.0 - 6.0 - 2.5
Overall Mean	**180,6**	**78,0**	**13,5**	**2.6 - 4.8 - 2.6**

Props (4.3-6.5-0.8) - showed the highest degree of both endomorphy and mesomorphy and the lowest ectomorphy rating. This corresponds with the fact that they had the greatest body mass and fat percentage of all players.

Hooker (3.5-5.0-1.0) - similar to the props in the front row, the hooker showed the second highest degree of endomorphy and the second lowest ectomorphic rating of all players. This corresponds with the fact that he was the shortest and had the second highest fat percentage among the forwards.

Locks (2.8-3.5-4.0) - were distinct from the other forwards in being dominant ectomorphs and having the lowest mesomorphy rating. This corresponds with the fact that they were the tallest of all players.

Flankers (1.8-5.0-2.8) - were distinct from the other forwards in being ecto-mesomorphs, thus showing the lowest degree of endomorphy and correspondingly lowest fat percentage among the forwards.

Eighth-man (3.0-5.0-2.5) - was related to the other loose-forwards in showing a similar degree of mesomorphy but differed from them in having a higher endomorphic and lower ectomorphic rating, probably as a result of having a higher fat percentage than the flankers.

Fullback (2.0-5.5-2.5) - of the backline players, the fullback showed the second highest degree of mesomorphy and was the shortest.

Wings (2.0-4.0-3.3) - of the backs, the wings showed the second highest degree of ectomorphy, were the tallest and had a similar fat percentage to the fullback.

Centres (2.5-5.3-2.5) - were distinct from the other backs in being balanced mesomorphs. Correspondingly, they were the shortest and had the highest fat percentage of the backs, excluding the fullback and scrum-half, respectively.

Fly-half (1.5-2.5-4.5) - showed a unique physique among the backs, in being the only dominant ectomorph and having the lowest fat percentage. Additionally, the fly-half had the highest and lowest rating of ectomorphy and mesomorphy respectively, as well as the lowest body mass of all players in the team.

Scrum-half (3.0-6.0-2.5) - was distinct from the other backs in being an endo-mesomorph, having the highest fat percentage and yet still showing the highest degree of mesomorphy - thus having a somatotype more typical of the forwards in the team.

When comparing the somatotypes for the 1st XV high school rugby team per playing position (Table XX) with that determined for senior rugby players of a combined provincial and first league level (Van der Walt & Oosthuizen,1980), a marked contrast is evident. According to the latter study all players, irrespective of playing position, fell into the endomorph-mesomorph or endo-mesomorph areas of the somatochart. As mentioned earlier, both Desipres et al.(1982) and De Ridder (1993) reported the somatotypes of provincial high school forwards as endo-mesomorphic and backline players as balanced mesomorphs, while a study among senior provincial rugby players (Barnard & Coetzee,1991) found both forwards and backs to be ecto-mesomorphic. The present somatotype analysis for 1st team high school rugby players, thus tends to correspond with the former studies (Desipres et al.,1982; De Ridder,1993) with respect to the forwards and with the latter study (Barnard & Coetzee,1991) with regard to backline players.

1.2.2 MUSCULAR FUNCTION

FIELD-TEST DATA

Table XXI below, reflects the results of various field-tests used to evaluate isotonic / dynamic muscle function.

TABLE XXI: MEAN DYNAMIC MUSCLE FUNCTION SCORES OF SUBJECTS / COMPETITIVE LEVEL AND PLAYING POSITION

TEAMS / POSITION	: AGE : (Yrs)	AGILITY [1] (sec)	POWER [2] (cm)	STRENGTH/ENDURANCE [3/4] (PU 60s)	(SU 60s)
OPEN 1st	16,9	6,7] ***	49,7] *	36,3] *	41,1
2nd & 3rd	16,3	7,1	46,7	30,5	38,9
F	16,5	7,1] *	46,5] *	29,2] *	38,3
B	16,4	6,6	49,9	35,6	41,0
C	16,5	7,0	47,7	32,4	39,7
U/15 -"A"	14,8	6,8] *	48,3] ***	33,0] ***	43,1
-"B"	14,9	7,1	39,7	22,0	41,3
F	14,7	7,0	42,2	26,7	42,1
B	14,9	7,1	44,3	25,5	41,9
C	14,9	7,1	43,2	26,1	42,0
U/14 -"A"	13,7	7,0] **	41,7] *	22,2	46,1] **
-"B"	13,3	7,5	35,6	22,1	35,9
F	13,4	7,4	37,8	20,4	38,3
B	13,6	7,2	39,3	24,1	43,5
C	13,5	7,3	38,5	22,4	40,9

[1] Zig-Zag run (time - sec) [2] Vertical Jump (distance in cm)
[3] Push-ups (reps in 60 sec) [4] Sit-ups (reps in 60 sec)
F = Forwards B = Backs C = Combined F & B N = 125

Significance levels * $p<0,05$ ** $p<0,01$ *** $p<0,001$

Agility and Power

In essence, agility and muscle power are two variables of muscle function that are closely related. Agility is defined as the ability to change the direction of the body or parts of the body rapidly (Baumgartner & Jackson,1987). In turn, power may be defined similarly as the ability to exert a large force rapidly, and is thus a combination of strength and speed, requiring that a sportsman stop, start or change direction rapidly (Blum,1985).

The inter-relation between agility and power is borne out in the present results (Table XXI), in that members representing "A" teams, across all age groups, proved to possess significantly more agility and muscle power than their counterparts in "B" teams. When comparing forwards with backline players with regards to both agility and power, only the open age group showed any significant differences, with backs scoring a lower mean time on the agility run and achieving a greater vertical jump distance. This finding may be explained by the fact that the lower relative body fat observed for backs as opposed to forwards (Table XIII) was most significant at the open age group level, and serves to support the contention that excess fat hampers the mobility (agility) and musculoskeletal force production (power) capabilities of the body.

Upper-body Muscle Strength / Endurance

Members representing "A" teams at open and under-15 level proved to possess significantly greater upper-body strength/endurance than those in "B" teams. The under-14 age group was an anomalous exception to this, despite the "A" team having a significantly greater lean body mass and related lower body fat than the "B" team (Table XIII), although the latter was not significant ($p>0,05$).

Contrary to what one would expect as regards strength, when comparing forwards with backline players the latter were able to perform more push-ups in 60 seconds at the under-14 level, and significantly more at the open age-group (Table XXI). This finding may be as a result of the greater body mass that the forwards have to support when repeatedly performing a push-up exercise over a set period of time. This is indicative of the typical inherent weakness of field-tests in discriminating between pure muscle strength and endurance.

Abdominal Muscle Strength / Endurance

Members representing "A" teams, across all age groups, proved to possess greater abdominal strength/endurance than those in "B" teams, although only the difference at the under-14 age group was significant. When comparing forwards with backline players at the open and under-14 level, the backs appeared to have superior abdominal endurance in performing a greater number of sit-ups in 60 seconds, while at the under-15 level the vice-versa occurred. None of these differences were, however, significant ($p>0,05$).

Comparison to Age-Specific Norms

In comparing age-specific norms published in the literature for the utilized field-tests of dynamic muscle function (Table XXII), with the performance of subjects in the current study (Table XXIII), the following is evident:

The subjects of this study were superior for all ages as regards power and agility, the latter possibly being related to the standardized footwear (rugby boots) which provided traction benefits on the grass surface. The subjects of this study were inferior in upper-body strength/endurance in all but one instance (16 year-olds), which is a disconcerting finding. The the subjects of this study were superior or equal to the norm for abdominal strength/endurance in all cases, but one (17 year-olds). This latter finding may be indicative of a decline in abdominal strength/endurance for senior players among the high school rugby players studied, probably as a result of neglecting specific training to prevent age-related atrophy of the abdominal musculature.

TABLE XXII: DYNAMIC MUSCLE FUNCTION NORMS / AGE

AGE (Yrs)	:	AGILITY [1] (sec)	POWER [2] (cm)	STRENGTH/ENDURANCE [3/4] (PU 60s)	(SU 60s)
< 14	:	8,4	28	20	36
14 - 16	:	7,9	41	32	40
17 +	:	7,7	48	38	43

[1] Zig-Zag run - After Baumgartner & Jackson (1987) - values represent the 50th percentile / age-year. [2] Vertical Jump
[3] Push-ups / [4] Sit-ups in 60 seconds - After Kibler (1990).

TABLE XXIII: MEAN DYNAMIC MUSCLE FUNCTION SCORES [1] / AGE

AGE (Yrs)	:	AGILITY (sec)	POWER (cm)	STRENGTH / (PU 60s)	ENDURANCE (SU 60s)
13	:	7,4 +	36 +	18 -	37 +
14	:	7,1 +	42 +	27 -	45 +
15	:	7,1 +	43 +	27 -	41 +
16	:	7,0 +	47 +	32 =	40 =
17+	:	7,0 +	49 +	32 -	39 -

In comparison to published norms (Table XXII): [1] N = 125

= denotes that an equivalent score was attained by subjects
+ denotes that a superior score was attained by subjects
- denotes that an inferior score was attained by subjects

Gross-Flexibilty - Lower-back / Hamstrings

The results of the Standing Trunk-flexion test, utilized for evaluating gross-flexibility of the lower-back and hamstrings, are presented in Table XXIV. In interpreting the range of motion achieved in the test, a critical fail or pass distinction was made with regards to the scores of each subject, viz.:

i) a score of 0 or 1 was considered a failure; and
ii) a score of 2 - 5 was considered a pass.

This critical pass-criteria (i.e. subjects being able to touch their toes with the fingertips), is in accord with that originally proposed for the flexibility component in the Kraus-Weber tests of minimum muscular fitness (Kraus & Hirschland,1954). They propagated that this particular test indicated a minimum level of flexibility, below which the functioning of a healthy body as a whole seems to be impaired.

As is evident from the results (Table XXIV), the significant (p<0,001) majority of the subjects (73,6%) passed the test, thus indicating a satisfactory degree of gross lower-back and hamstring flexibility. Additionally, an age variation in the range of motion achieved by the subjects was observed, which could probably be attributed to typical growth-related factors, i.e. accelerated bone growth as opposed to slower concomitant musculo-tendinous growth (Micheli,1979; Leard, 1984). As such, there appeared to be an increase to peak flexibility from the age of 13 (68,7% pass rate) to that of 14 and 15 years old (79,2 and 80,0% pass rate). Thereafter, at the age of 16, flexibility decreased (62,5% pass rate) and then increased again at the age of 17 years (73,1% pass rate).

TABLE XXIV: LOWER-BACK/HAMSTRING FLEXIBILITY SCORES / AGE

AGE (Yrs)	**FREQUENCY (%) OF RANGE OF MOTION SCORES** [1] (N = 125)							
	0	**1**	**FAIL+**	**2**	**3**	**4**	**5**	**PASS++**
13	12,4	18,8	31,2	50,0	18,8	-	-	68,8
14	8,3	12,5	20,8	50,0	20,9	8,3	-	79,2
15	5,7	14,3	20,0	51,4	20,0	8,6	-	80,0
16	16,7	20,8	37,5	37,5	16,7	8,3	-	62,5
17+	7,7	19,2	26,9	34,6	19,2	15,4	1,0	73,1
MEAN (%)	9,6	16,8	26,4	44,8	19,2	8,8	0,8	73,6***

[1] As evaluated by the Standing Trunk-flexion Test, where:

0 = Fingers not in line with the maleolli;
1 = Fingers are in line with the maleolli;
2 = Fingertips touching the toes;
3 = All fingertips touching the floor;
4 = All fingers (but not palms) touching the floor; and
5 = Palms flat against the floor.

\+ Fail = a score of 0 or 1; ++ Pass = a score of 2 - 5.

*** Significance level p<0,001

Gross-Flexibilty - Bilateral Shoulders

The results of the Apley Scratch-test, utilized for evaluating bilateral gross-flexibility of the shoulders, are presented in Table XXV. As in the previous flexibility test, a general increase in range of motion of the shoulders was observed with increasing age from 13-15 years of age. Thereafter, range of motion tended to decrease somewhat at the ages of 16 and 17 years.

Concomitant to this general age-related increase in range of motion, an increase in the frequency of asymmetry for bilateral shoulder flexibility was also observed as subjects got older. In this instance, asymmetry was interpreted as the range of motion of the right side not being equivalent to the range of motion of the left side. The significant ($p<0,001$) majority of subjects were more flexible in their right shoulder than the left shoulder. That is, 73,6% of subjects were able to overlap their fingers with the right shoulder in external rotation and the left in internal rotation, as opposed to 51,2% of subjects for the vice-versa position. Given that 88% of the subjects were right-dominant in their upper-limbs (as determined by throwing preference), a plausible deduction may thus be made that subjects were more flexible in their dominant shoulder than the non-dominant.

ISOMETRIC / STATIC DYNAMOMETRY

Absolute Grip Strength

Table XXVI reflects that, as would be expected, there was a clear age-related increase in absolute grip strength among the subjects, ranging from a mean 30,5 kg for 13 year-olds to 51,9 kg for 17 year-olds. No significant differences

TABLE XXV: BILATERAL SHOULDER FLEXIBILITY SCORES / AGE

AGE (Yrs)	LIMB++	FREQUENCY (%) OF ROM SCORES [1] 1	2	3	FREQUENCY (%) OF ASYMMETRY+
13	RS	18,8	25,0	56,2	25,0
	LS	31,2	18,8	50,0	
14	RS	4,2	12,5	83,3	37,5
	LS	16,7	25,0	58,3	
15	RS	5,7	8,6	85,7	42,9
	LS	17,1	22,9	60,0	
16	RS	4,2	29,2	66,6	58,3
	LS	29,2	37,5	33,3	
17+	RS	3,8	30,8	65,4	50,0
	LS	26,9	23,1	50,0	
MEAN (%)	RS	6,4	20,0	73,6 ***	44,0
	LS	23,2	25,6	51,2	

[1] Range of motion (ROM) evaluated by the Apley Scratch Test
where: 1 = Fingers not touching;
2 = Fingers are touching; and
3 = Fingers are overlapping.

++ RS = right external rotation and left internal rotation;
LS = left external rotation and right internal rotation.

\+ ROM of the right side not equivalent to the left side.

*** Significance level p<0,001; N = 125

(p>0,05) were observed between left and right grip strength across all ages. Given that 88% of the subjects were right-dominant in their upper-limbs (as determined by throwing preference), this finding is a positive one indicating the absence of any significant asymmetry or contralateral strength imbalance.

Compared to age-specific norms (Table XXVII), the present subjects constantly achieved higher absolute left and right grip strength scores for all ages. It would thus appear that schoolboys who play rugby have superior upper-body isometric strength as compared to a general population of the same age. This finding may, however, be related to possible variations in the grip-size adjustment and type of dynamometer used in the present study (Takei Kiki), and that used in compiling the norms (Smedley Dynamometer).

Relative Grip Strength

When considering the relative grip strength of subjects (Table XXVI - mean of left and right measures expressed as a percentage of body mass), there was a significant increase in the mean for 13 year-olds (55,0%) to that of 14 year-olds (66,3%). For all other ages, this mean ratio was fairly constant at ± 66-68%.

In comparison to the norm suggested by Kibler (1990) - that absolute grip strength should be 60% of body mass for all ages, the present results surpassed this value in all but one instance (55,0% for 13 year-olds). It would thus appear as if the 13 year-old rugby players evaluated in this study, were weaker as regards relative grip strength when compared to older players and the suggested norm. Alternatively, the suggested norm may be somewhat stringent, and further research into this aspect may verify the efficacy of this contention.

TABLE XXVI: MEAN ABSOLUTE AND RELATIVE GRIP STRENGTH / AGE

AGE (Yrs)	:	L-HAND (kg)	R-HAND (kg)	MEAN L & R HAND (% Body Mass)
13	:	30,5	29,8	55,0 ⌉
14	:	37,6	37,6	66,3 ⌋ ***
15	:	44,4	43,7	68,4
16	:	45,8	46,2	68,1
17+	:	51,9	52,3	68,4

*** Significance level p<0,001; N = 125

TABLE XXVII: ABSOLUTE[1] AND RELATIVE GRIP STRENGTH NORMS/AGE

AGE (Yrs)	:	L-HAND (kg)	R-HAND (kg)	RELATIVE [2] (% Body Mass)
13	:	22,51 +	24,44 +	60 -
14	:	26,22 +	28,42 +	60 +
15	:	30,88 +	33,39 +	60 +
16	:	36,39 +	39,37 +	60 +
17+	:	40,96 +	44,74 +	60 +

In comparison to scores of subjects (Table XXVI):
+ denotes that a superior score was attained by subjects.
- denotes that an inferior score was attained by subjects.
[1] After Nelson & Johnson (1979); [2] After Kibler (1990).

On the whole, the subjects generally performed better than the norms (Table XXVII) suggested for both absolute and relative grip strength. This is in contrast to the earlier observation (Table XXIII), where the subjects generally performed poorer than the norm (Table XXII) for upper-body isotonic strength/endurance (push-ups in 60 sec.).

ISOKINETIC DYNAMOMETRY

Two of the essential goals in isokinetic assessment of muscular function are to identify asymmetry or weakness. Such data is important for a number of reasons, including:

i) the prevention of injuries due to muscle imbalance;

ii) ascertaining specific goals for resistance training programmes; and

iii) providing guidelines for orthopaedic rehabilitation and for resuming sports participation after injury.

With respect to rehabilitation in particular, if a patient has bilateral problems or a chronic unilateral problem that causes bilateral disuse atrophy, the uninvolved limb cannot be used to establish goals for the injured limb; thus normal data is needed.

The limited isokinetic research that has been conducted in South Africa thus far (Coetzee,1984; Davimes & Levinrad, 1990; Barnard & Coetzee, 1991; Krüger et al.,1992) and the majority of isokinetic data published elsewhere, has utilized the Cybex Dynamometer as research tool. Additionally, these studies have concentrated on populations which were either participating in other activities or were of a different age range than the subjects of the present study. As such, comprehensive isokinetic data has yet to be reported for South African youths and for high school rugby players, in particular. In this context the results of the current study, conducted using an Akron Isokinetic Dynamometer - which due to its affordability is becoming increasingly utilized in South Africa, provide a valuable source of information for the clinician working with a similar population of schoolboys.

One hundred and three high school rugby players were screened for bilateral isokinetic (60°/s) knee extensor (quadricep) and flexor (hamstring) torque generating capabilities and muscle imbalances. Of those evaluated, 33 subjects reported a previous or current complaint/injury of the knee joint or thigh musculature. Consequently, their results were excluded from the analysis of the main body of data presented here, for healthy subjects (N=70) stratified into five chronological age categories, viz.: 13 years (n=6); 14 years (n=14); 15 years (n=21); 16 years (n=12); and 17+ years (n=17).

Dominant versus Non-dominant Leg Strength

The vast majority (88,6%) of the subjects were right-leg dominant (as defined by kicking preference). It was thus considered that contrasting the dominant and non-dominant limbs as opposed to right and left limbs would be more sensible for analytical purposes. In addition, this approach has been followed in most research reports, except for studies which failed to determine this variable.

The results of numerous early isokinetic evaluations have documented significant differences between dominant and non-dominant limbs when testing different populations at various speeds, viz.:

i) 7-15 year-old boys and girls at 30°/s (Alexander & Molnar,1973; Molnar & Alexander,1974); ii) young male and female adults at 30°/s (Goslin & Charteris, 1979); iii) 25-34 year-old adult men at 60-300°/s (Wyatt & Edwards,1981); and iv) 18-24 year old inter-collegiate American Football players being tested at 90-300°/s (Stafford & Grana,1984) also demonstrated significant differences between dominant and non-dominant limbs for mean quadricep torque, but not for hamstrings.

Considering these respective reports, one might have expected to find dominant-limb values to be greater than non-dominant. Yet in the present study, when comparing the peak quadricep and hamstring torque and hamstring/quadricep ratio for the dominant versus non-dominant limbs across all ages, no significant differences (p>0,05) were found. While in contrast with the previously cited reports, this finding was in accord with that of other reports dealing with more comparable populations. To this effect, Gilliam et al.(1979a) and Parker et al.(1983), testing at 30 and 54°/s respectively, found no differences between left and right limbs among 15-18 year-old high school American Football players. Similarly Holmes and Alderink (1984), testing high school pupils aged 15-18 years at the same speed as this study (60°/s), found no significant differences between dominant (kicking preference) and non-dominant limbs.

In view of the results of this study and that of the cited studies dealing with the issue of dominant versus non-dominant leg strength, one could deduce that while significant differences may generally be present in male adult populations, this does not seem to be the case in younger male populations between 13 and 18 years old.

Holmes and Alderink (1984) make a valid comment in pointing out that the discrepancies observed with regards to dominant versus non-dominant leg strength may possibly be attributed to differing definitions of dominance used by the various authors. As in the current study, some researchers (Wyatt & Edwards,1981; Holmes & Alderink,1984) have logically defined it as the leg preferred for kicking, while others have described it as the stronger limb (Goslin & Charteris,1979) or did not specify how dominance was determined (Alexander & Molnar,1973; Molnar & Alexander,1974). Clearly a consistent definition of dominance should be established to make the interpretation of comparative research findings meaningful.

Absolute Isokinetic Strength

Table XXVIII and Figure 4.1 present the dominant-limb values (mean ± SD) for absolute peak quadricep and hamstring torque and the hamstring/quadricep ratio of subjects evaluated in this study. As can be observed, the mean quadriceps torque was greater than the mean hamstring torque for all ages. With the exception of the 13 year-old subjects, the observed superior mean quadriceps torque as opposed to mean hamstring torque across age categories, proved to be a statistically significant finding. This was a generally expected result, although it would appear that the dominance of the knee extensors over the flexors at a young age is not that marked. However, the relatively small subject number in the 13 year-old group may also have contributed to this spurious finding.

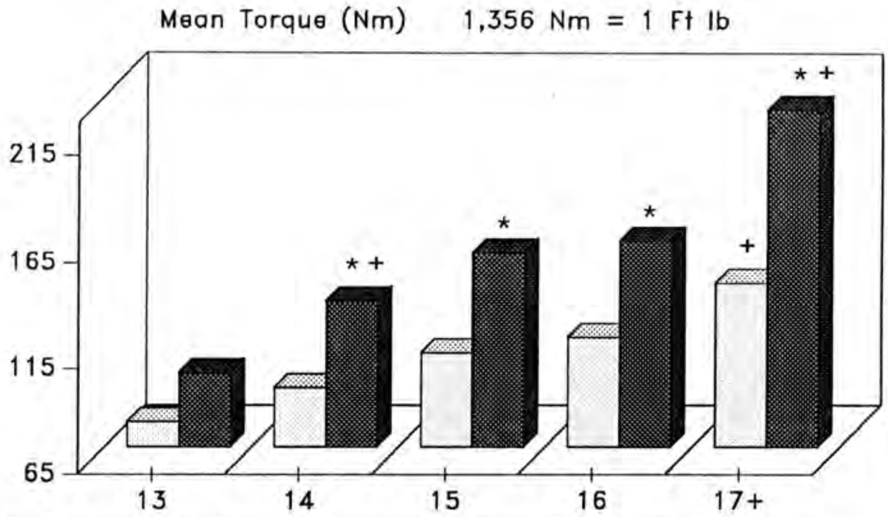
An overall pattern of increasing mean peak quadricep and hamstring torque was observed with age, although only the increments between the ages of 13 and 14 years for quadricep strength and between 16 and 17 years for both quadricep and hamstring strength were statistically significant. This finding is in general agreement with that of Miyashita and Kanehisa (1979) who tested a large group of healthy 13-17 year-olds. Their data demonstrated a linear increase in isokinetic knee-extensor muscle strength for 13-16 year old boys, while significant strength differences for girls were noted only between 13 and 14 years of age. Other investigators have also reported such age-related differences in the isokinetic strength of knee extensors and flexors among 15-18 year old (high school) American Football players (Gilliam et al.,1979a; Parker et al.,1983). Similarly, other studies have noted isokinetic knee strength differences in children aged 7-15 years old (Alexander & Molnar,1973; Molnar & Alexander,1974; Gilliam et al.,1979b). Unfortunately these studies were conducted

TABLE XXVIII: PEAK DOMINANT-LIMB ISOKINETIC KNEE EXTENSION/ FLEXION TORQUE AND HAMSTRING/QUADRICEPS RATIO

AGE :	**PEAK TORQUE Nm** (Ft lb)		**RATIO %**
(Yrs) :	**Quadriceps (Q)**	**Hamstrings (H)**	**H / Q**
13	**100,0 ± 29,8** (73,7 ± 22,0)	**76,9 ± 20,8** (56,7 ± 14,7)	77,7 ± 6,0
14	**134,2 ± 29,8** (99,0 ± 22,0)	**93,0 ± 21,7** (68,6 ± 16,0)	69,9 ± 9,6
15	**156,8 ± 37,4** (115,0 ± 27,6)	**109,5 ± 28,5** (80,8 ± 21,0)	70,2 ± 10,1
16	**162,3 ± 24,2** (119,7 ± 17,9)	**116,8 ± 23,0** (86,1 ± 17,0)	68,0 ± 8,8
17+	**223,6 ± 46,0** (164,9 ± 33,9)	**142,6 ± 28,3** (105,2 ± 20,9)	64,2 ± 6,2

N = 70 ; 1 Ft lb = 1,356 Nm

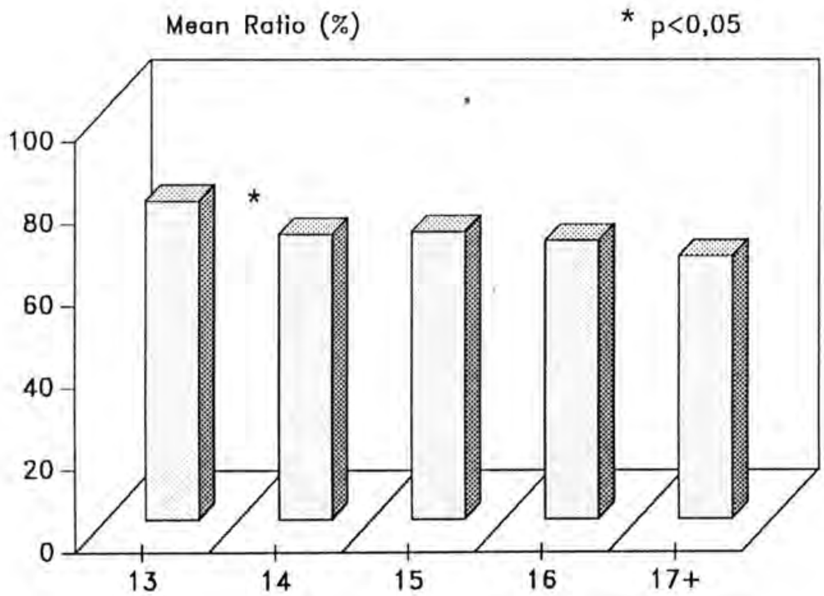
FIGURE 4.1: ABSOLUTE QUADRICEP AND HAMSTRING TORQUE / AGE



	13	14	15	16	17+
HAMS	76.9	93	109.5	116.8	142.6
QUADS	100	134.2	156.8	162.3	223.6

* Q > H ; + Q > Q & H > H Previous Age Category ($p<0,05$)

FIGURE 4.2: IPSILATERAL HAMSTRING / QUADRICEP RATIO / AGE



	13	14	15	16	17+
H/Q RATIO	77.7	69.6	70.2	68	64.2

at a time when isokinetic protocols suggested slower speeds of testing than the more recently recognized methodological approach employed in this study, of using 60°/s for strength testing (Davies,1987). This shift in accepted isokinetic protocol precludes a direct comparison of the torque values found in their studies with that documented in this study.

Ipsilateral Muscle Ratio

The ipsilateral antagonist/agonist torque ratio within an individual limb is considered a key value to evaluate in isokinetic testing. The rationale is that an imbalance between antagonist muscles may cause the weaker muscle group to be more vulnerable to stress. According to Osternig (1986), a wide range of values (43-90%) have been reported for the strength ratio of the knee flexor versus extensor muscles, each being specific to the predetermined isokinetic speed of testing and specific to the age and activity profile of the subjects evaluated.

Early investigations maintained that the mean flexor torque was approximately 50% of the extensor muscles (Hislop & Perrine,1967; Moffroid et al.,1969). Later a 60% hamstring to quadricep (H/Q) ratio was proposed (Coplin,1971; Scudder,1980) and based on the findings of various researchers reflected below, this latter value subsequently gained widespread acceptance and clinical application. In a general non-sporting population, Wyatt and Edwards (1981) documented a 72% and 71% H/Q ratio at 60°/s, among 24-35 year old male and female adults, respectively. Similarly, Davies (1987) suggests a 60-69% ratio for 15-40 year-old males and females at 60°/s. Ratios reported by Holmes and Alderink (1984) for boys and girls aged 15-18 ranged from 55-60% at 60°/s. A number of studies have focussed on H/Q ratios for American Football players of various ages and competitive levels. Davies et al.(1981), testing professional players at 45°/s found a 61% ratio. Stafford and Grana (1984) tested inter-collegiate players 18-24 years of age at 90°/s and found a ratio of 68%. Among groups comparable in age to the subjects used in this study, Gilliam et al.(1979a) and Parker et al.(1983) found H/Q ratios of 60% and 56%, when testing 15-18 year old high school players at respective speeds of 30 and 54°/s. Finally Schlinkman (1984), also evaluating high school players, but testing at a speed of 60°/s and correcting for the effect of gravity in flexion and extension, found a H/Q ratio of 54%.

In focussing on the pertinent results of the present study (Table XXVIII & Figure 4.2), a significant decrement was observed in the mean hamstring to quadriceps femoris muscle torque ratio between the ages of 13 (77,7 ± 6,0%) and 14 years (69,9 ± 9,6%). Thereafter the H/Q ratio for the 14-17 year old age categories, remained relatively constant at a mean of 68,1 ± 9,0% with no significant differences ($p>0,05$) being observed for any increment in age. This latter finding corresponds with that of Gilliam et al.(1979a), who found no significant difference in the H/Q ratio across age groups in their study of 15-18 year old high school boys participating in American Football.

It would thus appear according to the present age-specific results, that at the age category of 13 years, the development and torque generating capabilities of the quadriceps musculature is not yet as pronounced as at the other age groups, with the hamstring to quadricep ratio being closer to unity than in older subjects. This is supported by the previous observation (Table XXVIII & Figure 4.1), that the mean dominant quadriceps torque was not significantly greater than the mean hamstring torque for the 13 year-old subjects.

It is evident that the age-specific and overall H/Q ratios found in the present study, are generally higher than those documented by the relatively few comparable reports reflected on in the preceding paragraphs. As such, the mean H/Q ratio documented for all ages (68,5 ± 8,6%) is closest to the 68% ratio found by Stafford and Grana (1984) among inter-collegiate American Football players 18-24 years of age. It should be stressed, however, that they determined their finding at 90°/s, as opposed to the 60°/s testing speed employed in the current methodology.

One may contemplate the reasons for the apparently high hamstring to quadricep strength ratio found among the subjects in the present study. One plausible explanation is that sport-specific ratios may exist among sportsmen (Holmes & Alderink,1984), of which the high school rugby players evaluated in this study could be a possible example. An alternative explanation is the purported technological limitation of Akron Isokinetic Dynamometers in failing to correct for gravitational error. That is, when isokinetic dynamometers are used to record vertical movement torques, gravity either aids (knee flexion) or opposes (knee extension) the movement (Osternig,1986). It has been proposed, however, that the percentage error due to gravity effect torque (GET) tends to be less for forceful contractions at low speeds such as for example, the 60°/s test speed used in this study, than for less forceful contractions performed at high speeds of testing (Fillyaw et al.,1986).

Relative Isokinetic Strength

Research has indicated that muscle torque capabilities are not only related to gender and age, but also to body weight (Watson & Donovan,1977; Beam et al.,1982). A particular relationship between total body weight and peak quadriceps femoris and hamstring muscle output has been demonstrated. In professional football players Davies et al.(1981), testing at 45°/s, calculated an average quadricep femoris muscle to body weight ratio of 107%, when expressed in foot pounds of torque per pound of body weight (Ft lbs/lb). Davies (1987) further suggests that when testing at 60°/s, the quadricep femoris muscle torque to body weight ratio should be 100% (1 Ft lb/lb) and 80% (0,8 Ft lb/lb), for 15-40 year-old adult males and females, respectively. These values converted to metric equivalents translate into 300% (3 Nm/kg) and 240% (2,4 Nm/kg) respectively, where 1 Ft lb/lb = 3 Nm/kg.

Kibler (1990) has recently provided more specific peak torque to body weight ratio guidelines for both quadricep and hamstring musculature for young males and females ranging from under-14 to over 16 years of age (Table XXIX). Such guidelines are of particular value when evaluating individuals who have bilateral problems and where the measures of the uninvolved limb thus cannot serve as a suitable norm. The dominant-limb values of subjects evaluated in this study (mean ± SD), for relative peak quadricep and hamstring torque expressed in Nm/kg (Table XXX & Figure 4.3) can be also be judged according to those suggested by Kibler (1990) (Table XXIX).

As can be observed, the mean quadriceps torque per body weight was significantly greater than the mean hamstring torque per body weight for all ages. This was a generally expected result and corresponds to the previous finding (Table XXVIII) of a superior absolute quadriceps torque as opposed to hamstring torque across age categories. Furthermore an overall pattern of increasing mean peak quadricep and hamstring torque per body weight was observed with age. This finding was significant for the increments

TABLE XXIX: PEAK ISOKINETIC KNEE EXTENSION/FLEXION TORQUE RELATIVE TO BODY WEIGHT NORMS [1]

AGE / GENDER (Yrs)		RELATIVE PEAK TORQUE Nm/kg (Ft lb/lb) Quadriceps		Hamstrings	
< 14	Boys :	**1,80**	(0,60)	**1,20**	(0,40)
	Girls :	**1,80**	(0,60)	**1,20**	(0,40)
14 - 16	Boys :	**2,25**	(0,75)	**1,50**	(0,50)
	Girls :	**2,10**	(0,70)	**1,35**	(0,45)
16 +	Boys :	**2,55**	(0,85)	**1,80**	(0,60)
	Girls :	**2,40**	(0,80)	**1,65**	(0,55)

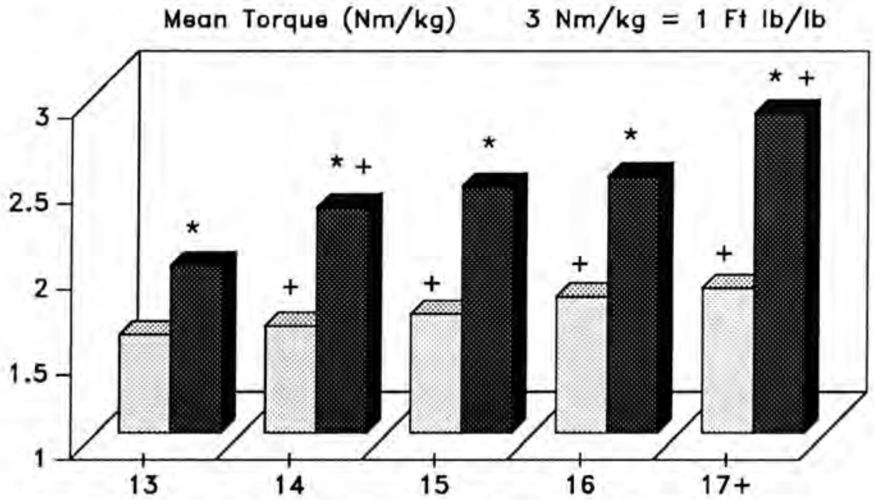
[1] After Kibler (1990); 1 Ft lb/lb = 3 Nm/kg

TABLE XXX: PEAK DOMINANT-LIMB ISOKINETIC KNEE EXTENSION/ FLEXION TORQUE VALUES RELATIVE TO BODY WEIGHT

AGE (Yrs)	RELATIVE PEAK TORQUE Nm/kg (Ft lb/lb) Quadriceps	Hamstrings
13	**1,98 ± 0,23** (0,66 ± 0,08)	**1,50 ± 0,08** (0,50 ± 0,03)
14	**2,32 ± 0,30** (0,77 ± 0,10)	**1,63 ± 0,23** (0,54 ± 0,08)
15	**2,44 ± 0,38** (0,81 ± 0,13)	**1,70 ± 0,30** (0,57 ± 0,10)
16	**2,50 ± 0,22** (0,83 ± 0,07)	**1,80 ± 0,20** (0,60 ± 0,07)
17+	**2,87 ± 0,39** (0,96 ± 0,13)	**1,85 ± 0,22** (0,62 ± 0,07)

N = 70 ; 1 Ft lb/lb = 3 Nm/kg.

FIGURE 4.3: RELATIVE QUADRICEP AND HAMSTRING TORQUE / AGE



	13	14	15	16	17+
HAMS	1.58	1.63	1.7	1.8	1.85
QUADS	1.98	2.32	2.44	2.5	2.87

* Q > H; + Q > Q & H > H Previous Age Category (p<0,05)

in relative quadricep strength between the ages 13 and 14 years and between 16 and 17 years, while the increments in relative hamstring strength from one age category to the next, were significant in all cases. The above data serves to emphasize that age-related increases in strength among the subjects evaluated exist not only for absolute strength measures (Nm), but also for strength measured relative to body weight (Nm/kg). This phenomena clearly bears testimony to natural anabolic process of physical maturation among youths (Watson & Donovan,1977).

In comparison to the age-specific norms (Table XXIX) suggested by Kibler (1990), the mean dominant-limb peak quadricep and hamstring torque relative to body weight recorded for subjects in the present study (Table XXX), was superior for all ages. It would thus appear that high school rugby players generally possess a high degree of leg strength relative to body weight in comparison to a general population of high school youths.

Previous Injury and Residual Symptoms

As indicated initially, of the 103 subjects that underwent isokinetic screening as part of the preparticipation evaluation procedure, some subjects reported a previous or current complaint/injury of the knee joint or thigh musculature. Subsequently their results, which were reserved from that of healthy subjects, are presented here after being analyzed for residual contralateral imbalances in isokinetic peak torque, work and power generating capabilities of the knee extensor (quadricep) and flexor (hamstring) muscle groups.

Grace et al.(1984) are of the opinion that the widely held belief of muscle imbalance being related to subsequent injury, seems to have evolved from the observation that individuals who have had previous joint injuries or surgery, often have persisting muscle weakness and imbalance in comparison to the contralateral limb (Campbell & Glenn,1979; Grimby et al.,1980; Arvidsson et al.,1981; Campbell & Glenn,1982).

When reflecting on the degree of contralateral imbalance of the knee extensors and flexors (Table XXXI below) among subjects in this study who reported a previous or current complaint/injury of the knee joint or thigh musculature (N=32), the above observation is generally confirmed. As such, a mean contralateral percentage difference of 10% or greater, was found for both quadriceps and hamstrings for each of the variables analyzed. Similarly, when the degree of imbalance was analyzed at incremental discrepancies of 10%, an imbalance of 10% or more was a frequent finding, being the case in the majority of subjects for peak quadriceps torque (56,3%), work done (56,3% for both quadriceps and hamstrings) and total power generated (59,4 and 56,3% for quadriceps and hamstrings, respectively).

TABLE XXXI: DEGREE OF CONTRALATERAL IMBALANCE FOR ISOKINETIC VARIABLES AMONG PREVIOUSLY INJURED SUBJECTS

VARIABLE TESTED		PERCENT (%) DIFFERENCE	FREQUENCY OF IMBALANCE		
			<10%	10-19%	≥20%
Torque	Quad	12,0 ± 9,8	14	13	5
Torque	Hams	10,5 ± 9,0	17	10	5
Work	Quad	13,6 ± 10,8	14	9	9
Work	Hams	14,1 ± 10,7	14	9	9
Power	Quad	14,2 ± 10,2	13	9	10
Power	Hams	13,1 ± 9,6	14	12	6

N = 32

A contralateral difference in muscle strength greater than 10-15% is proposed to constitute significant asymmetry predisposing to injury (Osternig,1986). Given the observed prevalence of such contralateral imbalance of the knee extensors and flexors, this accentuates the potential risk for reinjury and the need for preparticipation isokinetic evaluation and rehabilitation of previously injured sportsmen, in particular. In this respect, a consistent criteria for the ratio between injured and uninjured limbs to determine discharge from rehabilitation and resumption of sports participation is not evident in the literature. Some mention a fairly large 10-20% discrepancy as being acceptable (Grace,1985), while others suggest more stringent standards of a 93% ratio (Prinsloo,1986), or between a 95 and 98% ratio (Wyatt & Edwards,1981) as being the goal that should be aimed for in rehabilitation.

In final addition to the above considerations, Campbell and Glenn (1979;1982) emphasize that, although the general goal in rehabilitation programmes of restoring strength to the involved limb is commonly adhered to by clinicians, little attention is usually given to the related functions of specific muscular endurance or muscular power. As measured by the Akron Isokinetic Dynamometer and the present methodology these respective variables would correspond to a bilateral comparison of the amount of work done by each muscle group over a period of 10 seconds (defined as the torque integrated over the angle moved through) and the rate at which this work was performed. Based on the observed degree of contralateral imbalance in muscle function relating to work and power (Table XXXI), the present results support the contention of Campbell and Glenn (1982) that, apart from peak torque, clinicians also need to emphasize the quality of specific muscle endurance and power during individual assessment and rehabilitation.

2. INJURY SURVEILLANCE DATA

Prior to presenting the injury surveillance results, it would be appropriate to briefly reflect on similar epidemiological studies that have addressed the problem of injuries among South African rugby players. Although a study has been conducted by the Northern Transvaal Rugby Union (Wessels,1980; NTRU,1982) the data collected was not detailed. As such four pertinent reports (Nathan et al.,1983; Roux et al.,1987; Malan & Strydom,1987; Clark et al.,1990) have been published on the injury incidence and extrinsic risk factors for injury, the results of which can be discussed within the context of the present study. At the outset it would, however, be prudent to contrast specific variations in methodology employed by each study.

After identifying an apparent world-wide lack of adequately controlled prospective investigations into the nature and frequency of schoolboy rugby injuries, Nathan, Roux and Noakes undertook such a study of the injuries experienced at one school in the Cape Province during the 1982 season (Nathan et al.,1983). Of importance in their methodology was the age range of the cohort studied, which constituted both primary and high school players attending the particular school, and their definition of injury. For the purpose of their study an injury was defined as one which was severe enough to prevent the player from returning to rugby for at least seven days after the injury. The authors motivated two reasons for choosing this definition: i) it was felt that this degree of injury would be easily identified by their particular survey method used (which consisted of a weekly visit to the school on the Monday following the preceding Saturdays' match-fixtures to identify pupils who had missed a game and thus factors related to the injury were determined by a questionnaire); and ii) it was their opinion that injuries which did not prevent the player from participating for at least seven days, were trivial or minor and of little short- or long-term consequence and could thus safely be ignored because their inclusion would overestimate the true risk of playing rugby.

Subsequent to this study, a follow-up investigation was conducted in 1983 by Roux, Goedeke, Visser, van Zyl and Noakes (Roux et al.,1987). Of importance in their methodology was that while the previous definition of injury was retained this study concentrated only on high school players, but the size of the cohort was expanded to twenty-six schools in the Cape Province. Twenty of these schools were monitored by correspondence and the remaining six were monitored by two of the investigators, using essentially the same data collection procedure as described in their previous study. A principal finding of this study was that the incidence of injury in the twenty schools monitored by correspondence was substantially lower than for the six schools monitored closely (Table XXXII). This anomaly was ascribed to a problem of under-reporting of injury in the correspondence-monitored cohort. The researchers concluded that intensive monitoring of a single school would result in the most accurate injury reporting, and this recommendation thus provided the foundation for the methodology employed in the current study, as detailed in the previous chapter.

A third study, dealing with the quantification of injuries among high school rugby players at provincial level during the 1985 Craven Week, was conducted by Malan and Strydom (1987). Of importance in their methodology was that the cohort consisted of elite high school players and that the tournament-based investigation, although entailing a high match frequency, only allowed for a brief injury monitoring period as opposed to a seasons' duration in the preceding studies. Consequently, their definition of injury also differed, with injuries severe enough to prevent players from continuing in the specific match being recorded.

Finally, in 1988 Clark, Roux and Noakes conducted a comparative study of the incidence and nature of injuries among adult rugby players participating at club level in the Cape Province (Clark et al.,1990). This study was carried out using the same injury definition as the previous schoolboy investigations (of at least seven days absence from participation following injury) with players themselves completing the injury forms which were then collected on a weekly basis by the researchers.

To recapitulate, the aim of the injury surveillance phase of the present study was to re-assess extrinsic and identify intrinsic aetiological risk factors among high school rugby players, based on a comprehensive pool of injury data collected in a prospective manner over a full season of participation. Thus, to attain the above and to avoid the "ice-berg" phenomena referred to in the previous chapter, the following inclusive injury definition was employed:

* Any traumatic condition resulting while competing, that:

i) required first aid treatment during or after a match / practice; and/or

ii) necessitated the complete cessation of participation in a match / practice.

2.1 NUMBER, INCIDENCE AND SEVERITY OF INJURIES

A total of 171 injuries were sustained by 76 players over the 14 weeks duration of the rugby season, with 46 players thus suffering multiple injuries. This gave rise to an overall injury incidence of 1 injury per 21 player-hours (1:21 player-hours) or 4,8 injuries per 100 player-hours. When employing stricter definitions of injury to isolate injuries of a more serious nature, 36 (21%) of all the injuries recorded required medical consultation while significantly (p<0,01) fewer (10%) resulted in a loss of at least seven days participation-time. Using these respective criteria, the injury incidence fell to 1:100 player-hours if only those injuries requiring medical consultation are considered, while an even lower major injury incidence of 1:212 player-hours or 0,5 injuries per 100 player-hours was recorded if only those injuries which resulted in a loss of at least seven days participation-time are considered.

Reflecting on the data in Table XXXII, this latter major injury incidence of 1:212 player-hours recorded in the present study for injuries of a more serious nature (i.e. causing a loss of at least seven days participation in rugby) is fairly similar to the incidence of 1:243 player-hours as documented by Nathan et al.(1983) in the initial epidemiological study of schoolboy rugby players conducted in the Cape Province during the 1982 season. As such the slightly higher incidence of injury found in the present study could probably be attributed to a more meticulous methodological approach, where constant personal surveillance by monitoring each teams' weekly practice sessions and matches that took place during the season, allowed for a detailed cumulative recording of real exposure-time and subsequent accurate calculation of injury incidence. In contrast to this, Nathan et al.(1983) relied on an global estimate of 3 hours practise per week for all teams throughout the season in their calculation of total exposure-time. The results of the present study nonetheless suggest that the incidence of injury (as experienced over a season at one school) among high school players in the Natal Province corresponds notably with that found in the

Cape Province, despite being conducted a decade later, and supports the contention of Roux et al.(1987) that the intensive monitoring of a single school would result in the most accurate injury reporting. Furthermore, the specific 1:212 player-hours major injury incidence of this study, accentuates the possible spurious finding of a decreased incidence of injury (1:625 player-hours) during the 1983 follow-up study of Roux et al.(1987), as compared to 1:243 player-hours for the preceding 1982 study of Nathan et al.(1983). Finally, it should be noted from Table XXXII that the comparative overall incidence of injury documented for South African high school rugby players in the current and foregoing studies (Nathan et al.,1983; Roux et al.,1987), is lower than that reported by Clark et al.(1990) for adult players.

TABLE XXXII: COMPARATIVE REPORTS OF INJURY INCIDENCE AMONG RUGBY PLAYERS AT HIGH SCHOOL AND ADULT LEVELS

STUDY	YEAR	SUBJECTS / LEVEL	INJURY INCIDENCE*
Present	1992	High School Players	1:212 player-hours
Nathan	1982	High School Players	1:243 player-hours
Roux	1983	High School Players	1:426 player-hours+
Roux	1983	High School Players	1:736 player-hours++
Roux	1983	High School Players	1:625 player-hours+++
Clark	1988	Adult Club Players	1:171 player-hours

* Injury incidence as recorded prospectively over a season and defining an injury as one resulting in a loss of at least 7 days of participation. + Injury incidence as recorded for 6 closely monitored schools; ++ Injury incidence as recorded for 20 schools monitored by correspondence; +++ Overall injury incidence as recorded for all 26 schools monitored.

Nathan et al.(1983); Roux et al.(1987); Clark et al.(1990)

2.2 IDENTIFICATION OF RISK FACTORS / AETIOLOGY OF INJURY

The use of an "inclusive" data generating definition of injury in this study has provided a comprehensive pool of injury data. This has allowed for a subsequent aetiological analysis of risk factors based on an overall injury occurrence, ranging in severity to include those injuries usually purported to be less serious (not causing a loss of participation) and injuries of a more serious nature (causing a loss of at least seven days participation).

To recollect, it would be appropriate at this point to again define intrinsic and extrinsic risk factors for injury from an epidemiological perspective. A study of intrinsic risk factors relates to the individual physical characteristics of the participant. Extrinsic risk factors, on the other hand, relate to exposure factors (nature of the activity), environmental circumstances, injury mechanism and equipment usage at the time of injury.

In the course of the forthcoming evaluation of extrinsic risk factors, the interaction of the following aspects in relation to injury occurrence are analysed, as identified from the data of the present study and within the context of other research findings:

* Match-play & Practice
* Age Group
* Competitive Level
* Phase of Play
* Playing Position
* Anatomical Site
* Type of Injury
* Mechanism of Injury
* Type of Footwear
* Stage of the Season
* Period of Play
* Time of Day
* Surface & Weather Conditions
* Rule-Revision & Application
* Warm-up Exercises
* Skills Training
* Mouth-guard Use
* Bracing & Strapping

2.2.1 EXTRINSIC RISK FACTOR ANALYSIS

MATCH-PLAY VERSUS PRACTICE

Of all 171 injuries recorded, the significant (p<0,001) majority of 143 injuries (84%) were sustained during matches as opposed to 28 injuries (16%) being incurred during practice. Accordingly, a higher overall incidence of injury of 1:5 player-hours was recorded for match-play, compared to 1:101 player-hours recorded for practices. When considering only major injuries (causing a loss of at least seven days participation) a corresponding pattern was found. Significantly (p<0,01) more major injuries were sustained during matches (82%) as compared to practices (18%) and the respective major injury incidence recorded for match-play was 1:55 player-hours as opposed to 1:945 player-hours for practices. These findings are in agreement with previous studies (Table XXXIII), which also found that the majority of injuries among high school players (Nathan et al.,1983; Roux et al.,1987) and adults (Clark et al.,1990) occur during match-play with a resultant higher incidence of injury being recorded for matches than practices.

It is thus evident that match-play is a major risk factor, with the incidence and risk of injury during matches being far greater than during practice at both schoolboy and adult levels. This is of particular significance if one considers that considerably more time is spent in practice than in match-play. One could deduce that the all-out effort, competitive element and aggressive commitment so characteristic of match-play, must be important components contributing to injury. In addition a "win at all costs" mentality and related pre-game psychological motivation of players may contribute to intensity of play and resultant high incidence of injury during match-play. In fact, the Medical Advisory Committee of the Rugby Football Union of Great Britain has expressed itself strongly against the process of "psyching-up" among schoolboy players (Harrison et al.,1980). The lower risk of injury during practice could, however, also be related to the non-contact nature of practices, during which the majority of time is taken up by practising individual and team skills in an unopposed manner. This contention gains further credibility when the practice activities during which injuries were sustained in this study are identified, namely: i) match-practice was responsible for the majority (79%) of all practice-related injuries, followed by ii) warm-up activities (18%); and iii) skill training (3%).

TABLE XXXIII: COMPARATIVE REPORTS OF INJURY INCIDENCE* DURING MATCH-PLAY VERSUS PRACTICE

STUDY	YEAR	LEVEL	MATCHES	PRACTICE	
Present	1992	High School	82,0 %	18,0 %	of injuries
Nathan	1982	High School	63,0 %	37,0 %	of injuries
Roux	1983	High School	71,0 %	29,0 %	of injuries
Clark	1988	Adult Club	85,0 %	15,0 %	of injuries
Present	1992	High School	1: 55	1: 945	player-hours
Nathan	1982	High School	1: 84	1: 506	player-hours
Roux	1983	High School	1:142	1:1825	player-hours
Clark	1988	Adult Club	1: 60	1: 780	player-hours

* Injury incidence as recorded prospectively over a season and defining an injury as one resulting in a loss of at least 7 days of participation.

Nathan et al.(1983); Roux et al.(1987); Clark et al.(1990)

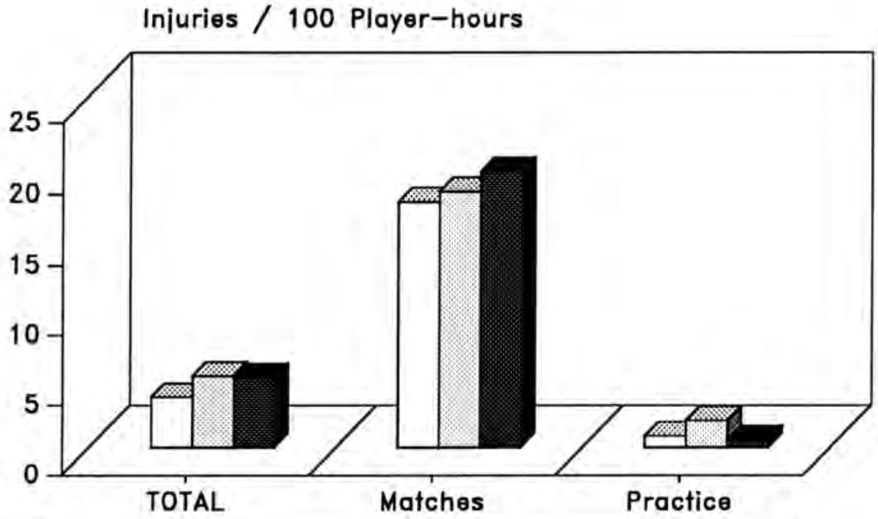
It is of interest to reflect on the incidence of injury during match-play found by researchers in overseas rugby playing countries, although varying definitions of injury and age composition of populations preclude direct comparisons. Davidson et al.(1978) have reported an injury incidence of 1:73 player-hours of match-play among Australian schoolboys aged between 7 and 18 years. Their study included all injuries seen at a medical facility on the day of injury. Durkin (1977) reported an injury incidence of 1:54 player-hours of match-play among adult 1st League players in England between 1972 and 1976. Considering that a corresponding injury definition was used, the injury incidence of 1:60 player-hours of match-play reported for adult 1st League players in the Cape Province (Clark et al.,1990) compares favorably, despite the latter study being conducted a decade later.

AGE GROUP AND COMPETITIVE LEVEL

Figure 4.4 shows the overall injury incidence per age group for injuries incurred in totality and those incurred during matches and practices, respectively. In totality, the injury incidence increased from the under-14 age group (3,6 injuries per 100 player-hours) to the under-15 age group (5,1/100 player-hours) but thereafter the injury incidence levelled off, with the incidence for the open age group (5,0/100 player-hours) being essentially equivalent to the preceding under-15 age category.

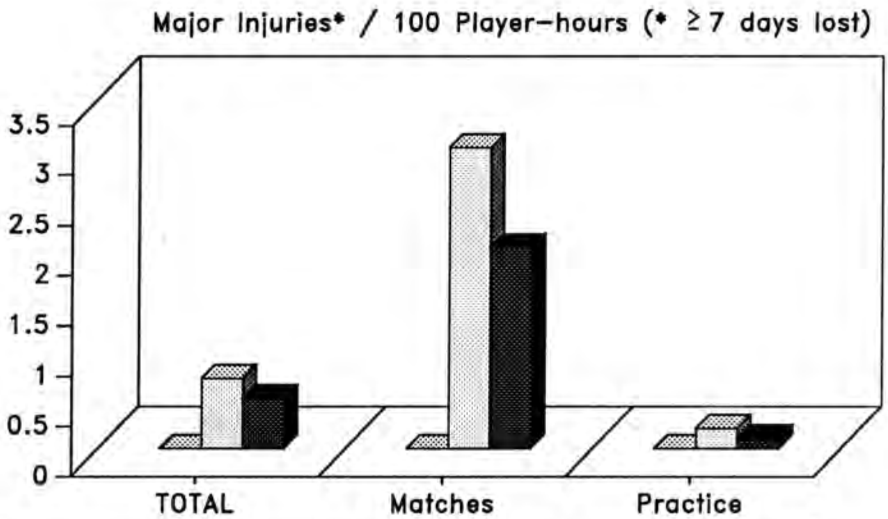
When matches are viewed separately, the observed increased injury risk during matches as opposed to practices is again illustrated, and it is evident that the injury incidence during match-play continued to rise as the age of the participants increased. When practices are viewed separately, however, a different pattern emerges. In this

FIGURE 4.4: OVERALL INJURY INCIDENCE / AGE GROUP / ACTIVITY



	TOTAL	Matches	Practice
U / 14 □	3.6	17.5	0.8
U / 15 ▨	5.1	18.2	1.9
OPEN ■	5	19.6	0.5

FIGURE 4.5: MAJOR INJURY INCIDENCE / AGE GROUP / ACTIVITY



	TOTAL	Matches	Practice
U/14 □	0	0	0
U/15 ▨	0.7	3	0.2
OPEN ■	0.5	2	0.1

case, injury incidence increased from the under-14 age group to the highest incidence at the under-15 age group, but thereafter decreased to its lowest level at the open age group.

Figure 4.5 displays the same analysis as the previous, but considering only major injuries. At the under-14 age group no such injuries occurred. In contrast, the highest incidence of major injuries sustained during both practices and matches and thus in totality, occurred at the under-15 age group, followed in turn by the open age group. The low risk of injury at the under-14 age group is thus confirmed by this analysis. Although the open age group showed the highest overall incidence of injury during match-play (Figure 4.4), this finding differs when only major injuries are considered (Figure 4.5) where the under-15 age group showed the highest major injury incidence during both match-play and practice and thus in totality.

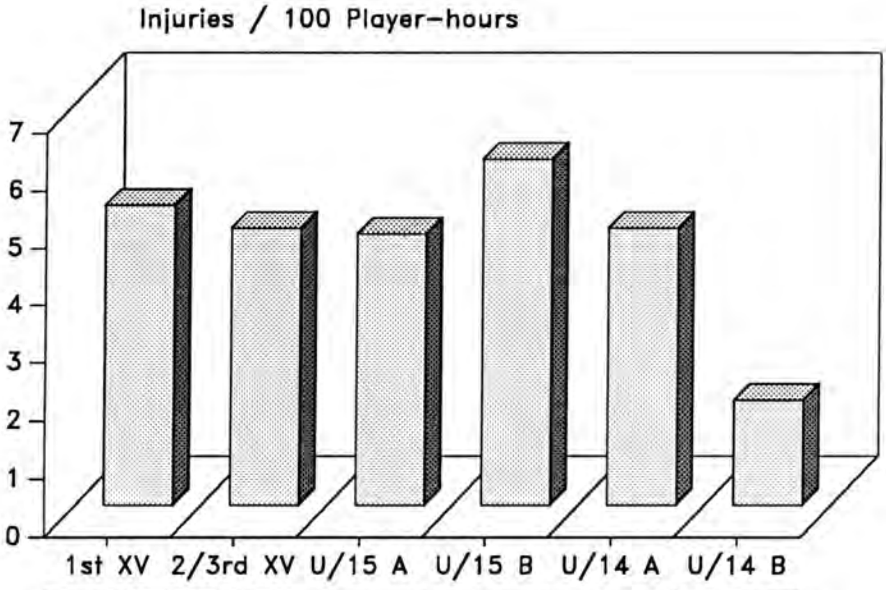
The reason behind the higher overall practice-related injury incidence at the under-14 and under-15 age group, as opposed to the open age group (Figure 4.4), and the higher major injury incidence during practice at the under-15 age group (Figure 4.5), can probably be linked to questionable approaches to coaching at these levels. As such, extensive use was made of match-practice as a coaching method in these age groups, with the "A" team typically playing against the "B" team or against older opposition in the next age category (i.e. under-14 "A" vs under 15 "B" or under-15 "A" vs the 3rd XV open team).

While trial games and match-practice at the start of a season are justified, continual use thereof in preference to fitness and skill training would appear to be counter-productive, considering the previously illustrated high risk of injury during match-play. In fact, in the absence of regular skill and fitness training under the supervision of a team coach, the majority of "B" team practice sessions, at under-15 level in particular, were in the form of practice games. The fact that 85% of all practice injuries incurred at the under-15 level (U/15 "A" - 66% & U/15 "B" - 100%) and 71% of practice injuries at the under-14 level (U/14 "A" - 75% & U/14 "B" - 66%), took place during match-practice serves to support the above contention.

Figure 4.6 shows the overall injury incidence of the teams per competitive level at each age group. At the open age group the injury incidence was slightly higher at 1st XV level than for the incidence of the lower 2nd and 3rd teams combined. At the under-14 level a similar, but more pronounced, pattern of injury was found with the "A" team having a far higher incidence of injury than the "B" team. At the under-15 level a reversed pattern was found, with the under-15 "B" team having a higher incidence of injury than the "A" team and the highest overall injury incidence of all teams.

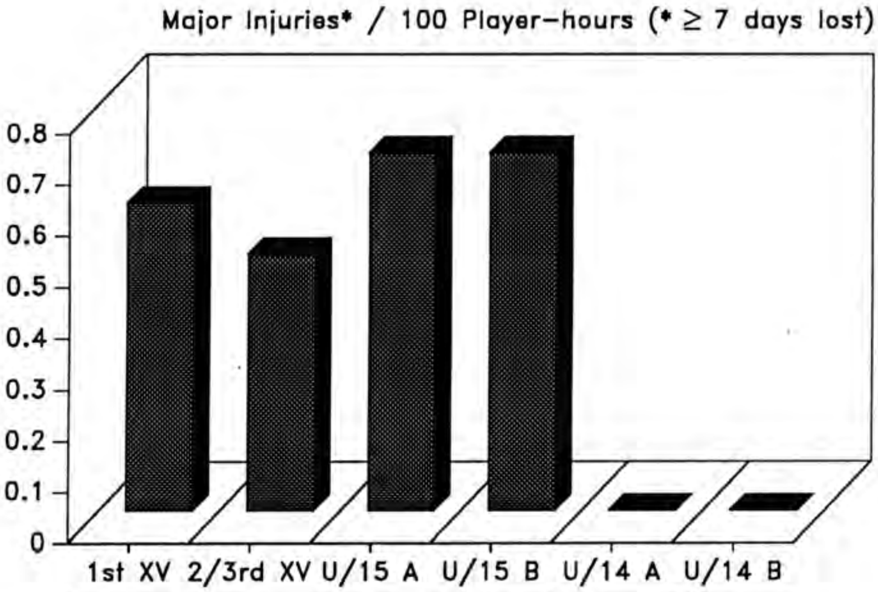
Figure 4.7 displays the same analysis as the previous, but considering only the major injury incidence for the teams per competitive level for each age group. As indicated previously, no major injuries were sustained at the under-14 level. At the open age group the injury incidence was again slightly higher at 1st XV level than for the lower 2nd and 3rd teams combined. In contrast, at the under-15 level the major injury incidence was equal for the "A" and "B" teams and higher than for the open teams (1st, 2nd & 3rd XV). A general trend thus appeared, as observed at the open and under-14 age group, of a higher injury incidence being recorded for teams competing at a higher level, that is in 1st teams or "A" teams than in 2nd or "B" teams per age group although at the under-15 level findings were

FIGURE 4.6: OVERALL INJURY INCIDENCE / COMPETITIVE LEVEL



1st XV	2/3rd XV	U/15 A	U/15 B	U/14 A	U/14 B
5.2	4.8	4.7	6	4.8	1.8

FIGURE 4.7: MAJOR INJURY INCIDENCE / COMPETITIVE LEVEL



1st XV	2/3rd XV	U/15 A	U/15 B	U/14 A	U/14 B
0.6	0.5	0.7	0.7	0	0

anomalous in this regard. The reason for this general trend could logically be linked to the greater competitiveness in higher teams per age group, which in turn may also be related to the emphasis on winning and associated "psyching-up" of players referred to previously.

According to the overall incidence of injury per competitive level, the finding that the under-15 "B" team showed a higher incidence than the "A" team and of all teams (Figure 4.6), constitutes an apparent spurious finding that deserves consideration. This finding can, however, be attributed to the fact that the under-15 "B" team experienced relatively less exposure-time than the other teams, and as indicated earlier, its exposure was mostly in the form of high risk match-play or match-practice activity. One may further contemplate the reasons why the under-15 age group teams showed the highest major injury incidence during both practice and match-play and thus in totality for all age groups (Figure 4.5), and the highest major injury incidence of all teams (Figure 4.7). A possible explanation is that at this intermediate age group the musculoskeletal structure of the players is undergoing various growth-related changes and is thus least able to resist the competitive demand required at this level, which is very similar to the high intensity of play that is characteristic of the senior open age group competition.

In conclusion, with respect to the risk of injury per age group and competitive level, the results of the present analysis tend to agree with those of previous findings reported for schoolboy rugby players (Nathan et al.,1983; Roux et al.,1987). Both these authors found the incidence of injuries (causing a loss of at least seven days participation) to be low in the under-14 age groups, with a a sharply increased incidence in the under-15 age group. Roux et al.(1987) reported a continued linear rise in injury incidence from the under-15 age group to the under-16 and under-19 age group players. However, similar to the present study, Nathan et al.(1983) reported a decrease in injury incidence from the under-15 to the under-16 age group, the latter corresponding with the present 2nd and 3rd team players, followed by an increased incidence among under-19 players, which essentially correspond with the present 1st XV players. In addition, both these authors found that "A" team players per age group were injured more frequently, with the under-19 "A" (1st team) players being particularly injury prone.

STAGE OF THE SEASON

The fourteen-week season commenced in the last week of March and ended after the first week of July. Table XXXIV and Figure 4.8 reflect the injury incidence per 100 player-hours of match-play for each week of the playing season. In addition, Table XXXIV also reflects the success record for the fixtures played, which can be interpreted as indicative of the standard of competition encountered during the weekly matches. From a global point of view the season could be divided into two distinct periods, namely:

i) the first four weeks before the Easter (April) vacation; and

ii) the remaining ten weeks after this vacation.

During the first four weeks of the season (pre-vacation) only the 1st and 2nd XV and the under-15 "A" team competed in a limited number of matches, which could essentially be considered pre-season fixtures. Only the 1st XV team played a match in the first week, and predictably a lack of match exposure prior to the first match of the season gave rise

TABLE XXXIV: WEEKLY INJURY INCIDENCE AND TEAM SUCCESS RATE

WEEK	INJURY INCIDENCE*		MATCH-SUCCESS RECORD		
	Overall	Major**	Played	Won	Lost & Drawn
1	18,2	0,0	1	0%	100%
2	20,8	4,2	2	50%	50%
3	14,8	0,0	6	50%	50%
4	18,4	0,0	3	100%	0%
5+	.	.	.	.	.
6	16,7	0,0	4	100%	0%
7	34,0	5,7	4	50%	50%
8	15,2	2,8	7	57%	43%
9	22,8	3,3	7	43%	57%
10	15,1	3,8	4	50%	50%
11	11,6	1,5	5	60%	40%
12	17,4	0,0	5	20%	80%
13	6,7	0,0	1	0%	100%
14	23,4	1,9	8	13%	87%

* Injury incidence / 100 player-hours; ** Major injury defined as one causing a loss of at least 7 days; + During the fifth week of the season no matches were played.

FIGURE 4.8: INJURY INCIDENCE / WEEK OF THE SEASON

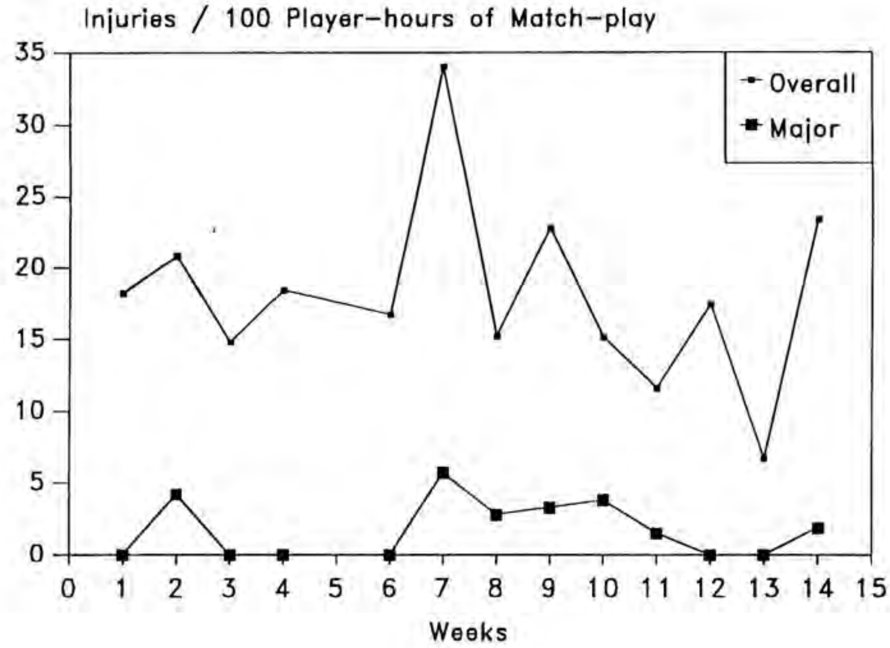
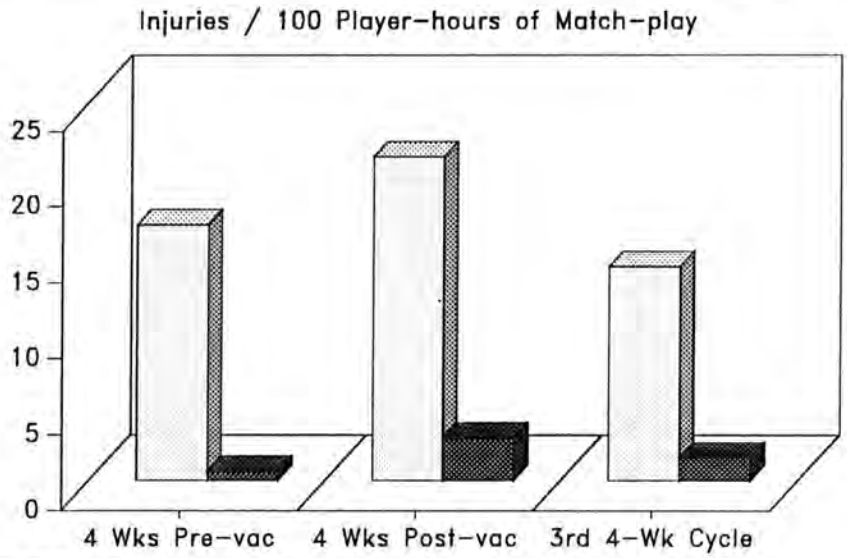


FIGURE 4.9: INJURY INCIDENCE / PHASE OF THE SEASON



	4 Wks Pre-vac	4 Wks Post-vac	3rd 4-Wk Cycle
Overall	16.8	21.3	14.1
Major	0.6	2.8	1.5

to a relatively high overall injury incidence of 18,2 injuries/100 player-hours, although no major injuries occurred.

In the second week the 1st XV and the under-15 "A" team participated in a rugby day festival to which a number of particularly strong teams had been invited. As may have been expected, the competitive spirit typical of such matches, may have contributed to a resultant peak pre-season overall injury incidence (20,8 injuries/100 player-hours) and major injury incidence (4,2 injuries/100 player-hours) being recorded.

Thereafter, during the third week the injury occurrence dropped to the lowest level of the pre-season period, with an overall incidence of 14,8 injuries/100 player-hours and no major injuries being documented. This was a somewhat unexpected finding, considering that the fixtures for this period demanded a heavy playing schedule, with the 1st and 2nd XV and the under-15 "A" team playing a total of 6 matches against four touring teams - all within the short space of one week. This suggests that the match exposure gained during the preceding two weeks, may have been of benefit in providing the players involved with greater degree of physical conditioning by the third week of the season.

During the fourth week only the 1st XV team were active, during which the team participated in a week-long Easter tournament. Typically such tournaments are of a brief but intense format requiring a high match frequency with relatively little rest. As such, teams were required to play a total of three matches with one day rest in-between. As is also typical of such tournaments, the competition was strong with a number of reputable teams, including those from other provinces, being invited to take part. By the end of the tournament, the study-team had remained unbeaten in all their matches and emerged as winners of the tournament. The concomitant effect, as may have been anticipated, was that the overall injury incidence increased to 18,4 injuries/100 player-hours during this week, although continually improving match-fitness may once again, as in the third week, have contributed to no major injuries being documented.

During fifth week of the season, that is, the first week after the vacation, no matches were played and therefore no injury values are indicated in Table XXXIV and Figure 4.8. During week six, the first matches of the post-vacation period were played, which thus signalled the start of the formal seasonal fixtures. During this week, however, the opponents (JR) could only provide four fixtures and the competition offered was not of a very high standard with all the matches being won convincingly. Probably as a result of this, a relatively low overall injury incidence, in comparison to pre-season findings, of 16,7 injuries/100 player-hours and no major injuries, was recorded. This finding was in contrast to a generally expected high injury incidence during opening matches following a vacation. Apart from the weak opposition encountered during matches, the fact that the teams had not played a fixture the previous week, and thus had two weeks to prepare themselves physically for the ensuing match, may also have contributed to the relatively low injury incidence recorded during the sixth week.

During the seventh (second post-vacation) week, a dramatic increase in injury was observed and the highest incidence of the season was documented for both the overall and major injury incidence, being recorded as 34,0 and 5,7 injuries / 100 player-hours, respectively. As in the previous week, the weeks' fixture was against traditionally weak opposition (ESH). In this instance, however, only the "B" teams per age group were therefore allowed to compete and in a further attempt to make the competition fair, the teams under study all played one team up, that is, the "B" teams played against the "A" teams of the opposition. While this arrangement may have been of benefit to the opposition in terms of equating the competition, a noticeable result was that, probably due to an observed generally superior physical development, the opposition encountered by the teams under study was particularly strong and robust. Ultimately the resultant effect of this compromise was counterproductive, in that it appeared to create an increased risk of injury among the teams under study.

During the eighth and ninth weeks all 7 teams had fixtures to play (versus ST and RB, respectively). During the eighth (third post-vacation) week both the overall (15,2 injuries/100 player-hours) and major (2,8 injuries/100 player-hours) injury incidence dropped substantially as compared to the previous week. In the case of the overall injury incidence, a level slightly lower to that recorded in the sixth week was documented. This could possibly be attributed to the conditioning benefits that may have accrued among players by the third post-vacation week of the season.

During the ninth week both the overall and major injury incidence again increased, as compared to the previous week. In the case of the overall injury incidence (22,8 injuries/100 player-hours) this increase was fairly sharp, while the major incidence increased slightly to 3,3 injuries/100 player-hours. As it were, this fixture coincided with what was traditionally considered the annual "grudge" match against a neighboring town (RB) and the negative effect of such a win at all costs approach, was subsequently illustrated clearly in the increased incidence of injury.

During the tenth week of the season, the return match took place against the same opposition (JR) that had been beaten convincingly in the sixth week. In this case the overall injury incidence (15,1 injuries/100 player-hours) again dropped to a similar level as in the eighth week, prior to the preceding "grudge" match. The major injury incidence, however, continued to increase slightly to 3,8 injuries/100 player hours. This latter negative finding could probably be related to the fact that two of the "B" teams were again forced to play one team up - against the opponents' "A" teams in an attempt to equate the competition, leading to a similar counter productive resultant effect as previously described.

During the eleventh and twelfth weeks the under-14 and under-15 "B" teams did not have fixtures (versus SNTL and PNTL, respectively) and thus five matches were played in each instance. In the eleventh week both the overall (11,6 injuries/100 player-hours) and major (1,5 injuries/100 player-hours) injury incidence dropped further to approximate the lowest level of the season. It would thus appear that by this stage of the season the player' conditioning was at an optimal level and this, together with mediocre opposition and a high (60%) success rate, probably contributed to the relatively low incidence of injury for this fixture.

During the twelfth week the major injury incidence dropped even further to a zero incidence, but the overall injury incidence, however, again rose to 17,4 injuries/100 player-hours. This latter finding was contrary to the general trend of a decreasing injury incidence prevailing at this stage of the season. This anomaly could possibly be ascribed to the strength of the opposition, with the teams under study only being able to win 20% of their matches for this fixture. During the thirteenth week of the season, only the 1st XV played and lost a match against a touring team from the Eastern Province (DSP). None of the injuries that occurred during this fixture were major, and the lowest overall injury incidence of the season (6,7 injuries/100 player-hours) was recorded.

During the final (fourteenth) week of the season the prevailing trend of a decreasing injury incidence was, however, again disrupted by an increase in both the overall and major injury incidence. The overall injury incidence (23,4 injuries/100 player-hours) increased to the second highest level of the season, while the major incidence increased slightly from zero to 1,5 injuries/100 player-hours. A number of reasons may have contributed to this finding. Firstly, during this week the 1st XV played and lost two midweek matches against extremely strong touring teams from the Western Province (RBSCH and DLC). During the latter match, in particular, the play was very robust and challenging, resulting in injuries which forced the 1st XV to withdraw from the ensuing and last weekend fixture of the season. Thirdly, this final Saturday fixture (RB) was the return "grudge" match of the season and thus the attendant risk of injury referred to previously, was again in play for the remaining six teams participating. Finally, only the 1st XV had played a match the preceding weekend and this potential lack of match-fitness was further compounded by the fact that school examinations had been written during the two weeks preceding the final match and as a result the players involved had generally not attended practice and thus had undergone very little or no preparatory training.

In conclusion, Figure 4.9 reflects the injury incidence per four-week cycle of the season. As can be observed both the overall and major injury incidence was the highest for the four-week period following the Easter vacation. This pattern of injury tends to correspond, in principle, with that of previous reports for schoolboy rugby players (Nathan et al.,1983; Roux et al.,1987). Both these authors found that the incidence of injuries (causing a loss of at least seven days participation) to be highest for the four-week periods at the beginning of the season and after the winter vacation. Their suggestion that a related lack of match fitness was responsible for this observed pattern of injury, would appear to be partially confirmed by the results of the present study.

PHASE OF PLAY AND PLAYING POSITION

Figures 4.10 and 4.11 reflect the respective overall and major injury incidence, expressed as a percentage, per phase of play during which injuries were incurred by players. Figures 4.12 and 4.13, reflect the respective overall and major injury incidence per playing position as corrected for unequal numbers of players in the different playing positions. This correction has been derived by doubling the number of injuries in playing positions in which there is only one player per team and then expressing all injuries as a corrected percentage.

Considering the overall injury incidence per phase of play, players were injured significantly ($p<0,001$) more frequently during the various facets of broken play (92%) than during the set-pieces (8%) of scrums (7%) and line-outs (1%). It is evident (Figure 4.10) that the combined tackle-related phases of play (43%) posed the greatest risk of injury, while individually, being tackled (30%); the ruck and maul (25%); open play (23%); and tackling (13%) followed in descending frequency. Foul play (1%), as in the case of line-outs, was responsible for the minimum of injuries.

FIGURE 4.10: OVERALL INJURY INCIDENCE / PHASE OF PLAY

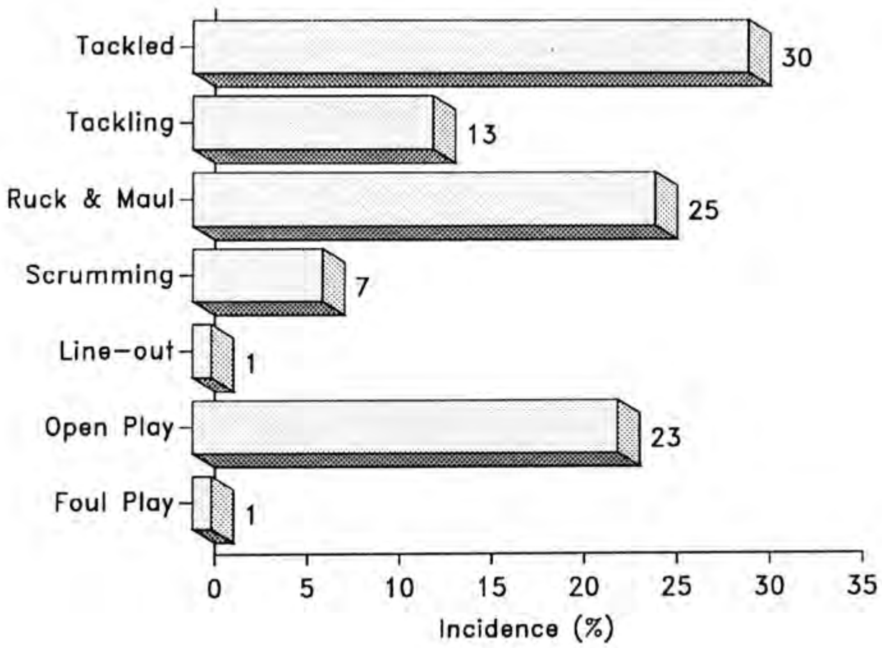


FIGURE 4.11: MAJOR INJURY INCIDENCE / PHASE OF PLAY

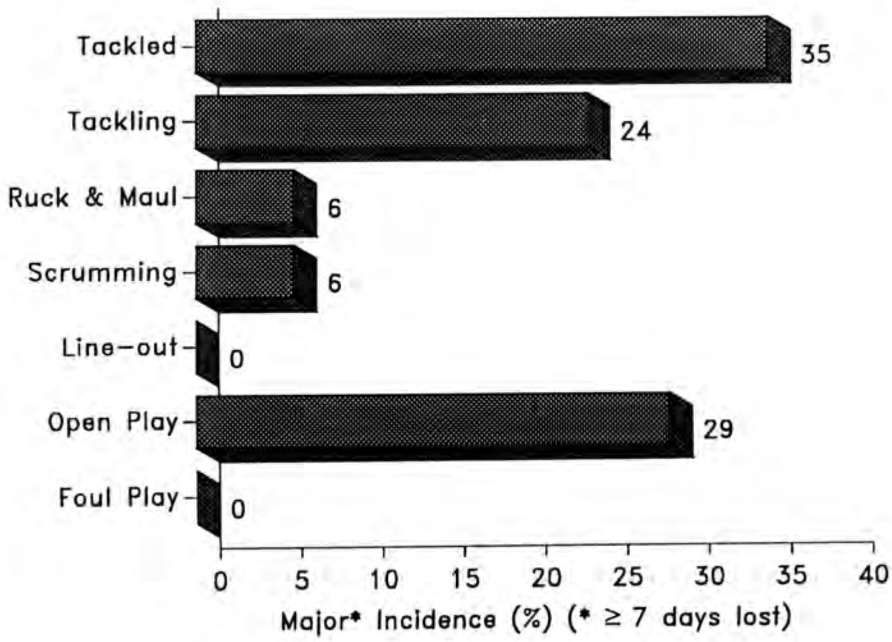


FIGURE 4.12: OVERALL INJURY INCIDENCE / PLAYING POSITION

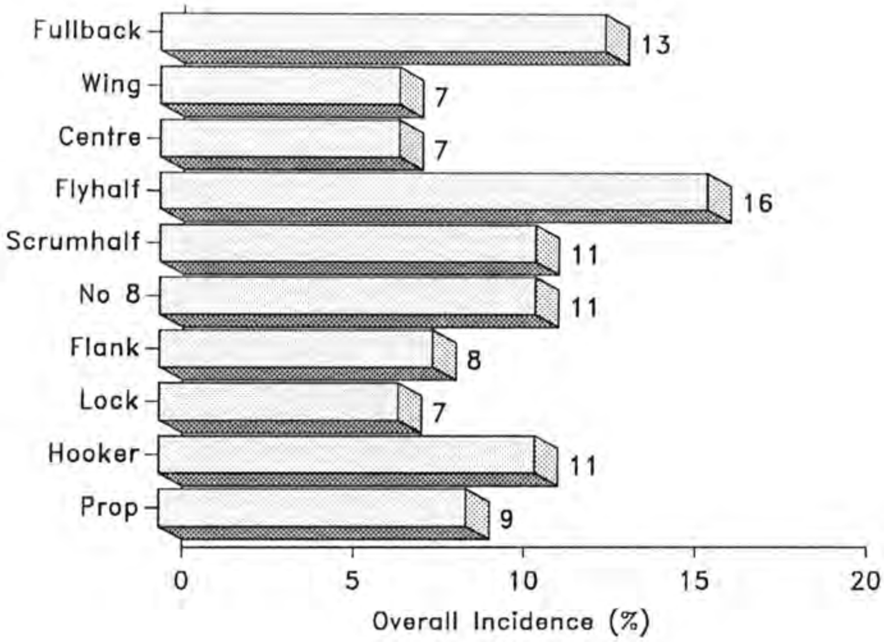
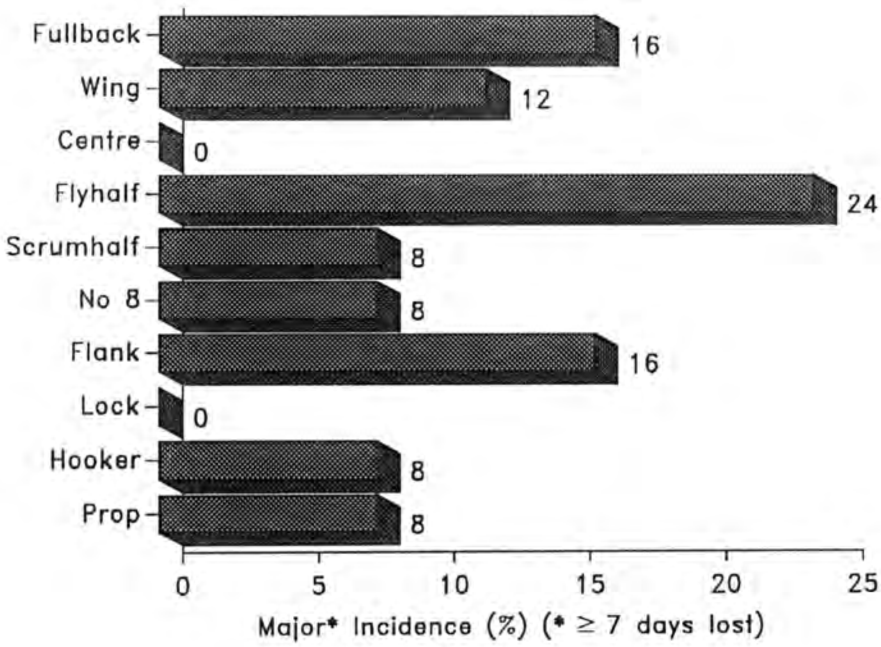


FIGURE 4.13: MAJOR INJURY INCIDENCE / PLAYING POSITION



In considering the major injury incidence (Figure 4.11) per phase of play, players were again injured significantly (p<0,001) more frequently during the various facets of broken play (94%) than during the set-pieces (6%) of scrums (6%) and line-outs (0%). It is evident that the combined tackle-related phases of play (59%) still posed the greatest risk of injury, while individually, being tackled (35%); open play (29%); tackling (24%); and the ruck and maul (6%) followed in descending frequency. Foul play, as in the case of line-outs, was not responsible for any major injuries.

Considering the overall injury incidence per playing position (Figure 4.12), backline players (54%) were injured more often than forwards (46%), but not significantly (p>0,05) so. It is evident that flyhalf (16%) and fullback (13%) were the positions at greatest risk. This was followed, in descending frequency of injury, by scrumhalf, eighthman and hooker (11% each); prop (9%) and flank (8%); while wing, centre and lock (7% each) were the positions least affected by injury.

In considering the major injury incidence per playing position (Figure 4.13), backline players (60%) were again injured more often than forwards (40%), but not significantly (p>0,05) so. It is evident that flyhalf (24%) remained the position at greatest risk. This was followed, in descending frequency of injury, by fullback and flank (16% each); wing (12%); scrumhalf, eighth-man, hooker and prop (8% each); while centre and lock were not affected by major injuries.

In summary of these findings, the following can be highlighted in terms of the respective phase of play and playing position involved at the time of injury:

Being tackled and open play - posed the greatest overall and major injury risk, while tackling was particularly conducive to major injury. Although the ruck and maul phase of the game contributed significantly to the overall injury incidence, this was not so in the case of major injuries. Foul play and line-outs were least implicated in any form of injury.

Flyhalf and fullback were at the highest overall and major injury risk, while flank and wing were also particularly prone to major injury. In contrast, centre and lock appeared to be the safest playing positions.

The findings of the major injury incidence per phase of play and playing position can be viewed in relation to corresponding comparative injury profiles (Table XXXV & XXXVI, respectively), as reported by other pertinent studies conducted over the past decade (Nathan et al.,1983; Roux et al.,1987; Malan & Strydom,1987; Clark et al.,1990). This comparison is possible because the definition of injury used to identify major injuries in this study (injuries causing a loss of at least seven days participation), is the same as that used in three (Nathan et al.,1983; Roux et al.,1987; Clark et al.,1990) of these four comparative studies. The only exception to this, is the study of Malan and Strydom (1987) - who used a comparable but not identical severity criteria, defining an injury as one severe enough to prevent players from continuing in the specific match being monitored during the Craven Week.

It is important to note that in the interim period since the studies cited in Tables XXXV and XXXVI were conducted and the 1992 season during which the present study took place, a number of rule changes were introduced to the game of rugby (Appendix G). Therefore a comparison of their

TABLE XXXV: COMPARATIVE INJURY PROFILE / PHASE OF PLAY

PHASE OF PLAY	Present 1992 Major Injury	Other Schoolboy Studies 1982 [1]	Other Schoolboy Studies 1983 [2]	Adults 1988 [4]
Tackled	35%	25%	30%	26%
Tackling	24	22	25	14
Ruck/Maul	6	6	18	17
Scrumming	6	18	8	9
Line-out	0	4	1	3
Open play	29	11	8	21
Foul play	0	8	4	5
Other	-	6	7	5

TABLE XXXVI: COMPARATIVE INJURY PROFILE / PLAYING POSITION*

PLAYING POSITION	Present 1992 Major Injury	Other Schoolboy Studies 1982 [1]	Other Schoolboy Studies 1983 [2]	Other Schoolboy Studies 1985 [3]	Adults 1988 [4]
Fullback	16%	15%	11%	0%	11%
Wing	12	5	12	17	15
Centre	0	5	10	6	10
Flyhalf	24	8	12	8	8
Scrumhalf	8	10	9	12	5
Eighth-man	8	13	13	8	9
Flank	16	6	10	2	9
Lock	0	4	6	5	6
Hooker	8	32	8	16	19
Prop	8	2	8	8	6

* Values are corrected for unequal numbers of players in the different positions, by doubling the number of injuries in positions in which there is only 1 player per team and then expressing all injuries as a corrected percentage.

[1] Nathan et al.(1983) - Majority of data from High School level and a small portion (19%) from Primary School subjects; [2] Roux et al.(1987) - High School level; [3] Malan & Strydom (1987) - High School Craven Week; [4] Clark et al.(1990) - Adult players participating at club level.

results to that of the present study may serve to evaluate the effect of these rule changes on the injury incidence. In particular, these rule changes were aimed at modifying the extrinsic risks of phase of play and playing position involved at the time of the injury. A decreased incidence of potentially serious injuries related to specific phases of play and/or among players in certain playing positions, would illustrate the effectiveness of the rule-revisions.

From Table XXXV it is evident that the following noteworthy observations can be made in the above regard, in terms of the risk of injury per phase of play:

Being tackled - previous incidences ranged from between 25 and 30% for schoolboys and 26% for adults. The present incidence of 35% would suggest a definite increase and indicates that being tackled remains the phase of play involving the greatest risk of injury at both schoolboy and adult level. This increased incidence may be related to the effect of the 1992 rule-revisions, such as law 11 which dictates that the scoring value of a try has increased to five points. This has essentially again transformed the game of rugby into a high speed activity with the accent on entertaining running rugby. The inevitable end-result would appear to be that the incidence of injuries incurred as the result of being tackled has unfortunately increased.

Tackling - previous incidences ranged from between 22 and 35% for schoolboys and 14% for adults. The present incidence of 24% falls into the previously observed schoolboy range and suggests that although being injured in the process of tackling remains a major risk, this risk has essentially remained unaltered.

Ruck and maul - previous incidences ranged from between 6 and 18% for schoolboys and 17% for adults. It would appear that the initial 6% incidence reported by Nathan et al.(1983) may have been a spurious finding. Subsequently, the present incidence of 6% thus constitutes a decrease in the incidence of injuries incurred during the ruck and maul. This decreased incidence may be related to the 1988 rule-revision of law 18 governing the tackle and lying with or near the ball, as well as the 1990 schoolboy revision of law 20 governing which team gains possession of the ball for a scrummage following a breakdown in play.

In particular, the 1988 rule-revision of law 18 ruled that:

a) A tackled player must immediately pass or release the ball and get up or move away from the ball.

b) A player who goes to ground to gather a ball or with the ball in his possession but who is not tackled, must immediately get onto his feet with the ball in his possession or pass / release the ball or move away from the ball.

c) Any other player must be on his feet before he can play the ball.

The rewrite of this law in fact served to clarify and not alter the law. It also again emphasized that danger may arise if a tackled player fails to pass or release or move away from the ball at once or is prevented from doing so and decreed that in such cases the referee should not delay in awarding a penalty kick. In so doing the rule effectively discouraged the formation of loose-scrums which eventually lead to a potentially injurious ruck and maul.

In the second instance, the 1990 schoolboy rule-revision of law 20 ruled that when an infringement occurs the team not responsible for the infringement shall put in the ball. This rule was in effect expanded on and extended to adult level during the 1992 law revision, which ruled that in a ruck and/or maul when the ball becomes unplayable or stationary, the team not in possession at the start thereof will put the ball into the ensuing scrummage. Essentially this rule encouraged teams to keep the ball alive and players to remain on their feet, thus also discouraging the formation of "pile-ups" during the ruck and maul.

Scrumming - previous incidences ranged from between 8 and 18% for schoolboys and 9% for adults. Subsequently, the present incidence of 6% appears to constitute a decrease in the incidence of injuries incurred during the scrum. On reflection, it is worthwhile noting that the original function of the scrum phase was to serve as a means to restart play but this function has been lost in an effort to use the scrum to gain a competitive edge over the opposition. Successful scrumming became a powerful offensive skill in providing a base for attacking play and in wearing down the opposition. In addition, scrumming also became a defensive measure in denying the opposition their share of clean possession.

This competitiveness led to the adoption of techniques that are contrary to the spirit of the game and in some cases predispose players to an increased risk for controversial catastrophic neck injuries to players in the front row of the scrum. These techniques include collapsing and rotating the scrum whilst it is in progress, breaking the scrum up early and "crashing" the scrum on engagement. As a result of these practices and their concomitant injury risk numerous rule-revisions were implemented. In particular crashing the scrum, that is making forceful contact with the opposing front rows' shoulders during engagement, has been implicated by Sher (1982) as the primary example of these disruptive techniques. The 1988 revision to law 20 (2) sought to eliminate this practice by specifying each front row should touch on the upper arms and then pause prior to engagement in the sequence: crouch - touch - pause - engage. The mechanics of injury that this amendment aimed at preventing had been identified as hyperextension or hyperflexion of the cervical spine when malalignment of the scrum and subsequent collision of the heads of the opposing front rows took place on scrum formation. It is quite conceivable, however, as argued by Torg (1992) that in such circumstances injury may in fact occur by way of axial compression if the mechanics of crashing the scrum are equated to the outlawed technique of "spearing" in American Football where players tackle by striking an opponent with the top or crown of their helmet.

Subsequent to this, the 1990 schoolboy rule-revisions went a step further in attempting to depower the scrum by introducing the so called staggered scrum. This law (20 [2]) required that every scrummage be stationary with the middle line parallel to the goal lines until the ball has been put in. In addition, before commencing engagement each front row must be in a crouched position with heads and shoulders no lower than their hips and not more than one arms' length from their opponents' shoulders. On the referees command the scrum forms in three phases: i) a front row of three players; ii) a second row of two players; and iii) the remaining players taking part in the scrummage. In a very appropriate study Du Toit (1993) recently investigated the kinetics of full-scrum and staggered-scrum engagement among high school rugby players. Their findings showed that the magnitude of the total engagement force application as it is applied to the shoulders of the front rows was significantly greater with the implementation of the full-scrum engagement technique as opposed to the staggered-scrum engagement technique. The same was found for the individual playing positions of front rows, locks and loose forwards respectively. In addition to this no differences were found in sustained force application between the two techniques. This led them to conclude that the large engagement force experienced by players with the implementation of the full-scrum engagement technique is unnecessary and may increase the incidence of injury to the cervical spine, should the scrum misalign on engagement.

The following further amendments to law 20 aimed at controlling the wheeling (destabilization via rotation), duration and collapsing of the scrum in an attempt to prevent injuries were also introduced, viz. A scrummage must not be wheeled beyond a position where the middle line becomes parallel to the touch line (90 degrees), in which case the scrummage will be reformed at the original mark (1988). While the scrummage is in progress a minimum of five players shall remain bound in the scrummage until it ends (1988). No player may deliberately prevent the ball from emerging from a scrummage (1990 - Schoolboy Law). It is illegal to intentionally lift an opponent off his feet or force him upwards out of a scrum (1992).

Line-out - previous incidences ranged from between 1 and 4% for schoolboys and 3% for adults. The present zero incidence would suggest a further slight decrease to the observed consistently low injury risk in the line-out. This slight decrease could be related to the revisions of law 23 instituted in 1990 for schoolboys and in 1992 for all levels of rugby.

The 1990 schoolboy rule-revision stated that at a formed line-out the ball must be throw-in such that it is within the area formed by the outer shoulders of the players in the line-out. The 1992 revision stated that the former half metre space required between lines of players is increased to one metre and a player jumping for the ball must use both hands or his inside arm. These revisions may have contributed to making line-outs more controlled and cleaner than in the past where, at senior level in particular, a range of illegal tactics such as obstruction by barging, pulling down or using the inside arm to push down on an opponent when jumping for the ball, characteristically caused tempers to flare and thus proved to be a source of foul play.

Open play - previous incidences ranged from between 8 and 11% for schoolboys and 21% for adults. The present 29% incidence is far higher in comparison, approximating that reported for adults. This finding may, however, be spurious due to inclusion of those injuries classed as "other" in the comparative studies, although their criteria for this categorization is not clear.

Foul play - previous incidences ranged from between 4 and 8% for schoolboys and 5% for adults. The present zero incidence would suggest a further decrease to the observed relatively low contribution of foul play to injury. This decrease could be related to the 1988 revision of law 6B applicable to both adults and schoolboys where it became mandatory for touch judges to report incidents of foul play. This law was introduced as deterrent to foul play and misconduct under circumstances where the referee may be unlikely to observe it. Additionally two further revisions seem to have had a beneficial reduction in the incidence of injuries as a result of foul play. Firstly, the 1990 schoolboy amendment to the penalty (law 26B) stated that for a grievous offence of such a nature as would warrant sending off the field or to the cooler, the referee will award the non-offending team a penalty kick anywhere along the 22 m line, or if the offence occurs within the opposing teams' 22 m area, the non-offending team will have the option of a penalty at the place of infringement or anywhere along the 22 m line. Secondly, the 1992 revision pertaining to the throw-in at a line out (Law 23B) dictated that when a penalty is kicked directly into touch the same team will have the throw-in.

From Table XXXVI it is evident that the following noteworthy observations can be made in terms of the risk of injury per playing position:

Fullback - the finding of a zero injury incidence by Malan and Strydom (1987) would appear to be spurious with incidences ranging from between 11 and 15% for schoolboys and 11% for adults. The present incidence of 16% would suggest a similar or slightly increased incidence. If the slight increase in injury to fullbacks were to be an accurate deduction, it may have been brought about by the 1992 change in law 23B.

This new law pertaining to the acts of kicking for touch and taking a quick throw-in from touch, ruled that when a player receives the ball outside his 22 m area and runs behind the 22 m line to kick for touch, he may not gain ground from the kick; and at a quick throw-in the ball may be thrown from any point along the touchline nearest to the defending teams' goal line, provided the player uses the same ball and retrieves it himself.

Although neither of these laws apply solely to players in the fullback position, in practical terms he is the player most affected. In the first instance according to the traditional "safe" approach, the fullback would typically retreat into his own 22 m area in order to kick directly into touch when under pressure of the opponents, and thus relieve the pressure on himself and his team as well as gain ground by forcing a pause in play through a line-out. Now he cannot do so and instead tends to run himself out of trouble, and in so doing is more exposed to being tackled. In the second instance, by allowing greater leeway in terms of taking quick throw-ins, what typically happens is that the fullback, as the last player in defence, tends to launch a counter-attack if not under pressure, and in so doing is again more exposed to being tackled than in the past.

Wing - the finding of a 5% incidence by Nathan et al. (1983) would appear to be unrealistic, with incidences ranging from between 12 and 17% for schoolboys and 15% for adults. The present incidence of 12% would suggest a relatively similar and unchanged incidence. It would thus seem that, as indicated by others (Lingard & Sharrock, 1976), speed of play which is characteristic of the wing position, has remained a major contributor to injury.

Centre - previous incidences ranged from between 5 and 10% for schoolboys and 10% for adults. The present zero incidence suggests a definite reduction in injuries to the centre position. This reduced incidence may be related to the 1988 revision in law 26 pertaining to the high tackle as a form of foul play. This new law ruled that tackling or attempting to tackle a player around the neck or head or above the line of the shoulders must be punished severely and a penalty awarded in all such cases. The aim of this law was to reinforce the need to deter and penalize any form of high tackle, which medical review (Kew et al.,1991) has shown to be responsible for numerous neck injuries among players in the centre position. It would thus appear that this new law provision has had a profound positive effect.

Flyhalf - previous incidences ranged from between 8 and 12% for schoolboys and 8% for adults. The present 24% incidence suggests a definite increase in injuries to the flyhalf position. It could be speculated that this increased incidence may be related to some extent to a prevailing popular commitment to running rugby involving all fifteen players.

This approach may thus have converted the flyhalf from being a protected player - dictating the game through constant tactical kicking so typical of "10-man" rugby, to a player who is now more involved in the game in being the target for and running at the opposition in the process of setting-up so called "crash-ball" from which second phase attacks are launched. This would necessarily imply that the flyhalf would have to tackle more frequently and also be more exposed to tackles, particularly late-tackles, from the opposition than was the case in the past.

Scrumhalf - previous incidences ranged from between 9 and 12% for schoolboys and 5% for adults. The present incidence of 8% would suggest a fairly similar or slightly decreased incidence. The slight decrease in injury to scrumhalves may be related to the 1990 schoolboy rule-revisions to law 24B which pertains to off-side at the scrummage.

This new law ruled that a player is off-side if he, being the player of either team who puts the ball in the scrummage, advances beyond the centre line of the scrummage, or if he is the immediate opponent of the player putting in the ball, takes up a position on the opposite side of the scrummage in front of the off-side line. This essentially means that the opposing scrumhalf is no longer allowed to shadow his opponent while waiting for the ball to emerge from the scrum and thus the scrumhalf clearing the ball from the base of the scrum is less exposed to being tackled from behind by his direct opponent.

Eighth-man - previous incidences ranged from between 8 and 13% for schoolboys and 9% for adults. The present incidence of 8% would suggest a fairly similar or slightly decreased incidence. The slight decrease in injury to eighth-men may be related to the 1990 schoolboy rule-revisions to law 20 which pertains to the duration of the scrummage.

This new law ruled that no player may deliberately prevent the ball from emerging from a scrummage. This essentially means that the eighth-man may no longer hold and control the ball at his feet in preparation to picking it up and starting a driving movement down-field at the opponents. Subsequently the ball is more often cleared from the scrum to the flyhalf, thus decreasing the eighth-mans' potential exposure to an opponents tackle.

Flank - the finding of a 2% injury incidence by Malan and Strydom (1987) would appear to be spurious with incidences ranging from between 6 and 10% for schoolboys and 9% for adults. The present incidence of 16% suggests a definite increase in injuries to the flank position. The reason for this is not clear. It could be speculated that as the playing activities of the eighth-man appear to have been curtailed to some extent, as indicated in the previous paragraph, players in the flank position have now become the dominant loose-forwards and as a result are more exposed to potentially injurious situations than before.

Lock - previous incidences ranged from between 4 and 6% for schoolboys and 6% for adults. The present zero incidence would suggest a decrease to the observed consistently low injury risk among players in the lock position. This slight decrease in injury to locks could logically be linked to the amendment of the line-out laws discussed previously.

Hooker - the finding of a 32% injury incidence by Nathan et al.(1983) would appear to be spurious with incidences ranging from between 8 and 16% for schoolboys and 19% for adults. The finding of a 16% incidence by Malan and Strydom (1987) would also appear to be unrealistically high for schoolboys - unless the risk of injury to the hooker among schoolboys at provincial level is in fact similar to the 19% of adult levels. The present incidence of 8% is the same as that reported by Roux et al.(1987) and suggests that the incidence of injury to hookers at high school level has essentially remained relatively low and unaltered, despite the amendments to the scrum laws discussed previously.

Prop - the finding of a 2% injury incidence by Nathan et al.(1983) would appear to be spurious with incidences for the present and other studies being constant at 8% for schoolboys and 6% for adults. Similar to the situation regarding the other front row position of hooker, it would appear that the incidence of injury to props at schoolboy level has essentially remained relatively low and unaltered, despite the amendments to the scrum laws discussed previously.

PERIOD OF PLAY

Of the overall 143 injuries incurred during match-play, more injuries (55%) occurred in the second-half as opposed to the first-half (45%) of the match, but this difference was not significant (p>0,05). A possible explanation for this observation may be that more second-half injuries occurred as a result of cumulative neuromuscular fatigue (Gandevia,1992). In comparison to major injuries (causing a loss of at least seven days), the reverse was observed with more first half injuries (57%) occurring than second-half injuries (43%), although this difference was not significant (p>0,05). Major injuries thus did not seem to be fatigue-related.

TIME OF DAY

Of the overall 143 injuries incurred during match-play, the significant (p<0,05) majority of injuries (60%) occurred in morning-fixtures as opposed to injuries incurred (40%) during afternoon-fixtures. A similar observation was found with regard to major injuries (causing a loss of at least seven days) with 57% occurring in morning as opposed to 43% in the afternoon, although this difference was not significant (p>0,05). It may be speculated that the low or decreased temperatures experienced during early morning matches could be related to a loss of motor performance (Meeusen and Lievens,1986; Noonan et al.,1993), thus enhancing the risk of injury. A rival hypothesis is, however, that more matches may have taken place in the morning than in the afternoon and in the absence of considering such possible exposure bias, speculation is cautioned.

TYPES OF INJURY

As would be expected from a contact/collision sport such as rugby, the significant (p<0,001) majority (98,8%) of all injuries incurred were of a traumatic nature and only 1,2% were due to overuse, being interpreted as having an acute (sudden) or chronic (gradual) onset, respectively. Table XXXVII reflects the injury profile per injury type for the present and comparative studies.

TABLE XXXVII: COMPARATIVE INJURY PROFILE / INJURY TYPE (%)

INJURY TYPE	High School (HS) Present Study		High School (HS) Roux [1]	HS Provincial Malan [2]	Adults Clark [3]
	Overall	Major			
Muscle	29	29	17	47	33
Bone Bruise	32	0	6	0	4
Ligament	26	29	25	41	32
Dislocation	0	0	10	6	9
Fracture	2	18	27	2	11
Laceration	2	0	0	4	3
Concussion	5	18	12	0	10
Internal	3	6	3	0	1
Ear Haematoma	1	0	3	0	0

[1] Roux et al.(1987) - High School players; [2] Malan & Strydom (1987) - High School Craven Week ; and [3] Clark et al.(1990) - Adult players participating at club level.

In terms of the overall incidence, bone bruises/osseous contusions were the commonest injuries (32%) followed in close succession by muscle injuries (comprising both contusions and strains) and ligament sprains with a 29% and 26% incidence, respectively. As far as major injuries are concerned, all were of an acute nature, with muscle injuries and ligament sprains again being the most prevalent (29% each) with fractures and concussion (18% each) also being predominant. This prevalence of major injury type is more or less in agreement with the findings of the comparative studies among schoolboys and adults, although Roux et al. (1987) did find a higher prevalence of fractures (27%) and a lower under-reported frequency of concussion (12%) among their schoolboy cohort. The data of the remaining schoolboy study (Malan & Strydom,1987) are anomalous to interpretation in this context.

A noteworthy observation is that when ligamentous sprains (excluding those to the interphalangeal and first carpometacarpal joints) and muscle strain injuries are combined, 62% of the overall sprain and strain incidence and 70% of the major sprain and strain injuries were incurred in spite of an adequate warm-up prior to participation. Although this study only focussed on musculoskeletal injuries, it can be reported anecdotally that four cases of respiratory distress in the form of bronchospasm were recorded. One may speculate that weather conditions in the form of an extended drought period during the season contributed to these conditions in that the playing fields were extremely dry and dusty, being exacerbated by frequent scrummages. In fact three of the four cases of bronchospasm were incurred by front-row forwards in the process of scrumming.

ANATOMICAL SITES OF INJURY

Tables XXXVIII and XXXIX reflect the injury profile per anatomical site for the comparative and present studies, respectively. In terms of both the overall and major incidence the lower-limbs were affected (42%) significantly more ($p<0,05$) than the upper limbs, while there was no significant difference ($p>0,05$) between the injury incidence to the head and neck as opposed to the trunk. In terms of the overall incidence, the lower-limbs were affected mostly (42%) followed in close succession by head and neck injuries (23%), injuries to the upper-limbs (21%) and lastly injuries to the trunk (14%). As far as major injuries are concerned, the lower-limbs were again mostly

TABLE XXXVIII: COMPARATIVE INJURY PROFILE / ANATOMICAL SITE

ANATOMICAL SITE (%)	High School (HS) Present Study Overall	Major	Roux [1]	HS Provincial Malan [2]	Adults Clark [3]
Lower-Limbs	42	41	37	41	44
Upper-Limbs	21	6	20	27	27
Head & Neck	23	35	29	25	23
Trunk	14	18	13	8	7

[1] Roux et al.(1987) - High School players; [2] Malan & Strydom (1987) - High School Craven Week; and [3] Clark et al.(1990) - Adult players participating at club level.

TABLE XXXIX: INJURY PROFILE / SPECIFIC ANATOMICAL SITE (%)

ANATOMICAL SITE	INCIDENCE Overall	Major	ANATOMICAL SITE	INCIDENCE Overall	Major
LOWER-LIMBS			**UPPER-LIMBS**		
Thigh	12	12	Shoulder	9	6
Knee	10	12	Elbow	0	0
Shin	6	5	Forearm	1	0
Ankle	12	12	Wrist	1	0
Foot	1	0	Hand	1	0
Toes	1	0	Fingers	9	0
Total :	**42**	**41**	**Total :**	**21**	**6**
HEAD & NECK			**TRUNK**		
Head	9	17	Clavicle	1	6
Neck	4	6	Ribs	6	0
Face	9	12	Back	2	0
Ear	1	0	Abdomen	5	12
Total :	**23**	**35**	**Total :**	**14**	**18**

affected (41%) followed by head and neck injuries (35%), injuries to the trunk (18%) and lastly injuries to the upper-limbs (6%). This pattern of major injury per anatomical site is very similar to the findings of the comparative studies among schoolboys and adults, with the lower-limbs being at greatest risk throughout and the trunk being at lowest risk in all cases but one, while the head/neck and the upper-limbs had an intermediate risk of injury.

MECHANISMS OF INJURY

Of all 171 injuries recorded, irrespective of their severity, the significantly ($p<0,001$) predominant (86%) injury mechanism identified was that of contact/collision - resulting primarily from impact with another player (74%), the ground (10%) or the ball (2%). The remaining injuries were of a non-contact nature (14%), incurred as a result of acceleration/deceleration forces of the limbs.

In an attempt to determine evident aetiological patterns among all injuries recorded, the following analysis is based on the respective identification of the specific anatomical site (as reflected in Table XXXIX in conjunction with Figures 4.14-4.17), the circumstances under which the injury occurred, the mechanism of injury and the ensuing injury type.

LOWER-LIMBS

Thigh - Twenty-one (12%) of the injuries were to the thigh. Eight were of a non-contact nature occurring as a result of sudden acceleration/deceleration movements involved in open play activities of sprinting (6 cases), kicking (1 case)

FIGURE 4.14: LOWER-LIMB / ANATOMICAL SITE INJURY PROFILE

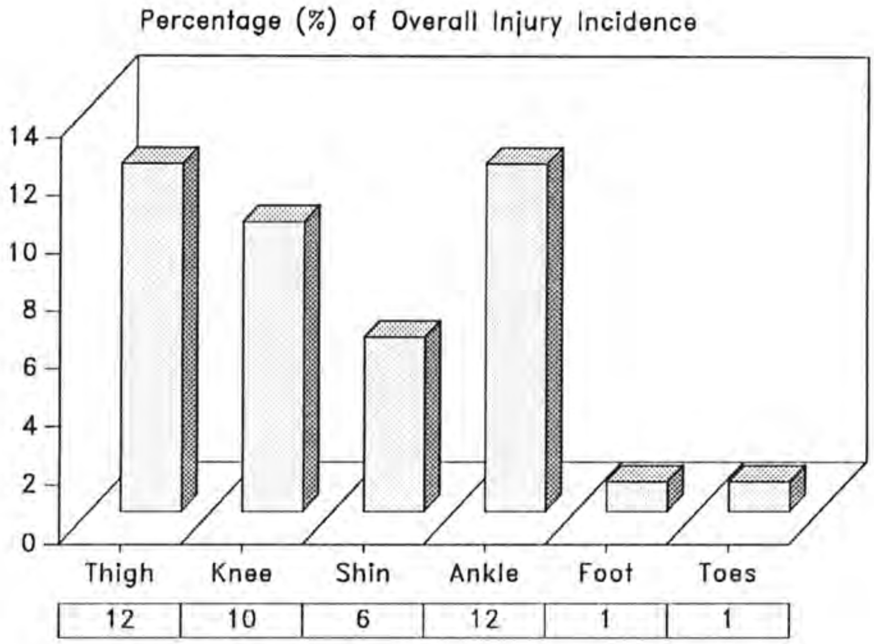
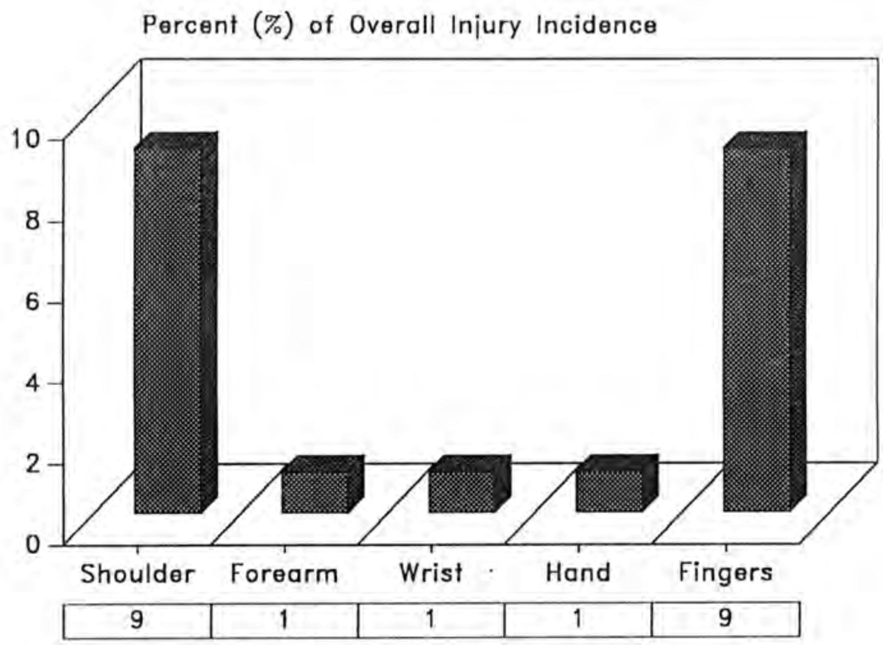


FIGURE 4.15: UPPER-LIMB / ANATOMICAL SITE INJURY PROFILE



and callisthenics (1 case). This led to strains of the quadriceps, hamstring, groin and abdominal musculature. Thirteen injuries were of a contact nature. Ten of these injuries were incurred via impact with an opponent whilst being tackled (5 cases), stood on in a loose-scrum (3 cases) and running into another player (2 cases) all leading to contusions of the quadriceps musculature. The remaining three contact injuries were incurred via impact with the ground during a fall ensuing from the tackle phase leading to contusions of the gluteus musculature.

Knee - Eighteen (10%) of the injuries were to the knee joint, all of which were of a contact nature sustained via impact with an opponent. Five were incurred whilst being tackled and three from a kick in the loose-scrum, leading to nine osseous contusions. The other nine injuries were all tackle-related ligamentous sprains. Six of these affected the lateral collateral structures and three affected the medial collateral structures, resulting from the respective injurious varus and valgus forces associated with the tackle phase. Two of the latter injuries were compounded by a subsequent awkward fall over the opponent and concomitant torsion of the joint, respectively. Of the nine ligamentous sprains, two were recurrent - both of which were incurred in the absence of the potential protection of supportive strapping or bracing.

Shin - Eleven (6%) of the injuries were to the lower-leg/shin area. Three were of a non-contact nature occurring as a result of sudden acceleration/deceleration during sprinting, leading to strains of the tibialis anterior (2 cases) and gastrocnemius musculature. Eight injuries were of a contact nature. Seven of these injuries were incurred whilst being stood on in a loose-scrum leading to contusions of the gastrocnemius musculature (2 cases) and tibial osseous contusions (5 cases). The remaining injury also comprised a tibial osseous contusion incurred via impact with an opponents' boot whilst being tackled.

Ankle - Twenty (12%) of the injuries were to the ankle. Nine were of a non-contact nature occurring whilst running in open play, all of which resulted in ligamentous sprains of the subtalar joint. One of these injuries affected the medial collateral structures and eight affected the lateral collateral structures resulting from forced eversion and inversion, respectively. Two of the latter injuries were specifically incurred in the process of performing the "side-step" skill. Eleven injuries were of a contact nature. Nine of these injuries resulted in ligamentous sprains. Seven of these affected the subtalar joint lateral collateral structures incurred via forced inversion following an awkward fall after a tackle, and one affected the medial collateral structures as a result of forced eversion after being stood on during a loose-scrum. The remaining ligamentous sprain involved the talocrural joint which resulted from forced dorsiflexion following a fall from a tackle. The remaining two contact injuries comprised contusions of the ankle resulting from being stood on by an opponent during open play and from the impact of the corner flag sustained whilst being tackled close to the try-line.

The injury mechanism of the nine non-contact ligamentous sprains of the subtalar joint could well be linked to the uneven surface conditions brought on by the drought period alluded to earlier. Notably also, all eighteen ligamentous sprains were incurred in individuals wearing "low-cut" boots. This suggests that although enhancing mobility as opposed to the stability of "high-cut" boots, the loss in ankle support particularly during lateral movements whilst wearing low-cut boots comprises a risk factor for ligamentous sprains of the ankle. Finally, of the eighteen ligamentous sprains, five were recurrent - four of which were incurred in the absence of the potential protection of supportive strapping or bracing.

Foot - Two (1%) of the injuries were to the foot. Both were of a contact nature, incurred whilst being kicked and stood on by an opponent during a loose scrum - leading to osseous contusions of the metatarsals.

Toes - One (1%) of the injuries was to the toes and was of a contact nature. The injury was incurred whilst being stood on by an opponent after a tackle - leading to an osseous contusion of the hallux.

UPPER-LIMBS

Shoulder - Fifteen (9%) of the injuries were to the shoulder area all of which were of a contact nature. Five were incurred via impact with the ground in a fall after being tackled - leading to four contusions of the involved musculature in four cases and a ligamentous sprain of the glenohumeral joint as a result of forced horizontal abduction in one case. Ten injuries were incurred via contact with an opponent. Two of these cases were sustained in the process of making a tackle, with the impact leading to contusions of the involved musculature. Six cases involved a destabilized collapsing scrum leading to strains of the shoulder musculature. The final two cases also involved close contact/wrestling with an opponent in a loose-scrum and being tackled, leading to a muscle strain and a ligamentous sprain of the acromio-clavicular joint, respectively.

Forearm - Two (1%) of the injuries were to the forearm both of which were of a contact nature incurred whilst being stood on by an opponent during ruck and maul and after making a tackle respectively, leading to contusions of the involved musculature.

Wrist - One (1%) of the injuries was incurred at the wrist and was of a contact nature. The injury was incurred via impact with the ground whilst landing on an out-stretched hand in the process of breaking a fall after being tackled, causing forced dorsiflexion and resulting in a ligamentous sprain of the radiocarpal joint.

Hand - Two (1%) of the injuries were to the hand both of which were of a contact nature incurring whilst being stood on by an opponent leading to contusions of the metacarpal bones.

Fingers - Fifteen (9%) of the injuries were to the fingers all of which were of a contact nature. Four were incurred via impact with the ball during a mis-catch, causing forced hyperextension leading to ligamentous sprains of the proximal inter-phalangeal joint of the involved digit in all cases. Eleven injuries were incurred via impact with an opponent. Eight of these cases were sustained in the process of making a tackle, causing forced hyperextension leading to ligamentous sprains of the first carpometacarpal joint (3 cases) and proximal inter-phalangeal joint (5 cases) of the involved digit, respectively. The remaining three cases were contusions of the phalanges sustained whilst being stood on by an opponent.

TRUNK

Back - Four (2%) of the injuries were to the back all of which were of a contact nature. Two injuries were osseous contusions incurred via impact with the ground after a

FIGURE 4.16: HEAD & NECK / ANATOMICAL SITE INJURY PROFILE

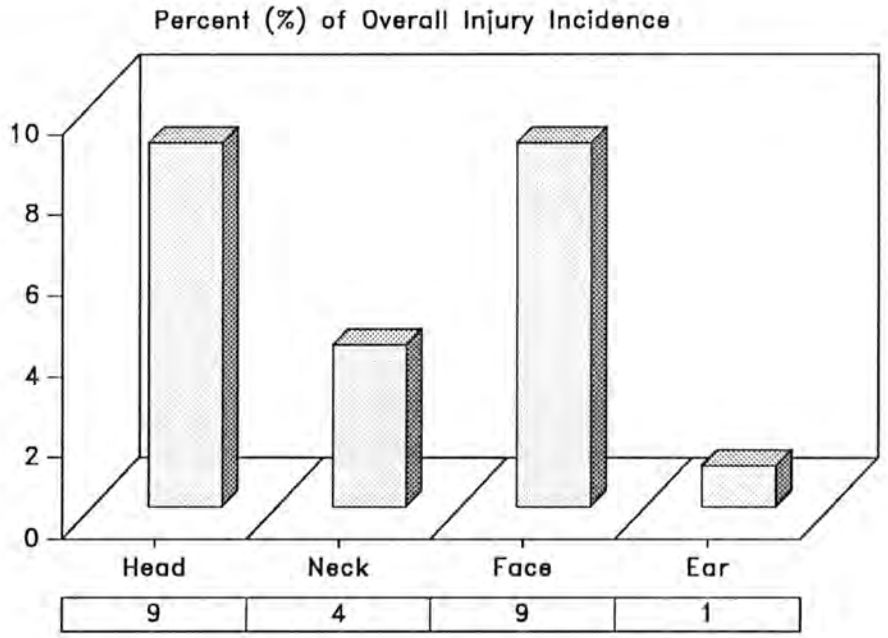
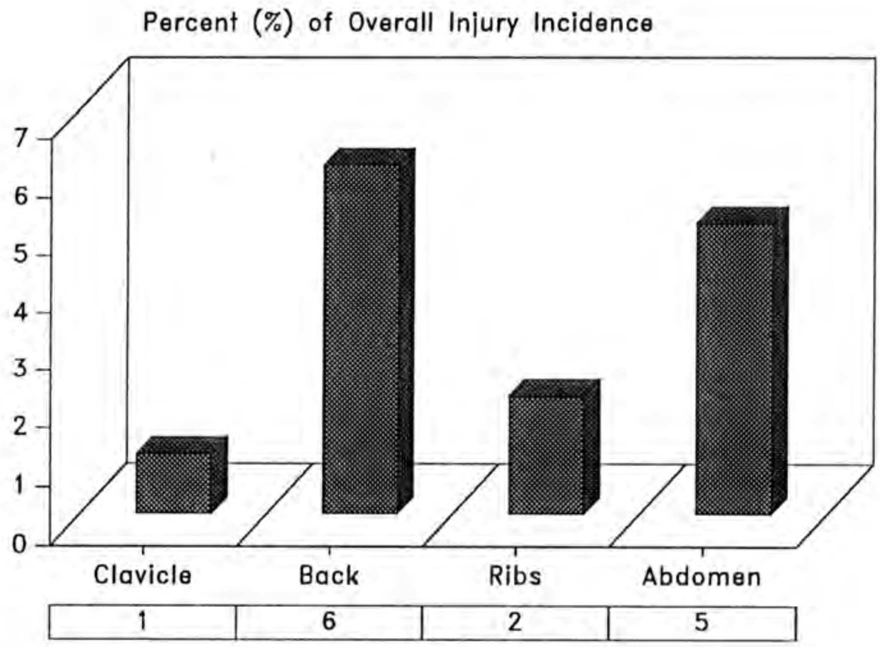


FIGURE 4.17: TRUNK & BACK / ANATOMICAL SITE INJURY PROFILE



"whiplash" tackle and a player landing on his coccyx in the absence of support following a line-out. The remaining two injuries entailed a strain of the erector spinae musculature due to a collapsed scrum and a contusion following being stood on or "raked" by an opponent during a loose-scrum.

Clavicle - One (1%) of the injuries was to the clavicle and was of a contact nature. The injury was incurred via impact whilst tackling an opponent thus leading to a subsequent fracture.

Abdomen - Eight (5%) of the injuries were to the abdominal area. Three were of a non-contact nature resulting in strains of the abdominal musculature incurred during a respective fall after being tackled, sprinting activity in open play and performing a "jack-knife" movement during callisthenic warm-up exercises. Five injuries were of a contact nature incurred via impact with an opponent after being tackled late in all but one instance. This resulted in transitory paralysis of the diaphragm or being "winded" after a blow to the solar plexus (4 cases) and a contused bladder (1 case).

Ribs - Eleven (6%) of the injuries were to the ribs - all of which were of a contact nature and resulted in osseous contusions. One injury was incurred via impact with the ground following a fall subsequent to being tackled. Nine injuries were incurred via impact with opponents whilst being tackled (4 cases), opponents falling on top of them after tackling (2 cases) and the loose-scrum collapsing (2 cases). The remaining two injuries were incurred whilst being "raked" or stood on by an opponent during a loose-scrum.

HEAD AND NECK

Head - Sixteen (9%) of the injuries were head injuries all of which were of a contact nature. Nine injuries comprised concussion incurred via impact with the ground after being tackled (4 cases) or with an opponent whilst being tackled (2 cases), making a tackle (2 cases) and during a loose-scrum (1 case). Seven injuries comprised osseous contusions incurred in a similar manner as concussion, via impact with an opponent in a collision during open play (2 cases), a loose-scrum (2 cases), while tackling and being tackled (1 case each). The remaining contusion was incurred via impact with the ground after being tackled. Of all the concussion injuries, 89% were incurred in the absence of a gumgaurd being worn by the player - as was the case with all of the major-concussion injuries. Considering that all concussion injuries were incurred via impact with the ground, the drought-related unyielding surface conditions referred to previously, seems to have contributed to the injury mechanism.

Neck - Seven (4%) of the injuries were to the neck, all of which were of a contact nature. Five injuries were strains of the cervical musculature resulting from forced extension via the aforementioned "whiplash" tackle (1 case) and forced flexion due to the scrum either being "popped" - lifted illegally (1 case) or collapsed (3 cases). The remaining two injuries were cervical ligamentous sprains, both being the result of forced flexion due to malalignment of the front rows on scrum engagement and during a loose-scrum, respectively.

Face - Fifteen (9%) of the injuries were orofacial - all of which were of a contact nature following impact with an opponent. Two oral injuries were incurred in being "handed-off" whilst making a tackle and during a loose-scrum, respectively - both of which resulted in lacerations to the lower-lip, the former being sustained in the absence of wearing a gumgaurd. Three jaw injuries were incurred whilst tackling and during a loose-scrum, resulting in a fracture and two osseous contusions of the mandible, respectively. Six nose injuries were incurred. Five of these were sustained in the loose-scrum resulting in osseous contusions of the nasal septum (4 cases) and a related epistaxis or "nose-bleed". Three injuries involved the eye area. Two of these injuries were orbital haematomas or "black eyes" incurred during a loose-scrum and foul punch, respectively. The remaining injury also entailed foul play, incurred during an intentional "head-but", resulting in a laceration of the eye-brow.

Ear - One (1%) of the injuries was to the ear and was of a contact nature. Predictably, the injury was incurred by a tight-head prop via scrumming where the contact/friction against the opponent in the front row led to an acute case of haematoma auris or inflamed "cauliflower ear" - despite the ear being covered with protective taping.

2.2.2 INTRINSIC RISK FACTOR ANALYSIS

In the forthcoming section intrinsic risk factors for injury are considered. To recapitulate, a study of intrinsic risk factors relates to the individual physical characteristics of the participant. It should be emphasized that this study is novel both in attempting to identify intrinsic risk factors among high school rugby players and in terms the prospective epidemiological design employed to do so. Consequently, no directly comparable data is evident and thus results are discussed within the context of related literature, where appropriate.

In the current analysis of intrinsic risk factors, an injury was defined as one either requiring medical referral or being severe enough to cause a loss of at least seven days from participation. Players incurring injuries conforming to the above definition, were subsequently labelled as the exposed group, while players who did not sustain such an injury were labelled as the non-injured controls. In the course of this evaluation the following potential intrinsic risk factors, as identified from the data of the present study are presented and discussed:

BODY COMPOSITION	**/ MORPHOLOGY**	**MUSCULAR FUNCTION**
* Stature	* Somatotype	* Relative Strength
* Body Mass	* Endomorphy	* Range of Motion
* Lean Body Mass	* Mesomorphy	* Relative Power
* Body Fat	* Ectomorphy	* Running Agility

BODY COMPOSITION / MORPHOLOGY

Table XXXX and Figures 4.18-4.22 reflect the morphological risk factor analysis. Profiles of the exposed (injured) players versus non-injured controls indicated a significantly greater mean stature (176,8 ± 8,6 vs 172,1 ± 8,7 cm: p<0,01); body mass (69,7 ± 11,3 vs 63,9 ± 12,6 kg: p<0,05); lean body mass (60,0 ± 9,7 vs 52,3 ± 9,6 kg: p<0,001); and a lower body fat (13,9 ± 3,1 vs 17,9 ± 6,6 % : p<0,001), respectively. Individual somatotype component variations did not differ significantly (p>0,05), being slightly lower for endomorphy (2,4 ± 0,9 vs 2,9 ± 1,5) but similar for mesomorphy (4,8 ± 1,0 vs 4,9 ± 1,2); and ectomorphy (3,2 ± 1,0 vs 3,2 ± 1,4).

TABLE XXXX: MORPHOLOGICAL INTRINSIC RISK FACTOR ANALYSIS

VARIABLE : MEASURED :	EXPOSED X ± SD	:	CONTROLS X ± SD		SIGNIFICANCE LEVEL	
Stature (cm)	176,8 ± 8,6	:	172,1 ± 8,7	:	p<0,01	**
Body Mass (kg)	69,7 ± 11,3	:	63,9 ± 12,6	:	p<0,05	*
Lean Mass (kg)	60,0 ± 9,7	:	52,3 ± 9,6	:	p<0,001	***
Body Fat (%)	13,9 ± 3,1	:	17,9 ± 6,6	:	p<0,001	***
Endomorphy	2,4 ± 0,9	:	2,9 ± 1,5	:	p>0,05	NS
Mesomorphy	4,8 ± 1,0	:	4,9 ± 1,2	:	p>0,05	NS
Ectomorphy	3,2 ± 1,0	:	3,2 ± 1,4	:	p>0,05	NS

Exposed/Injured Group (n=37) Non-Injured Controls (n=96)

Stature and Body Mass

The observation of a significantly greater stature (p<0,01) and body mass (p<0,05) among the exposed (injured) players versus non-injured controls in this study is not unexpected (Figures 4.18 & 4.19). The relationship between body stature and injuries may be due to the elevated position of the centre of gravity or to the length of the limbs. Greater limb length could produce greater leverage and thus more stress on the limb joints in situations which require a rapid change of direction (Taimela et al.,1990).

Similarly total body mass, in conjunction with speed of movement, has critical biomechanical implications in creating the force that typically produces acute injuries which mostly occur as a result of collision or from rapid acceleration and deceleration (Peterson & Renstrom,1986). In addition, the kinetic energy involved during a collision is proportional to the mass and speed of the players

FIGURE 4.18: BODY STATURE - INTRINSIC RISK FACTOR ANALYSIS

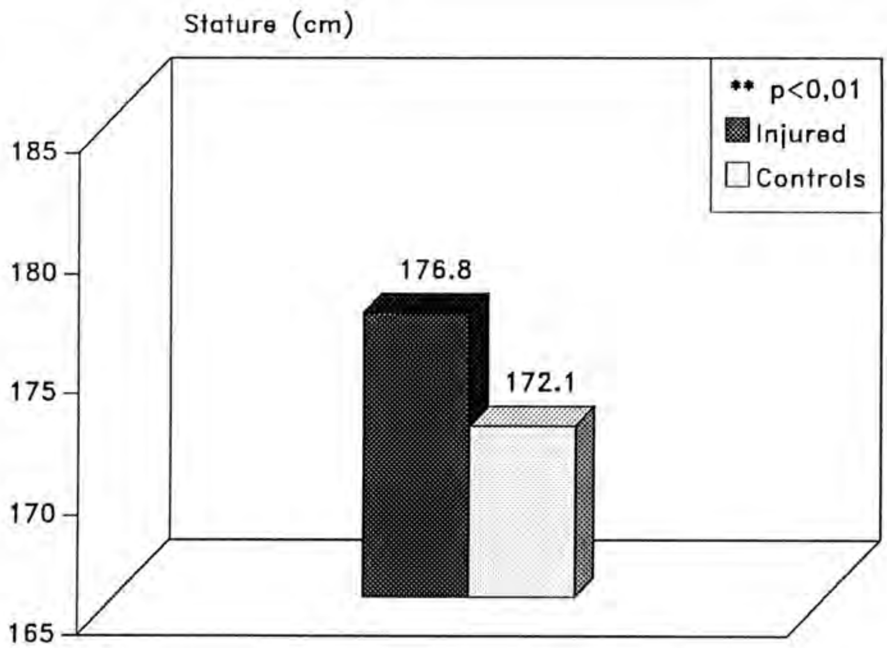
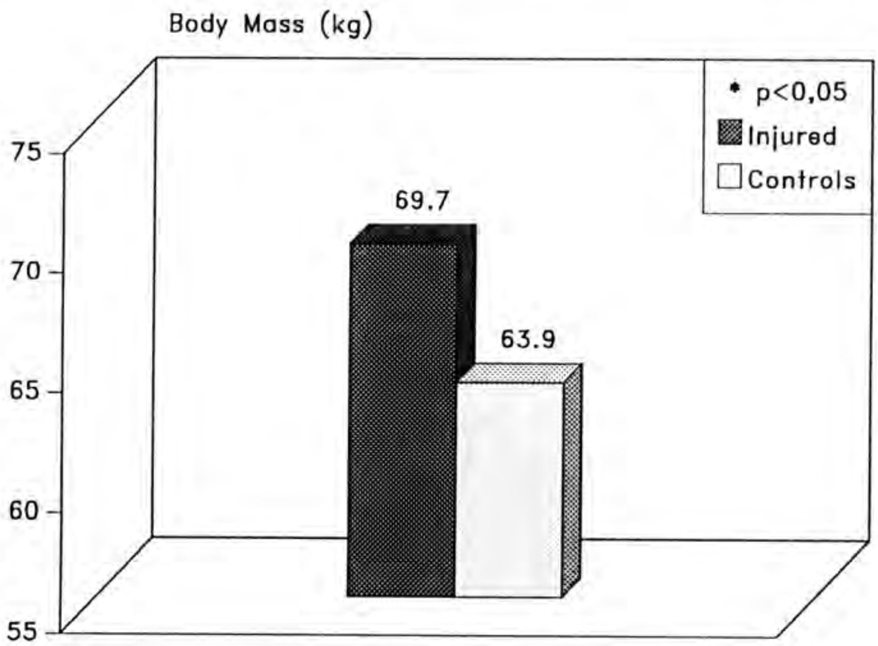


FIGURE 4.19: BODY MASS - INTRINSIC RISK FACTOR ANALYSIS



involved - thus the larger the objects colliding, the greater the likelihood of an injury. This postulate gains further credibility when one considers that speed of play was a major contributor to injuries sustained in the current study - as deduced from the predominant playing phases (94% from the various facets of broken play) and playing positions (60% to backline players) in which injuries were incurred.

Other studies conducted among high school American football players (Blyth & Meuller,1974; Goldberg et al.,1984) have also found excessive height and weight to predispose to injury. Considering that the nature of the two games is fairly similar, their findings thus lend further support to the observations of this study.

Lean Body Mass and Relative Body Fat

The observations with regard to the relative amounts of constituent body composition components of a significantly ($p<0,001$) greater lean body mass and lower body fat % among the exposed (injured) players versus non-injured controls in this study (Figures 4.20 & 4.21) is somewhat contrary to what one may expect. From a performance point of view, a high lean body mass and a low fat percentage is the ideal in optimizing the force production capabilities of the active musculoskeletal locomotor system and minimizing the negative load of the non-functional passive adipose tissue, respectively. In theory these motivations are equally applicable from an injury point of view. A high degree of muscularity (lean body mass) is considered to protect the athlete against violent insults, while overfatness would expose the participant to risk by virtue of greater physiologic and biomechanical stress during weight-bearing and deficient motor capabilities (Lysens et al.,1991).

FIGURE 4.20: LEAN BODY MASS - INTRINSIC RISK FACTOR ANALYSIS

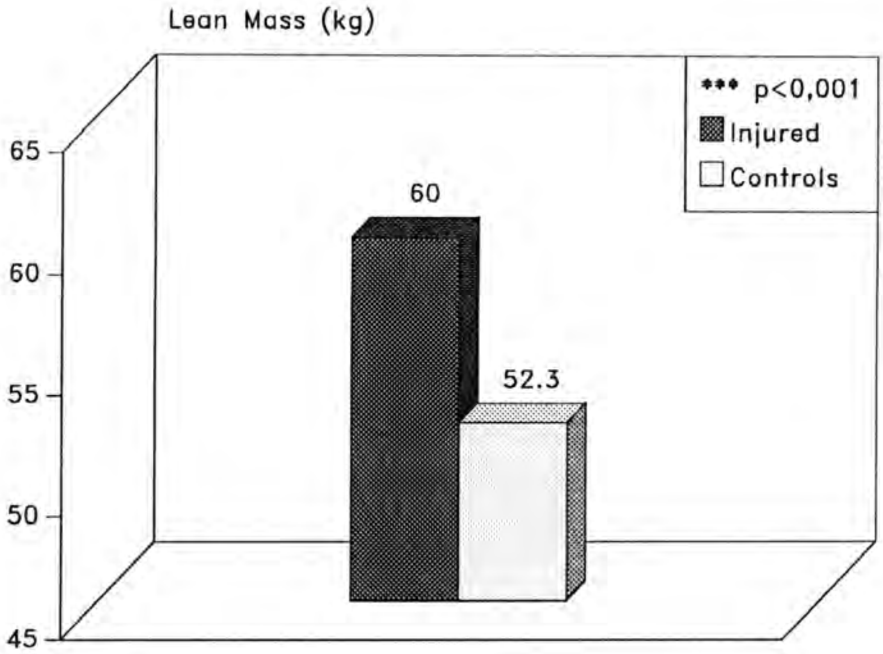
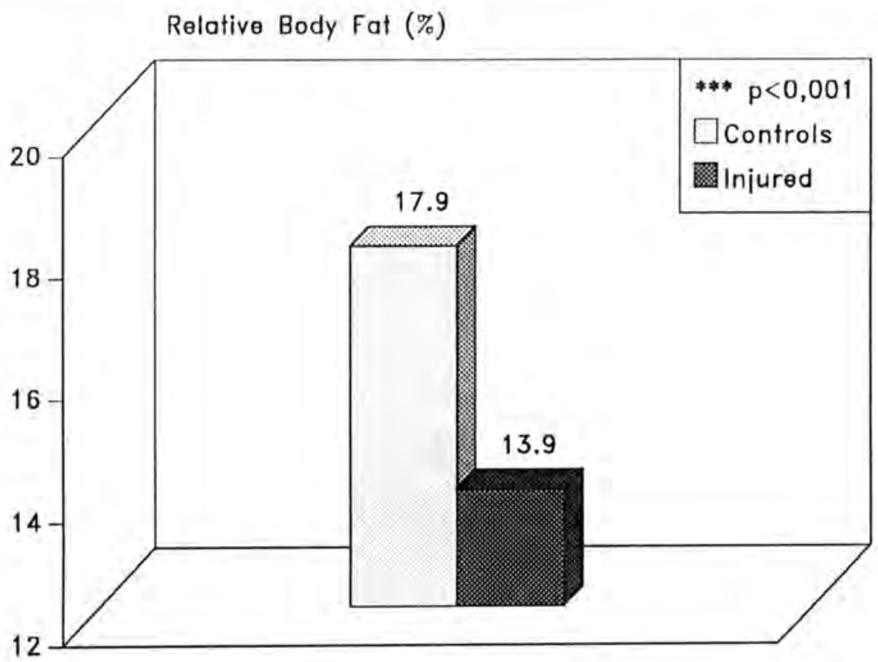


FIGURE 4.21: RELATIVE BODY FAT - INTRINSIC RISK FACTOR ANALYSIS



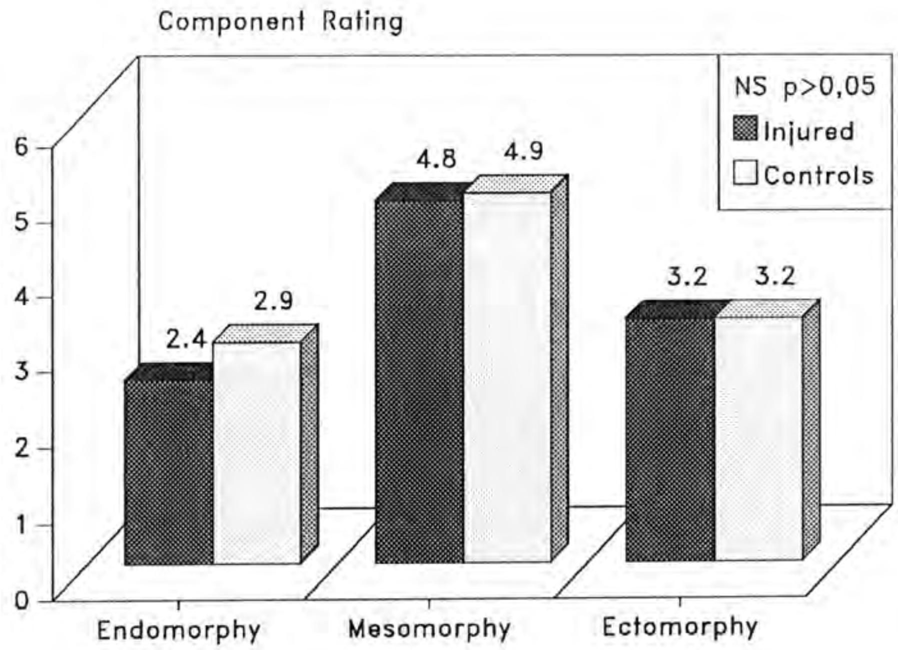
In a study of factors predisposing to injury in schoolboy rugby players Watson (1981), however, found no evidence to suggest that the incidence of injury was influenced by an excessive percentage body fat. Similarly, in the current study the greater lean body mass and lower body fat % among the exposed (injured) players versus non-injured controls appears to have predisposed rather than protect from injury. A possible reason could be the relative absence of the potential shock-absorbing properties afforded by fatty tissue in the event of a collision. A more plausible explanation, however, would be the concomitant enhanced mobility and speed of injured players, which as indicated in the previous section was a major contributor to injuries. It would thus appear that ideal body composition values for successful versus safe participation in high school rugby, are not necessarily synonymous.

Somatotype

From the perspective of somatotype being a potential intrinsic risk factor for sports-related injury, Ross et al.(1988) suggest that due to the variation in human physique, some activities and sports are more suited to some individuals than to others. In terms of the relationship between somatotype and injury in rugby, Noakes (1990) shares the opinion that certain physiques are more suited for a particular sport, by arguing that it is irresponsible to compel a thin, linear ectomorphic schoolboy to play the game of rugby.

In the current study, however, somatotype profiles of the exposed (injured) players versus non-injured controls (Figure 4.22) indicated no significant differences (p>0,05) for any of the individual components classifying both groups as ecto-mesomorphs, although the endomorphy rating

FIGURE 4.22: SOMATOTYPE - INTRINSIC RISK FACTOR ANALYSIS



was slightly lower for the injured players. Notably a study by Reilly and Hardiker (1981) relating somatotype to injuries in adult student rugby players also did not indicate any significant correlation between individual components of somatotype and injury incidence.

While somatotype would thus appear to be independent of injury risk in rugby, a recent study by Hopper et al.(1995) conducted among young elite female netball players found that individuals sustaining an injury had a significantly lower rating on the endomorphy somatotype scale and better jumping ability than did non-injured players. Netball is a deceivingly dynamic sport placing substantial stress on the musculoskeletal system. Although it cannot be classified in the same category as rugby, there may be some corresponding analogy in the tendency towards a lower endomorphy rating and subsequently a lower fat % among the injured players as found in the current study.

MUSCULAR FUNCTION

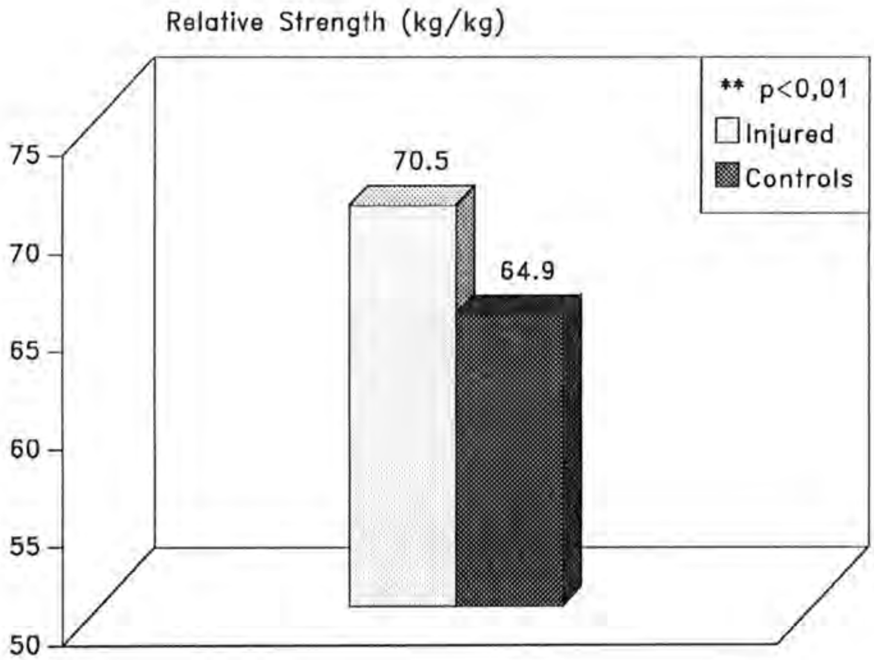
Table XXXXI and Figures 4.23-4.27 reflect the muscular function risk factor analysis. Profiles of the exposed (injured) players versus non-injured controls indicated a significantly greater mean relative grip strength (70,5 ± 8,5 vs 64,9 ± 9,9 kg/kg: p<0,01); relative vertical muscle power (15,3 ± 1,0 vs 14,3 ± 1,4 W/kg: p<0,001); and running agility (6,9 ± 0,4 vs 7,1 ± 0,4 sec: p<0,001). Gross range of motion (ROM) variations in the shoulders (2,4 ± 0,3 vs 2,5 ± 0,3) did not differ significantly (p>0,05), but gross low-back/hamstring flexibility scores (3,5 ± 1,2 vs 2,9 ± 1,1) were significantly higher (p<0,05) among the exposed (injured) group.

TABLE XXXXI: MUSCLE FUNCTION INTRINSIC RISK FACTOR ANALYSIS

VARIABLE : MEASURED :	EXPOSED X ± SD	:	CONTROLS X ± SD		SIGNIFICANCE LEVEL
Strength (kg/kg)	70,5 ± 8,5	:	64,9 ± 9,9	:	p<0,01 **
Power (W/kg)	15,3 ± 1,0	:	14,3 ± 1,4	:	p<0,001 ***
Agility (sec)	6,9 ± 0,4	:	7,1 ± 0,4	:	p<0,001 ***
ROM Shoulder	2,4 ± 0,3	:	2,5 ± 0,3	:	p>0,05 NS
ROM Low-back/ Hamstring	3,5 ± 1,2	:	2,9 ± 1,1	:	p<0,05 *

Exposed/Injured Group (n=37)   Non-Injured Controls (n=96)

FIGURE 4.23 MUSCLE STRENGTH - INTRINSIC RISK FACTOR ANALYSIS



Muscle Strength

Muscle strength has been proposed to be a primary protective mechanism for averting injury in contact or collision sports. The reasoning being that stronger tissue is expected to withstand the normal trauma such as forceful bumps and blows (contusions) and may provide greater protection to internal deep structures against external sources of trauma (fracture) by presenting an intervening fleshy shield on impact (Reilly & Hardiker, 1981; Rooks & Micheli,1988). Similarly, Murray (1989) contends that young athletes who have weak musculature may be at risk during contact/collision sport, especially those requiring movement against resistance.

The above motivations thus give rise to one of the most popular axioms in sport-related activity, namely that strong participants are better performers and have fewer injuries. Although the former statement may be true, Lysens and co-workers (1989) contend that a more subtle distinction needs to be made with regard to the latter statement. In their study among a general population of young male sportsmen, a high score in functional strength, upper body strength and limb speed predisposed to acute injuries. They thus propose that while static (isometric) strength seems to be a protective factor with a stabilizing effect on the locomotor system, dynamic strength on the other hand seems to be a risk factor for injury.

The above findings are in accord with the observations of the current study (Figure 4.23) - in that the exposed (injured) players demonstrated a significantly ($p<0,01$) greater relative dynamic (isotonic) grip strength per body mass than the non-injured controls. It would thus also seem, in contrast to the mentioned axiom, that among high school rugby players injured players had stronger upper body strength than non-injured controls because they were probably the better performers.

Muscle Power

Muscle power (explosive strength) may be defined as the ability to exert a large force rapidly and is thus a combination of strength and speed, requiring that a sportsman stop, start or change direction rapidly (Blum,1985). It is thus conceivable that superior muscle power would be of value in rapidly escaping potentially injurious situations. However, as indicated in the foregoing section, dynamic strength has been identified as a risk factor for injury (Lysens et al.,1989).

Similarly rapid initiation (acceleration) and/or termination (deceleration) of movement places considerable stress on the body and is directly proportional to the explosive power of an individual. It has also been observed that muscle strain injuries occur most often in sprinters (Lysholm & Wiklander,1987) or "speed athletes". Malone (1988) has indicated that muscles with a relatively high percentage of Type II or fast twitch muscle fibres are susceptible to injury. Accordingly Garret (1990), confirms that muscle strains are more common in sports and events or positions requiring bursts of speed, jumping, tackling, kicking and sprinting as in American football, basketball, soccer and rugby.

In accordance with the foregoing reasoning, the current study also established superior muscle power to be a risk factor for injury among high school rugby players, with exposed (injured) players possessing a significantly ($p<0,001$) greater relative vertical muscle power (W/kg) than the non-injured controls (Figure 4.24).

It has been suggested that ipsilateral and contralateral imbalances in muscle strength and power constitute risk factors for specific types of injury such as strains and

FIGURE 4.24: MUSCLE POWER - INTRINSIC RISK FACTOR ANALYSIS

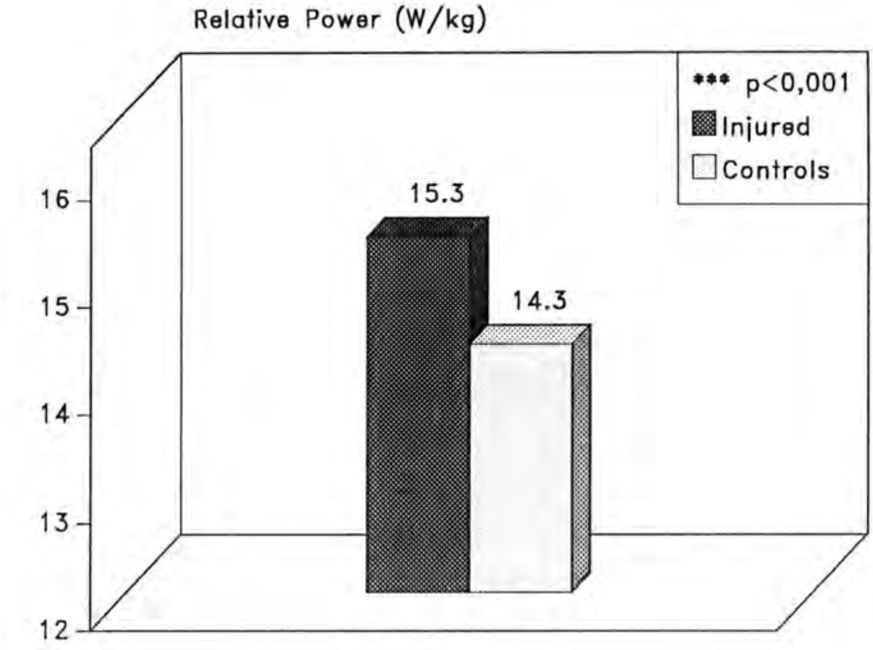
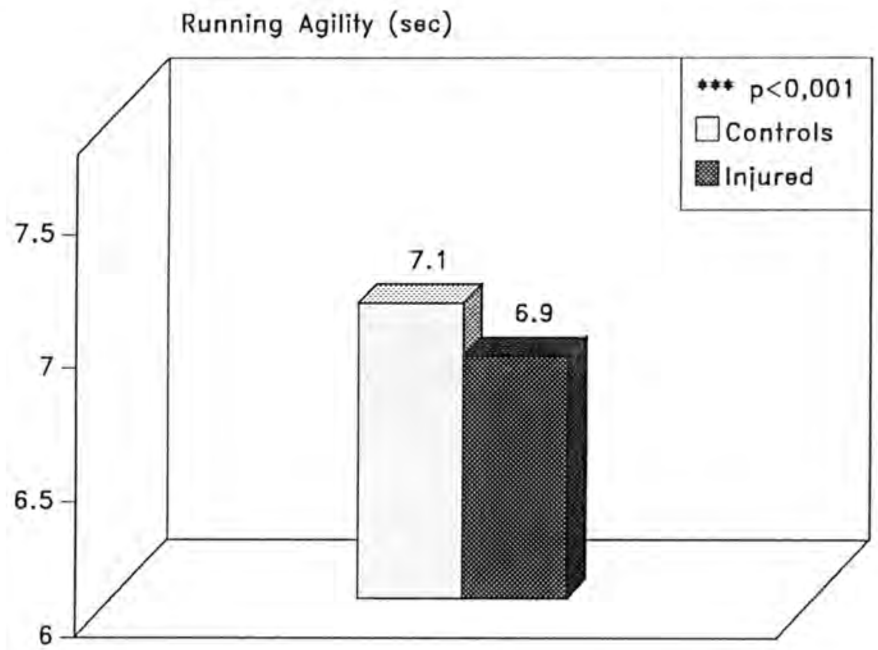


FIGURE 4.25: RUNNING AGILITY - INTRINSIC RISK FACTOR ANALYSIS



sprains (Grace et al.,1984; Herring,1990; Knapik et al., 1992). Although the current study did assess such imbalances via isokinetic dynamometry of the knee extensors and flexors a meaningful analysis was not possible as a result of inadequate numbers of such specific subsets of injury.

Agility

Since central motor control plays a major role in the successful execution of various sports-related activities it is reasonable to assume that it also plays a role in the outcome of injury. However, central motor control entails several independent motor ability components and its relation with injury proneness has only been studied in a random manner.

Inferior proprioception has been linked to back injury in an occupational setting (Owen & Damron,1984) and slow reaction-times to soccer injuries (Taimela et al.,1990). Montoye (1978) highlights the potential association of poor agility and injury. Cahill and Griffiths (1978) maintain that beginners who are less skillful generally sustain more injuries. Some authors (Beck & Day,1985; Beck & Wildermuth, 1985; Edwards,1988; Inkelis et al.,1988) suggest that poor coordination plays a role in being prone to injury. Lysens et al.(1991) concur with the above and state that skill and technique play an important role in the aetiology of injuries especially in events which place a high demand on coordination and balance, thus emphasizing the importance of sport-specific considerations.

It can be argued, particularly within the sport-specific context of rugby, that running agility (which requires the player to turn, stop or start at speed) as measure of central motor control encompasses most of the independent components mentioned above. It is apparent that to be agile one must also possess good strength, flexibility, reaction-time, speed, dynamic balance and coordination (Bosco & Gustafson,1983; Kirkendall et al.,1987; Baumgartner & Jackson,1987).

In cognizance of the foregoing it is conceivable that superior agility could be of value in escaping a potentially injurious situation such as a tackle. The findings of the current study are, however, in contrast to this expectation in that exposed (injured) players possessed a significantly (p<0,001) faster time in a running agility test than the non-injured controls (Figure 4.25). Thus in opposition to the above studies indicating a general association between low scores in the independent components of motor control and injury proneness, the current study established superior running agility to be a risk factor for injury among high school rugby players. This finding could be seen in relation to the concomitant lower relative body fat and higher relative power observed for exposed (injured) players versus non-injured controls.

Range of Motion / Flexibility

There has been speculation that the range of motion about a joint (flexibility) is associated with injury. It has been assumed that the more flexible an individual is the less the likelihood of injury. However, when evaluating flexibility and injury risk, distinction should be made between the composite components of muscle tightness and active joint mobility and hypermobility. The first two components are related and refer to the amount of movement of a joint through its normal plane of motion. Hyper-mobility on the other hand is an aspect of flexibility where joints are moved in their normal plane of motion but beyond some predefined extreme point, usually as a result of ligamentous laxity (Knapik et al.,1992).

Practical tests of gross flexibility measuring the linear distance between anatomic structures or from one body segment to another are common in both field and clinical settings in evaluating the association between flexibility and injury risk (Rooks & Micheli,1988). One such test is the trunk flexion test in its various forms which is commonly purported to be the best overall test of gross flexibility, although it is recognized that no single general flexibility test exists (Golding et al.,1989).

Several researchers have attempted to demonstrate an association between the various types of flexibility and injury risk with equivocal results. Nicholas (1970) reported an increased likelihood of knee ligament injury in American football players with hypermobility. However later studies (Kalenak & Morehouse,1975; Grana & Moretz,1978) among other populations of sportsmen did not support this contention. Burkett (1970) found no differences in sit and reach flexibility between injured and non-injured athletes in terms of hamstring strains. Muscle tightness has been related to strains in American football (Nicholas,1970) and in soccer (Ekstrand & Gillquist,1983). Steel and White (1986) failed to link a lack of general body flexibility to injury proneness in gymnastics. Similarly, others found little association between sit and reach flexibility and hamstring strains (Meeuwisse & Fowler,1988) or acute injuries in general (Lysens et al.,1991). Knapik et al.(1992) did, however, find that individuals who were at both extremes of sit and reach flexibility were more likely to suffer injury.

FIGURE 4.26: RANGE OF MOTION - INTRINSIC RISK FACTOR ANALYSIS I

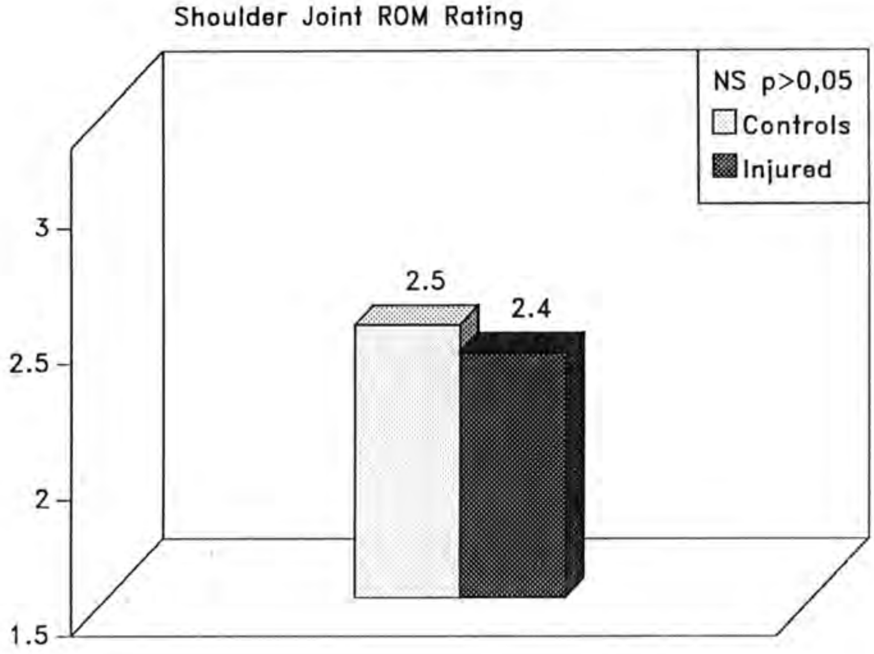
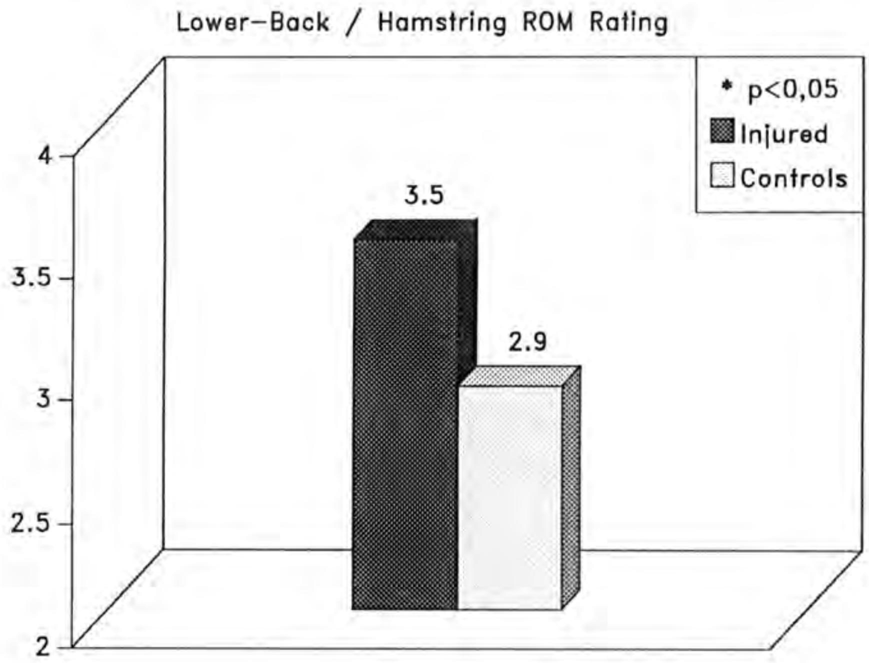


FIGURE 4.27: RANGE OF MOTION - INTRINSIC RISK FACTOR ANALYSIS II



As regards the findings of the current study (Figures 4.26 & 4.27), while it did not examine hypermobility, no significant differences (p>0,05) were observed in gross range of motion of the shoulders (as measured by the "Apley" Scratch Test) between exposed (injured) players and the non-injured controls. However, gross low-back/hamstring flexibility scores (as measured by a stand and reach test) were significantly (p<0,05) higher among the exposed (injured) group than among the non-injured controls. This latter finding is in partial agreement with that of Knapik et al.(1992) and it would thus appear that high scores in stand and reach flexibility comprises a risk factor for injury among high school rugby players.

In conclusion of the foregoing intrinsic aetiological risk factor analysis, the data suggests that contrary to general expectations, somatotype is independent of injury risk while morphological and muscular superiority appears to predispose rather than preclude from injury among high school rugby players. Thus while superior morphological and musculoskeletal qualities are essential for successful performance they are not necessarily synonymous with safe participation, as the characteristic contact/collision and competitive nature of rugby seeks to challenge those assets maximally.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

To recapitulate, the scope of research undertaken was delimited to an analytical epidemiological study. The study primarily focussed on the preparticipation evaluation and injury surveillance of a cohort of high school rugby players, utilizing a cross-sectional and prospective design, respectively. The conclusions and recommendations are presented accordingly.

1. PREPARTICIPATION EVALUATION PROCEDURE

Notable health history findings reported in ascending order of frequency were: syncope with exercise; heat-related illness; allergies; problematic paired organs; familial heart disease; concussion; and previous musculoskeletal injury. Voluntary medical examination detected problems in ascending order of frequency with the cardiovascular; urinary; and orthopaedic systems, respectively - with the last component also showing the highest diagnostic utility in yielding new findings not reported in the history. As an adjunct to the health history and medical examination, subjects were screened for morphological status and muscular function. Inter alia, the prevalence of obesity was noted and ipsilateral and contralateral imbalances in peak isokinetic torque of the quadriceps/hamstring musculature were recorded. The resultant disposition led to clearance being withheld in a few instances, pending referral for additional evaluation, with the remainder being granted unlimited participation.

2. INJURY SURVEILLANCE PROCEDURE

2.1 INCIDENCE OF INJURY

An overall injury incidence of 1 injury per 21 player-hours (1:21 player-hours) was recorded. This overall injury incidence was derived using an inclusive injury definition of any traumatic condition resulting while competing that required first aid treatment during or after a match/ practice; and/or necessitated the complete cessation of participation in a match/practice.

The injury incidence decreased to 1:100 player-hours when only those injuries requiring medical consultation were considered, while an even lower injury incidence of 1:212 player-hours was recorded if only those injuries which resulted in a loss of at least seven days participation-time (major injuries) were considered.

This last mentioned major injury incidence of 1:212 player-hours is fairly similar to the incidence of 1:243 player-hours as documented during an initial epidemiological study of schoolboy rugby players conducted in the Cape Province during the 1982 season (Nathan et al.,1983). As such the slightly higher incidence of injury found in the present study could probably be attributed to a more meticulous methodological approach. The results of the present study nonetheless suggest that the incidence of injury (as experienced over a season at one school) among high school players in the Natal Province corresponds notably with that found in the Cape Province, despite being conducted a decade later.

2.2 AETIOLOGY OF INJURY

Sports-related injuries are a multi-risk phenomena. While epidemiological studies are the accepted procedure to identify risk factors for injury, such studies also have inherent methodological constraints in tending to be hypothesis-generating rather than hypothesis-testing in nature. Consequently the causal pathways leading to the delineation of the aetiopathogenesis of sports injuries are complex and multi-factorial. The prospective analytical approach used in this study is, however, considered accountable in the pyramidal hierarchy of epidemiological designs.

2.2.1 EXTRINSIC AETIOLOGICAL RISK FACTORS

An association was identified between the following extrinsic risk factors and injury occurrence.

* Match-play was identified as a significant primary risk factor. The vast majority of injuries occurred during match-play and a resultant higher overall and major incidence of injury was thus recorded for matches as opposed to practices. The all-out effort, competitive element and aggressive commitment so characteristic of match-play, appear to be important components contributing to injury.

* Senior age groups and higher competitive levels ("A" team vs "B" team) were more at risk for injury. The injury incidence was the lowest in the under-14 age groups, followed by a subsequent linear rise with the under-19 "A" (1st team) players being particularly injury prone.

* The four-week period following the Easter vacation was the stage of the season during which the highest overall and major injury incidence was observed. It is thus likely that a related lack of match-fitness, induced by the foregoing vacation, could have been responsible for this observed pattern of injury.

* The various facets of broken play posed a significantly greater risk for injury than the set-pieces of scrums and line-outs. Being tackled and open play posed the greatest overall and major injury risk, while tackling was particularly conducive to major injury. Although the ruck and maul phase of the game contributed largely to the overall injury incidence, this was not so in the case of major injuries. Foul play and line-outs were least implicated in any form of injury.

* Backline players were significantly more at risk for injury than forwards. The flyhalf and fullback playing positions were at the highest overall and major injury risk, while flank and wing were also particularly prone to major injury. In contrast, centre and lock appeared to be the safest playing positions.

In evaluating the rule-revisions that were introduced since the previous epidemiological studies of schoolboy rugby were conducted in the Cape Province a decade prior to the current study - it is evident that although no overall decrease in the incidence of injury has been observed there has been a concomitant change in the pattern of injuries. As such, whilst the incidence of injury to front row players during scrumming has essentially remained relatively low and unaltered, the incidence of injury during the ruck and maul and foul play and to the centre playing position has decreased considerably. This in itself is a positive finding, as the observed controlled and decreased injury incidences correspond to those specific phases of play and/or playing positions usually related to potentially serious injuries.

* Contact/collision resulting primarily from impact with another player or the ground was the significantly dominant injury mechanism, irrespective of their severity.

* As expected from the dominant contact/collision injury mechanism, the significant majority of injuries were of an acute/traumatic nature. Bone bruises (osseous contusions) were the commonest overall injuries followed in close succession by muscle injuries (comprising both contusions and strains) and ligament sprains, respectively. As far as major injuries are concerned, all were of an acute nature, with muscle injuries and ligament sprains again being the most prevalent with fractures and concussion also being predominant.

* The lower-limbs were significantly more at risk for injury than the upper-limbs and any other anatomical site, while the risk of injury to the head and neck as opposed to the trunk, did not differ significantly.

2.2.2 INTRINSIC AETIOLOGICAL RISK FACTORS

In the analysis of intrinsic risk factors, an injury was defined as either requiring medical referral or being severe enough to cause a loss of at least seven days from participation. The analysis entailed two broad categories of intrinsic risk factors, namely morphology and muscular function.

* Morphological risk factor analysis of the exposed (injured) players versus non-injured controls indicated a significantly greater mean stature, body mass, lean body mass and lower body fat among the exposed (injured) group. Individual somatotype component variations did not differ significantly, with the exposed (injured) group being slightly lower in endomorphy but similar for mesomorphy and ectomorphy.

* Muscular function risk factor analysis of the exposed (injured) players versus non-injured controls indicated a significantly greater mean relative grip strength, relative vertical muscle power and running agility among the exposed (injured) group. Gross range of motion variations in the shoulders did not differ significantly, but gross low-back/hamstring flexibility scores were significantly higher among the exposed (injured) group.

In conclusion of the foregoing aetiological risk factor analysis the data suggests that contrary to general expectations:

* Somatotype is independent of injury risk while superior morphological status and muscular function appear to predispose rather than preclude from injury among high school rugby players.

* Thus, while superior morphology and muscular function may be essential for successful performance they are not necessarily synonymous with safe participation.

* The characteristic contact/collision and competitive nature of rugby typically seeks to challenge the musculoskeletal system to the maximum.

* Consequently it is suggested that further preventive research focus on extrinsic risk factor modification of the contact/collision nature of the game with particular attention being given to:

i) Continued rule-revision; and/or

ii) Additional protective equipment usage.

3. EPILOGUE

As alluded to in the prologue of this thesis the renewed awareness and interest in all forms of sport currently prevalent in the country is bound to lead to increased participation among youths. This will, however, also result in a concomitant increase in the incidence of injury and consequently the obligation of sports-related injury prevention is apparent. In this regard the following basic elements should form the foundation of any accountable organized physical activity and youth sports programme:

i) Capable officiating/supervision;
ii) Competent coaching/leadership;
iii) Appropriate equipment and facilities;
iv) Proper physical conditioning; and
v) Adequate health care.

The question which arises, is which of these identified elements lends itself the most to serve as a prophylactic measure to reduce the risk of injury. Although each has an important role to play, it can be reasoned that adequate health care, especially if seen to emphasize the preparticipation physical evaluation and continuous injury surveillance of participants, should be the cornerstone of preventive sports-medical care.

The value of preparticipation evaluation is evident from the results of this study in indicating that youths intending to participate in sports-related activity are not necessarily in a complete state of health. In cognizance it thus appears justified to recommend and propagate a full sport-specific preparticipation evaluation concentrating on the orthopaedic system on first entry, and a subsequent annual history of participants as routine practice. In so doing, if indicated, further counselling as to altered activity choice, evaluation and/or rehabilitation may be prudent before clearance being granted for unrestricted participation.

The value of injury surveillance in identifying extrinsic and intrinsic aetiological risk factors for injury is demonstrated by the results of this study. Although such independent epidemiological studies are constructive, continuous monitoring of sports injuries is mandatory if prevention is to progress. In cognizance it seems justified to recommend and propagate the development and implementation of a National Sports Injury Registry to generate reliable statistical data, observe the development of specific injury trends and to formulate effective measures to prevent or minimize the consequences of injuries.

Considering the increased measure of responsibility being placed on the youth sports coach in preventing injuries and the expanding field of knowledge pertaining to the sports health care of young participants, the need is apparent to identify a specialist for this purpose. In the South African context a Biokineticist or similarly qualified Human Movement Scientist would seem to be the appropriate professional to accomplish this task, either independently or in conjunction with the Human Movement Educator or coach of a particular school or community-based sports club.

APPENDIX A

PRELIMINARY STUDY REPORT

THE INCIDENCE AND NATURE OF SPORTS INJURIES DURING AN ANNUAL PRIMARY SCHOOLS TOURNAMENT

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SUMMARY

The incidence and nature of injuries among a cohort of 483 under 13 age-group primary school children competing in 5 sports during a two-day tournament was observed prospectively. An injury was defined as any traumatic condition whilst competing that necessitated the cessation of participation in the match and/or required first aid treatment thereafter. A total of 76 injuries were incurred by 66 participants, 14 (18,4%) being to girls and 62 (81,6%) to boys. All injuries had an acute onset and occurred during match-play. Sport specifically, tennis recorded no injuries, followed in frequency (injuries per player-hours) by hockey (1:61,6), soccer (1:20,6), netball (1:16,4) and rugby (1:6,6). Netball had a significantly higher (p<0,05) incidence of injury than hockey and soccer had a significantly lower (p<0,001) incidence of injury than rugby. Of all injuries, sprains (42%) and contusions (41%) predominated, followed by strains (11%), lacerations (4%) and fractures (2%). Most injuries occurred in the lower extremity (48%), followed by the head, neck and trunk (30%). Twenty-seven (36%) of all the injuries were recurrent and 15% which required immediate medical referral, were classified as mild or moderate.

Although an apparently high frequency of injury was recorded, most injuries were minor with none being classified as severe.

INTRODUCTION

The necessity of preventing sports injuries amongst school children has been emphasized by the South African Teachers Federal Council.[1] It is generally accepted that the basis of injury prevention lies in an epidemiological study of sports injuries to determine the risk of injury during sports participation and to identify factors associated with the risk of injury.[2,3] As such Damron,[4] cites the essential goal of acquiring sports injury data as providing factual evidence to protect and defend the integrity of sports-related activities, the benefits of which are dependant on efforts to control and prevent injuries. Mueller and Blyth[5] reiterate that surveillance of sports injuries among youths in particular, is mandatory if progress is to be made in prevention. A number of epidemiological investigations have been conducted in foreign countries to examine the incidence of sports-related injuries among the youth population.[6-10] In the South African context there is a paucity of such research, with studies thus far being limited specifically to reports on the epidemiology of rugby injuries among primary school[11] and high school players.[12,13] In cognizance of these concerns a study was conducted to determine the relative incidence and nature of injuries among primary school boys and girls competing in five popular sports during an annual tournament.

SUBJECTS AND METHODS

The entire group of participants involved in an annual country and districts primary schools (under-13 age-group) sports tournament were monitored. The group comprised 483 participants (276 boys and 207 girls) from 39 teams competing in tennis, hockey, netball, soccer and rugby. The cohort was observed prospectively for a total of 113 matches (Table I) played during the tournament over a period of two days. For the complete and accurate recording of injuries, cooperation between coaches and team managers, paramedical attendants and the investigator was coordinated prior to the start of the tournament.

TABLE I: NUMBER OF PARTICIPANTS AND TEAMS PER SPORT

Sport	**Boys**	**Girls**	**Teams**	**Matches**
Rugby	160	-	8	24
Hockey	-	104	8	28
Soccer	76	-	6	15
Netball	-	63	7	21
Tennis	40	40	10	25
Total	276	207	39	113

Triage Protocol

In the absence of a Medical Practitioner at the field-side to diagnose and direct the acute treatment of injuries sustained, the investigator as Biokineticist and four paramedical attendants served as the on-site triage officers. The role of the investigator was: i) to complete a specifically designed injury recording form and thus; ii) recognize and classify the injury according to the following characteristic criteria:

Strain : Stretch-induced injury to a muscle-tendon unit.
Sprain : Stretch-induced/torsion injury to a ligament.
Contusion : Compression (bruise) injury to a muscle.
Laceration: Puncture-type injury to the skin.
Fracture : Injury showing a break in the continuity of a bone.

The paramedical attendants were responsible for continual first aid treatment of injuries and selecting an appropriate means of transportation in the event of a serious injury requiring further evaluation or urgent medical attention i.e. players suffering extreme pain and/or obvious deformity and dysfunction. Such injured players were then presented at a medical facility where the examining doctors diagnosed and categorized the injury and severity according to their discretion as mild (1st degree), moderate (2nd degree) or severe (3rd degree) according to the degree of tissue damage.[14] This diagnosis was then indicated on the reverse of the accompanying injury recording form, which was collected and noted by the investigator on the injured players' return to the competition venue.

Definition of Injury

For the purpose of this study an injury was defined as any traumatic condition sustained during competition that: i) necessitated the complete cessation of participation in the match; and/or ii) required first aid treatment after the match. This definition was used rather than a more stringent time-loss from participation criteria,[14] due to the brief duration of the tournament and its applicability in the design of the triage protocol followed.

The incidence of injury is expressed in two forms, calculated as suggested in the *Manual of Sports Injury Research* of the American Orthopedic Society for Sports Medicine:[15] i) as injuries per 100 participants (i.e. number of injuries as numerator and the number of participants per sport as denominator); and ii) by taking exposure-time into consideration, according to player-hours (i.e. number of player-hours as numerator and number of injuries per sport as denominator; where player-hours was calculated as the number of 30 minute matches x 0,5 x number of players involved per match). A chi-square analysis[16,17] was used to determine the statistical significance of comparative injury incidences between particular sports.

RESULTS

Injury Occurrence - Overall / Gender and Sport

A total of 76 injuries were incurred by 66 participants, with repeat injuries being included and accounted for in the total number of injuries. Eight participants suffered 2 injuries, while another participant sustained 3 injuries. All injuries had a sudden (acute) onset and occurred during match-play. Fourteen (18,4%) of the 76 injuries recorded were sustained by girls and 62 (81,6%) by boys. Twelve (15%) of the injuries sustained were serious enough to require immediate medical attention or referral. Subsequent to being categorized by the examiner according to the degree of tissue damage, 6 (50%) of these injuries were diagnosed as mild and the remaining 6 as moderate. Twenty-seven (36%) of all the injuries recorded were to body sites that had been injured prior to participation in the current tournament.

Figure 1 reflects the incidence of injury for the individual sports. In Table II these injury rates, with the exception of tennis where no injuries were recorded, are further summarized according to injuries per player-hours. An injury incidence of 4,8 injuries per 100 participants or 1 injury per 61,6 player-hours was recorded for hockey. Netball recorded an injury incidence of 14,3 injuries per

FIGURE 1: INJURY INCIDENCE / SPORT

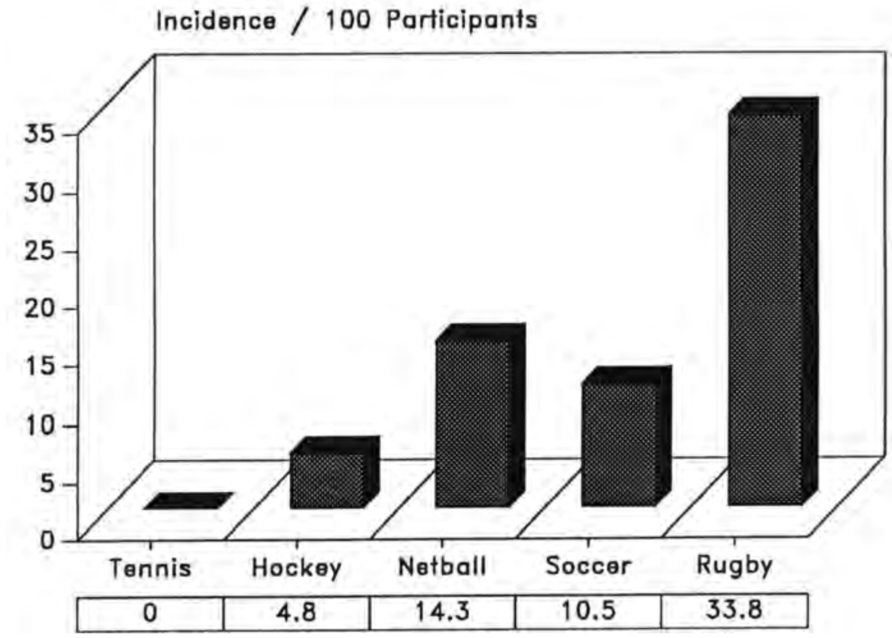

TABLE II: INCIDENCE OF INJURY PER SPORT

Sport	No. of injuries	Incidence per 100 participants	Incidence per player-hours
Hockey	5	4,8	1 : 61,6 } *
Netball	9	14,3	1 : 16,4 }
Soccer	8	10,5	1 : 20,6 } **
Rugby	54	33,8	1 : 6,6 }

* $p<0,05$; ** $p<0,001$

100 participants or 1 injury per 16,4 player-hours. An injury incidence of 10,5 injuries per 100 participants or 1 injury per 20,6 player-hours was recorded for soccer. Rugby recorded an injury incidence of 33,8 injuries per 100 participants or 1 injury per 6,6 player-hours.

Classification of Injury / Type and Anatomical Site

With respect to the variation in injury type (Figure 2), of the 76 injuries sustained, sprains (42%) and contusions (41%) were in the majority followed by strains (11%), lacerations (4%) and fractures (2%), with the last two categories of injury occurring only in rugby. Table III indicates the corresponding anatomical distribution of injuries. By region, the lower extremity suffered most (48%), followed by injuries common to the head, neck and trunk (30%) - of which 91% were incurred in rugby, and lastly the upper extremity with 22%.

DISCUSSION

Relative Risk / Sport and Injury Prevention

Tennis

The observation that tennis players were totally free of injury in this study confirms the low risk status of this sport among youths. In comparison, studies of injury incidence conducted over a number of seasons of participation among American high school tennis players ranged from zero incidence to 3 injuries per 100 participants for males and 0,6 to 7 injuries per 100 participants for females.[7-9]

FIGURE 2: INJURY TYPE CLASSIFICATION

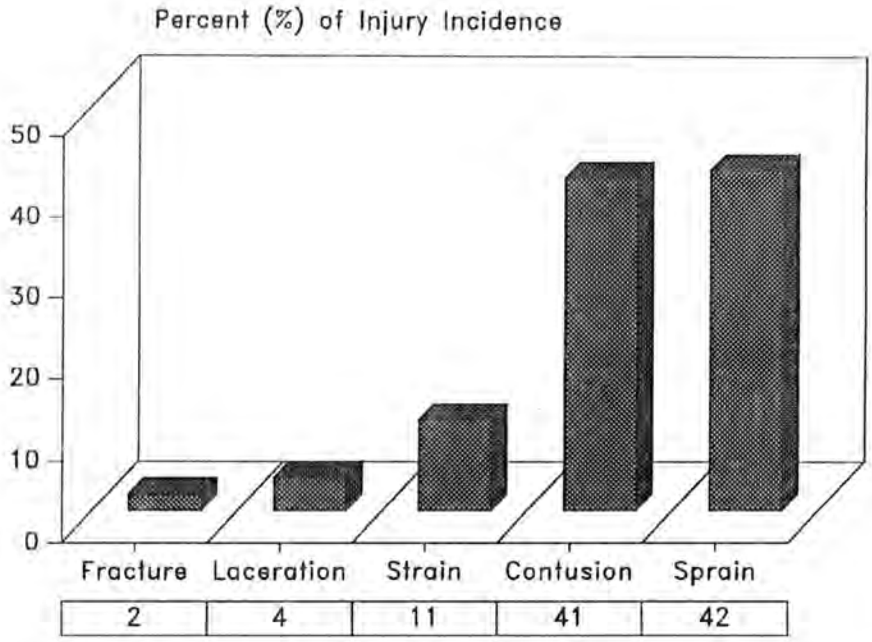

TABLE III: INJURY DISTRIBUTION BY ANATOMICAL SITE AND SPORT

SPORT	Head, neck & trunk n (%)	Upper extremity n (%)	Lower extremity n (%)	TOTAL (%) PER SPORT N (%)
Rugby	20 (37)	8 (15)	26 (48)	54 (71)
Netball	1 (11)	4 (44.5)	4 (44.5)	9 (12)
Soccer	1 (12.5)	2 (25)	5 (62.5)	8 (10)
Hockey	0 (-)	3 (60)	2 (40)	5 (7)
TOTAL (%) PER SITE	22 (30)	17 (22)	37 (48)	76 (100)

Hockey vs Netball

Considering girls team sports separately, netball had a significantly higher incidence of injury than hockey ($p<0{,}05$). This finding may be considered somewhat enlightening due to the fact that hockey is considered a contact sport and netball a non-contact sport. As such the characteristic extrinsic risk of being struck by the ball or opponents stick while playing hockey could lead one to expect a greater chance of injury than when playing netball. However, although the rules determine that no contact is permitted between players, netball is a deceivingly dynamic sport characterized by frequent jumping and landing activity. While participation in these activities are not that widespread in overseas countries, a study conducted in New Zealand[18] also found a higher frequency of injury in netball than hockey although injuries were of a more serious nature in the latter sport. A related publication[19] dealing the with the aetiology and mechanism of hockey and netball injuries occurring in this study, considered possible steps to prevention. In hockey compliance in wearing protective equipment and strict umpiring against over-robust defensive tackling were highlighted. In netball, where injuries were generally associated with falling and colliding with the ground following a jump for the ball and a poor landing, preventative suggestions included strengthening of the quadriceps and musculature supporting the ankle joint as well as the provision of well maintained even playing surfaces.

Soccer vs Rugby

Considering boys team sports separately, soccer had a significantly lower ($p<0{,}001$) incidence of injury than rugby. This finding was not unexpected as soccer, although classified as contact sport has a low risk of injury among youths.[3] As such an injury incidence of 5,3 % over a season has been reported by Mc Carroll[20] for players aged fourteen years or younger. When expressed in a comparative percentage form of 10,5%, the incidence of injury documented for soccer in this study characterized by the high match frequency of the tournament format, is essentially twice that of the above cited report.[20] In terms of injury mechanism, most of the injuries incurred in the current study were related to the tackle phase of the game. Therefore disciplined play and strict refereeing in this regard as well as the compulsory use of shock absorbing shin guards would appear to be prudent in the prevention of injury.

Being a collision sport, it may have been anticipated that a higher incidence of injury would be recorded for rugby compared to soccer. In the only other prospective study published on the incidence of rugby injuries among South African primary school boys, Nathan et al.[11] documented an injury incidence of 1 injury per 270 player-hours of match play over one season. Accurate comparison of their data with the rate of injury recorded for rugby in this study (1 injury per 6,6 player-hours) is, however, precluded by methodological differences. As such the higher incidence of injury in this study may inter alia probably be related to two factors: i) the less stringent injury definition used in this study - as Nathan et al.[11] only documented injuries severe enough to prevent the player from returning to rugby for at least seven days; and ii) the format of this tournament-based study which involved fairly intense competition concluded over a short period of time and thus demanding a high match frequency, may have contributed to a higher incidence of injury than that which a more ideal study lasting a complete season may document. The referred to study of Nathan et al.[11] and that of Roux et al.[12] which was conducted among high school rugby players in the Cape Province, evidently led to various rule changes being implemented in schoolboy rugby as a preventive measure to modify extrinsic risks of the game, such as phase of play and playing position. The efficacy of this measure is currently under investigation, but in their reports[11,12] these authors also referred to a lack of fitness as being a potential risk factor for injury. This suggestion correlates with a finding of this study in that a large number of the injuries recorded (36%) were to body sites that had been injured prior to participation in the current tournament. Similarly Martin et al.[10] reported a 26% incidence of recurrent injury in a study among elite youth participants.

In terms of prevention, employing preparticipation evaluation of prospective sports participants in general and of rugby players in particular, requires investigation. In this manner participants could be screened for potential intrinsic risk factors such as, among others, incompletely rehabilitated injuries and their physical status or suitability to participate in a particular sports activity.

CONCLUSION

The data presented provides insight into the relative risk of injury among various sports during an annual primary schools tournament and is of value to school coaches, participants and medical personnel attending primary schools sports events. In addition, the execution of this study increased the awareness of those involved as to the need for injury prevention, recognition and rehabilitation[21] as well as the role of the Biokineticist therein. The principal conclusions of this study follow:

* The risk of injury among primary school children participating in the tournament studied was generally higher for boys than for girls, but this is probably more related to the type of sport practised than to gender;

* Tennis has a low injury risk among primary school boys and girls. It would thus appear that preventive efforts should primarily be directed at netball for girls and rugby for boys, as opposed to hockey and soccer respectively, as the latter activities proved to have a relatively low risk of injury.

* Despite the apparently high frequency of injuries recorded in this study, none were classified as severe and youths participating at the under-13 level should not be discouraged from doing so on the pretext that they may suffer serious injury.

Acknowledgement:

The Natal Education Departments' approval to conduct this study is hereby gratefully acknowledged.

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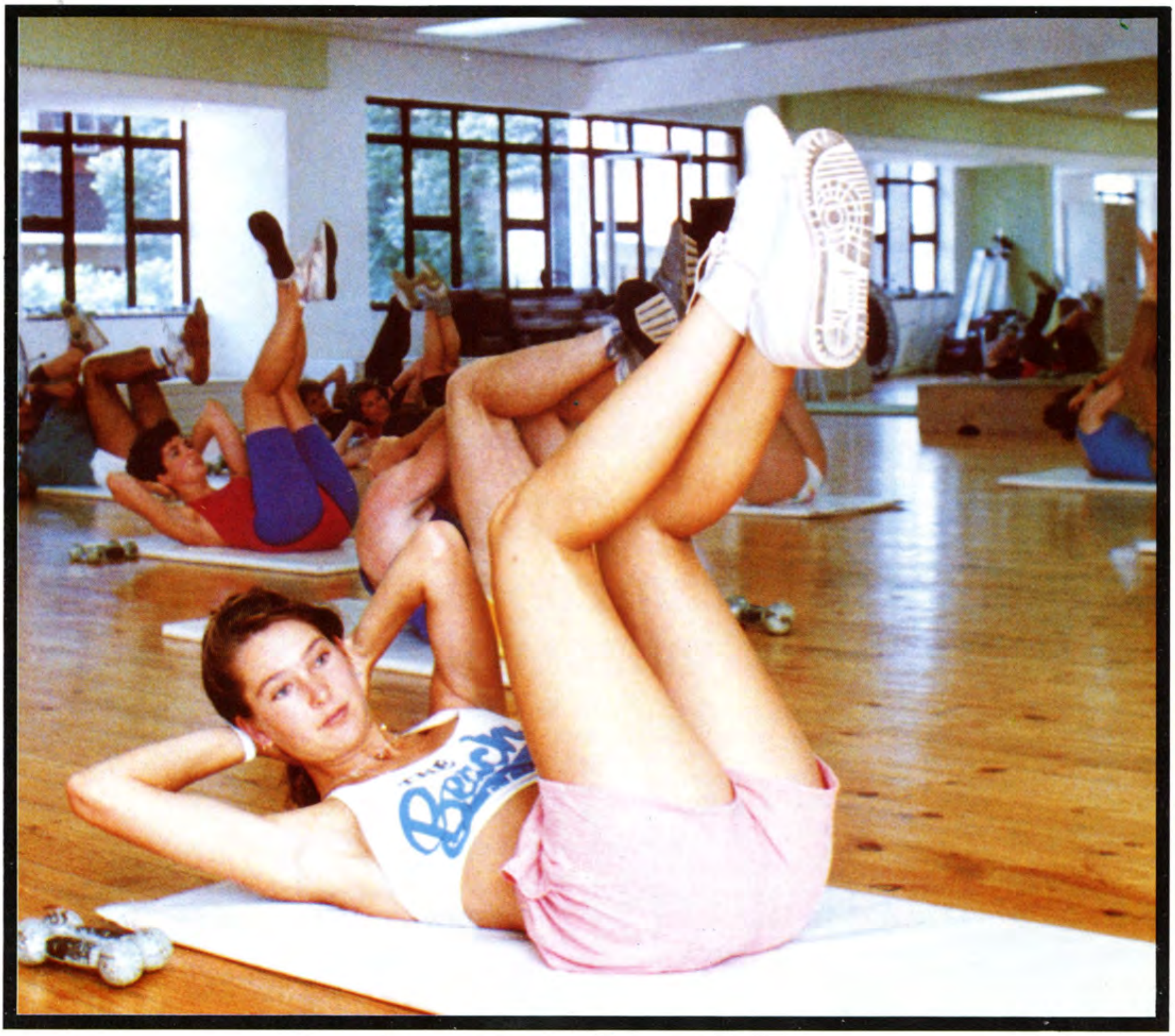

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DIE VOORKOMS EN ETIOLOGIE VAN BESERINGS IN HOKKIE EN NETBAL BY LAERSKOOL DOGTERS

HJ van Heerden

Sleutelwoorde: *Beserings, hokkie, netbal, laerskool dogters*

Erkenning: *Die Natal Onderwysdepartement se goedkeuring om hierdie studie uit te voer word hiermee erken.*

OPSOMMING

Die voorkoms, aard en meganisme van beserings onder 'n groep van 167 laerskool dogters gedurende deelname aan hokkie en netbal tydens 'n jaarlikse toernooi is vooruitgewys waargeneem. 'n Laer beserings-insidensie ($p<0,05$) van 4,8 beserings per 100 deelnemers of 1 besering per 61,6 speler-ure is vir hokkie opgeteken, teenoor 14,3 beserings per 100 deelnemers of 1 besering per 16,4 speler-ure by netbal. 'n Analise van moontlike etiologiese faktore soos die meganisme van beserings volgens speelposisie en spelfase het getoon dat beserings op 'n bepaalde wyse voorgekom het. Op grond hiervan is sekere voorkomingsmaatreëls aanbeveel.

INLEIDING

Volgens tradisionele oorlewering, is daar van seuns verwag om deur middel van en tydens sportdeelname hulle manlikheid te bewys, terwyl daar hoofsaaklik van dogters verwag is om hulle vroulikheid te bewys,[1] beide tydens sportdeelname of alternatiewelik deur nie aan sport deel te neem nie. Sulke botsende menings is egter besig om te verander en huidiglik is dit meer aanvaarbaar vir vrouens en dogters om lank, sterk en kompeterend te wees,[2] en hul fisieke talent op die sportveld uit te leef. In dié verband word gemengde sportdeelname op gelyke voet tussen seuns en dogters, wat nie in Suid-Afrika `n algemene verskynsel is nie, in die VSA by prepubesente jeugdiges selfs aangemoedig. Op postpubesente vlak word deelname egter as 'n reël geskei omdat 'n hoër risiko vir besering by dogters bestaan weens 'n laer spiermassa per eenheid liggaamsgewig.[3] Verder verhoog die onderliggende kompeterende element van sport[4] tesame met die verwante inherente eise, die risiko van besering ongeag ouderdom of geslag.[5,6] Hierdie studie is onderneem om onder andere die voorkoms, aard en mega-

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nisme van beserings te bepaal by laerskool dogters tydens deel-name aan hokkie en netbal, wat as twee van die gewildste sportsoorte onder jong blanke Suid-Afrikaanse meisies beskou kan word.

PROSEDURE EN METODE

'n Groep van 167 laerskool dogters (104 hokkiespelers en 63 netbalspelers) afkomstig van 15 spanne (8 hokkie en 7 netbal) wat in Natal op platteland en distrikte vlak aan 'n jaarlikse toernooi deelgeneem het, is vooruitgewys vir die duur van kompetisie oor twee dae waargeneem. Alle deelnemers het in die onder 13 ouderdomsgroep meegeding. Die optekening van beserings het op 'n vorm wat spesifiek vir die doel ontwerp is geskied. Vir die doel van hierdie studie is 'n besering gedefinieer as enige traumatiese toestand opgedoen tydens deelname aan 'n wedstryd wat staking van deelname aan die wedstryd genoodsaak het en/of daarna noodhulpbehandeling vereis het. Hierdie omvattende definisie is gebruik bo 'n strenger tydsverlies aan deelname kriteria,[7] weens die korte duur van die toernooi. Die versamelde data is ontleed om die volgende gegewens per sportsoort toe te lig:

- die getal en insidensie van beserings;
- moontlike etiologiese faktore soos die meganisme van beserings volgens speelposisie en spelfase; en
- die anatomiese ligging en tipe besering.

Die insidensie van besering is bereken as beserings per 100 deelnemers asook deur die mate van blootstelling in ag te neem,[8] volgens speler-ure (getal 30 minuut wedstryde x 0,5 x getal spelers betrokke per wedstryd). Die statistiese beduidenheid van die data is deur die chi-kwadraattoets bepaal.

RESULTATE EN BESPREKING

Insidensie van besering volgens sportsoort

Oor die twee dae van die toernooi is 'n totaal van 14 beserings opgeteken. Alle beserings was van 'n akute aard en het as gevolg van 'n skielike bespoedigende voorval tydens deelname aan 'n wedstryd ontstaan. Deelname aan hokkie en netbal was onderskeidelik vir 5 en 9 van die 14 beserings verantwoordelik. Een deelnemer het twee beserings opgedoen. Dit het meegebring dat 'n beduidend laer ($p < 0,05$) beseringsinsidensie van 4,8 beserings per 100 deelnemers of 1 besering per 61,6 speler-ure vir hokkie opgeteken is, teenoor 'n insidensie van 14,3 beserings per 100 deelnemers of 1 besering per 16,4 speler-ure vir netbal. (Tabel 1).

Die afwesigheid van soortgelyke data vir die sportsoorte in die literatuur bemoeilik 'n sinvolle vergelyking, maar in die geheel gesien blyk die insidensie van beserings onder dogters tydens die toernooi laag te wees en sal dit waarskynlik verskil van 'n beseringstempo oor die duur van 'n volle seisoen se deelname. 'n Analise van die moontlike etiologiese faktore kenmerkend van die beserings wat voorgekom het, soos die meganisme van beserings volgens speelposisie en spelfase by die individuele sportsoorte het die volgende bevindinge getoon.

Analise van hokkie-beserings

In Tabel 2 word aangedui dat 4 uit die 5 hokkie-beserings volgens spelfase tydens verdediging voorgekom het en dat die persone wat hierby betrokke was, by 3 uit die 4 geleenthede in die skakelposisie gespeel het. By 3 van hierdie verdedigingsverwante beserings was die meganisme van besering te wyte daaraan dat die beseerde speler in die proses deur die opponent se stok raakgeslaan is, wat dus tot kneusing gelei het - in 2 gevalle van die vingers aan regter/onderste greephand op die stok en in die ander geval, van die distale derde van die regter tibia ten spyte daarvan dat beskermde toerusting wel gedra is. By 'n verdere besering verwant aan verdediging, het die speler met haar vry uitgestrekte arm teen die grond geval en dit het gelei tot 'n herverstuiting van die linker polsgewrig. Die oorblywende hokkie-besering het tydens oopspel plaasgevind terwyl 'n speler in die vleuelposisie die bal agterna gesit het, en in die proses 'n verrekking van die kuitspier opgedoen het.

Tabel 1: Insidensie van besering volgens sportsoort

Sport	Beserings/100 deelnemers	Beseringinsidensie per speler-ure
Hokkie	4,8	1:61,6
Netbal	14,3	1:16,4

Tabel 2: Analise van beserings by hokkie

Posisie	Spelfase	Meganisme	Tipe	Ligging
R Skakel	Verdediging	Val	Verstuiting	Polsgewrig
M Skakel	Verdediging	Stok	Kneusing	2de Falanks
L Skakel	Verdediging	Stok	Kneusing	Duim
L Binne	Verdediging	Stok	Kneusing	Tibia
R Vleuel	Oopspel	Nael	Verrekking	Kuit

Tabel 3: Analise van beserings by netbal

Posisie	Spelfase	Meganisme	Tipe	Ligging
DV	Verdedigende	Val	Verstuiting	Polsgewrig
HDV	sprong	Val	Verstuiting	Polsgewrig
Senter	Aanval en	Skeeftrap	Verstuiting	Enkel
Senter	ontwyking	Skeeftrap	Verstuiting	Enkel
Senter	Vang	Bal	Verstuiting	Vinger
AV	Aanval of	Val	Verstuiting	Enkel
AV	ontwyking	Val	Verstuiting	Skouer
AV	Sprong	Landing	Verrekking	Knie
HD	Vang	Bal	Verstuiting	Vinger

DV = Doelverdediger HDV = Hulp Doelverdediger
AV = Aanvallende vleuel HD = Hoofdoel

Analise van netbal-beserings

By die ontleding van netbal-beserings, is dit uit Tabel 3 opvallend dat 8 uit die 9 gevalle ligamentbeserings as gevolg van verstuiting was. Ten opsigte van die anatomiese ligging van hierdie beserings, was die enkel 3 keer betrokke - waar 2 senters tydens aanvallende/ontwykende spel op 'n ongelyke oppervlakte skeefgetrap het, terwyl 'n aanvallende vleuel by verskillende geleenthede ook tydens aanvallende/ontwykende spel geval het, en 'n opponent daarna eerstens op haar enkel en toe haar skouer getrap het. Verder is die polsgewrig by 2 verdedigers beseer toe elkeen na 'n verdedigende sprong met 'n uitgestrekte arm teen die grond geval het. Laastens het 2 spelers hulle derde proksimale interfalanksegewrig van die hand beseer toe die bal in die proses van 'n vangpoging effens misgetas is. Uit hierdie 8 ligamentbeserings was 6 herbeserings aan dieselfde gewrig.

Ten opsigte van die relatiewe risiko vir besering tussen die twee sportsoorte, is die waarneming dat hokkie 'n laer ($p < 0,05$) insidensie van besering as netbal opgeteken het insiggewend, aangesien die inherente moontlikheid by die eersgenoemde om deur die bal of teenstander se stok getref te word 'n ooglopende groter ekstrinsieke risiko vir akute besering inhou.[9,10] Andersyds, alhoewel die reëls van netbal bepaal dat geen liggaamskontak tussen speelsters toegelaat word nie, mag hierdie sportsoort onder jeugdiges in terme van beseringsrisiko tot 'n mate vergelyk word met kontaksport. Dié stelling staan in verhouding tot die redenasie van sommige navorsers se mening,[10] dat wanneer deelnemers gereeld tydens sekere aktiwiteite val en die grond tref, soos by 4 uit die 9 netbalbeserings in hierdie studie, daar soortgelyke risiko bestaan vir besering as met tradisionele kontak sportsoorte, en dat sulke aktiwiteite dus as "beperkte kontak/impak" sport geklassifiseer kan word.

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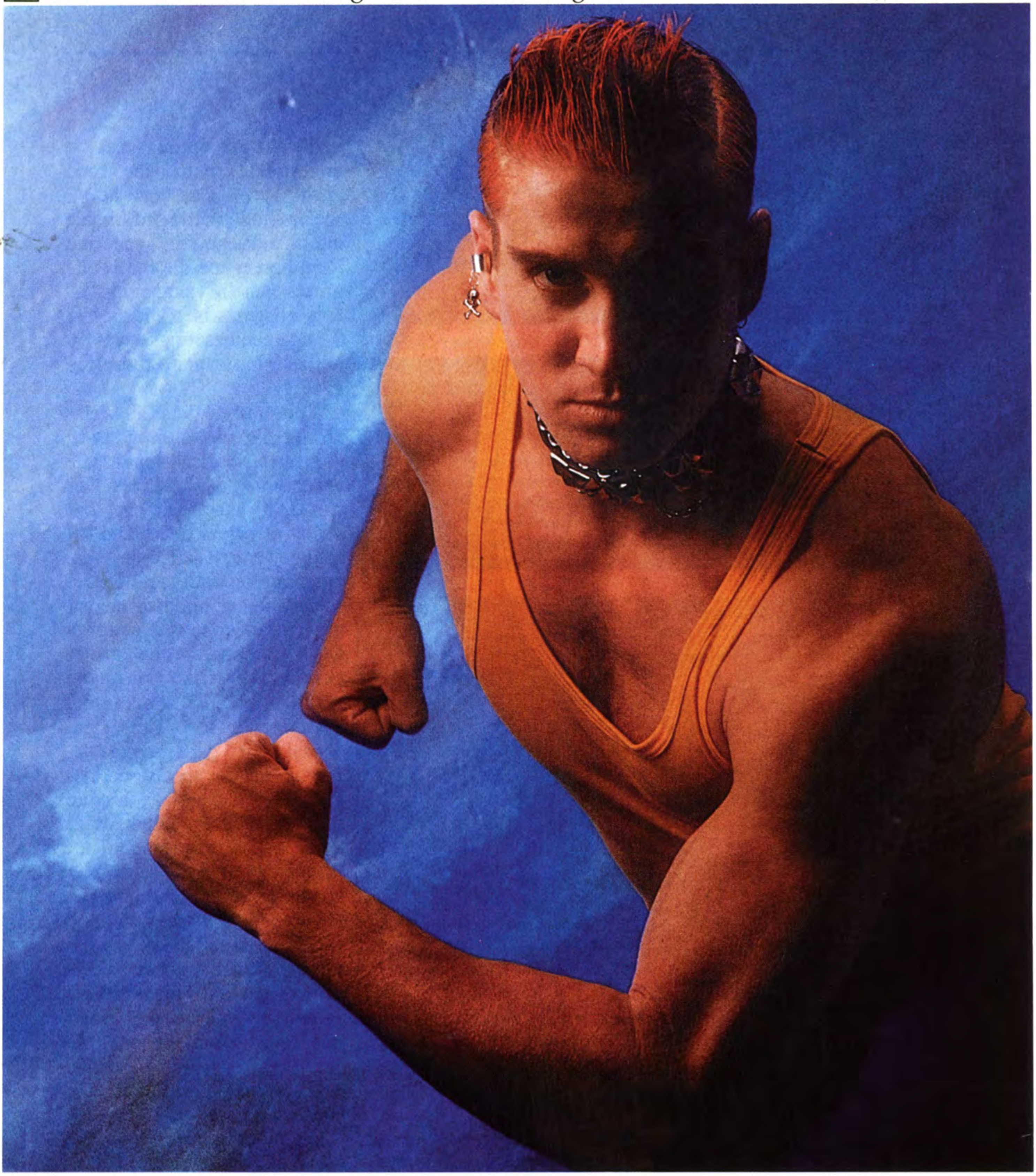

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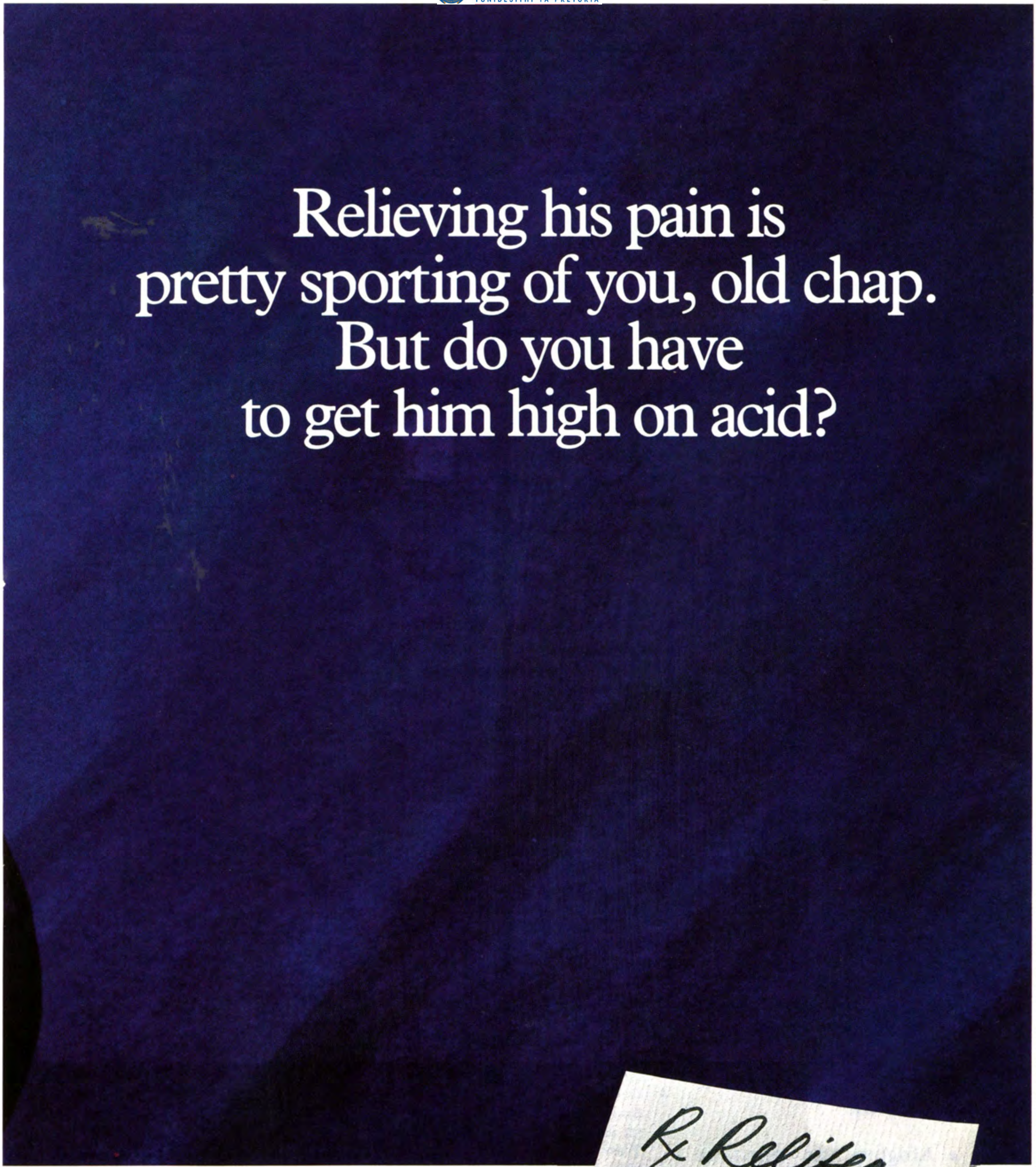

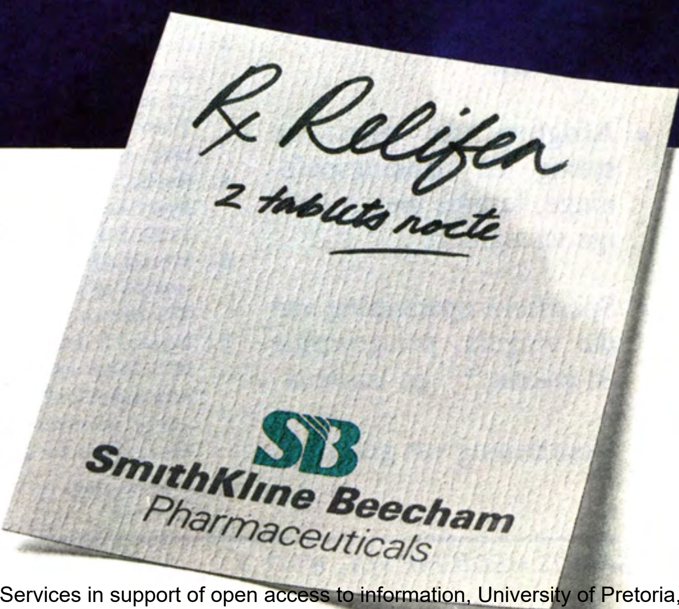

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OGILVY & MATHER, RIGHTFORD SEARLE-TRIPP & MAKIN 54981 geeneen van die betrokke gewrigte voor deelname aan wedstryde tydens hierdie toernooi met steunverbindings voorsien nie, terwyl die waarde van dié voorkomende praktyk by die beskerming van 'n bestaande besering tydens deelname, geredelik aangevoer word.[11,12] By hokkie blyk die potensiële risiko vir besering hoofsaaklik verband te hou met eksterne trauma soos die moontlikheid om deur die bal of die opponent se stok tydens verdediging getref te word, en gevolglik behoort die dra van beskermende toerusting[12] en streng optrede deur skeidsregters teen ongeoorloofde verdediging as voorkomende aspekte beklemtoon te word.[13,14] Wat netbal betref blyk besering verband te hou met spronge en aanvals - of ontwykingsbewegings wat aanleiding gee tot mistasting van die bal, slegte landings en/of skeeftrap, soms met 'n gevolglike val en tref van die grond. Gebaseer op hierdie waarnemings behoort aandag geskenk te word aan die volgende:

- Versterking van die quadricepspiere en die spiere rondom die enkelgewrigte om sodoende liggaamsbalans en stabiliteit te verbeter;[15]
- Afrigting van spesifieke spring en landingsoefeninge, tesame met 'n veilige valtegniek;
- Spesifieke opwarming van die vingers, polsgewrigte en enkels;[16,17] en laastens
- Voorsiening van gelyke en goed versorgte speel oppervlaktes.

SAMEVATTING

Oor die algemeen is daar min beserings onder dogters tydens deelname aan netbal en veral hokkie gedurende die toernooi opgeteken. Omdat die afleidings van hierdie studie afkomstig is uit 'n beperkte volume data behoort dit derhalwe met oordeel geïnterpreteer te word. Nieteenstande die feit, is daar by die analise van beserings by die individuele sportsoorte bevind dat beserings op 'n bepaalde wyse voorgekom het, en behoort die aanbevole voorkomingsmaatreëls dus steeds van pas te wees.

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Ander verwysings op versoek.

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DIE VOORKOMS EN ETIOLOGIE VAN BESERINGS IN HOKKIE EN NETBAL BY LAERSKOOL DOGTERS

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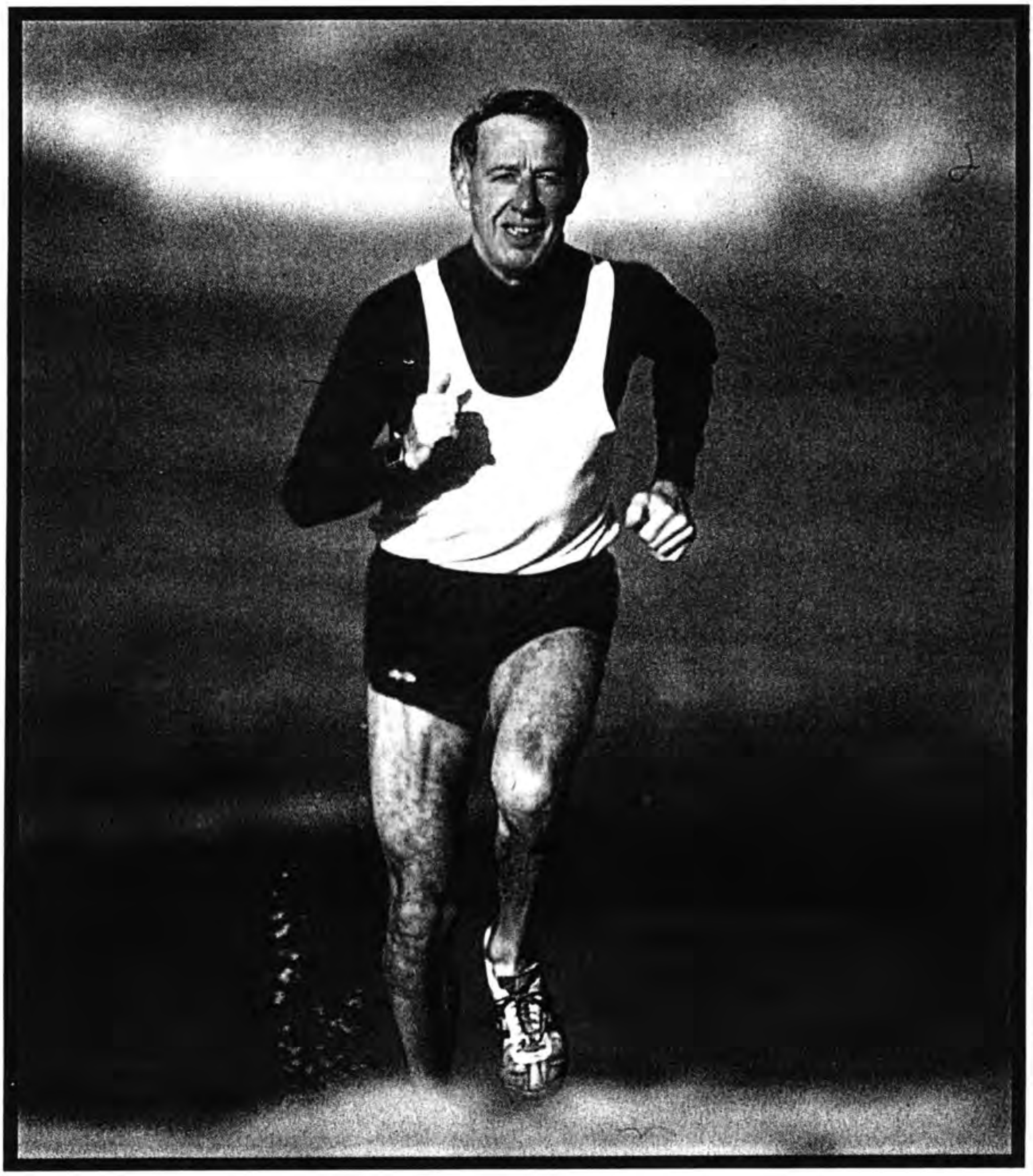

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- The evaluation of injury in junior soccer players
- Resistance training and the cardiac patient
- Metabolic cost of positive and negative work

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THE EVALUATION OF INJURY IN JUNIOR SOCCER PLAYERS

HJ van Heerden

Keywords: Injuries, soccer, youths.

INTRODUCTION

Soccer is the most widely played sport across the globe[1] and enjoys equal popularity among all ages in South Africa. Characteristically, vigorous and competitive sports participation does, however, involve the possibility of injury,[2] and as in other contact sports, soccer has an inherent injury risk.[3,4] An epidemiological study of sports injuries to determine the risk of participating and to identify the variables associated with injury, has become the basis of preventive strategies in sports medicine.[5] In overseas countries a number of studies have been conducted to determine the incidence and aetiology of injuries among both senior[6-9] and junior[10-12] soccer players. In the South African context, however, apparently only injuries among senior players have been reported.[13,14] In an attempt to address this problem, a study was thus conducted to determine the incidence, nature and aetiology of injury among junior soccer players.

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SUBJECTS AND METHODS

The players involved had been selected to represent regional under 13 age-group teams in an annual country and districts youth tournament held in the Natal Province. A cohort of 76 players, comprising 6 teams participating in a round robin competition with a total of 15 matches over a period of two days, was observed prospectively. A biokinetician and a team of paramedical attendants served as the on-site triage officers.

An injury was defined as any traumatic condition resulting while competing that:

- necessitated the complete cessation of participation in the match; and/or
- required first aid treatment thereafter.

This inclusive definition was used rather than a more stringent time-loss criteria,[15] due to the brief duration of the tournament. On occurrence of an injury the investigator:

- completed a specifically designed injury recording form and thus;
- recognized and classified the injury; and
- determined potential aetiological conditions.

The incidence of injury was expressed as injuries per 100 participants, and by taking exposure-time into conside-ration, according to player-hours.[16] (Number of 30 minute matches x 0,5 x number of players involved per match).

RESULTS

Over the two days of the tournament 8 injuries were incurred by as many participants, all of which had a sudden (acute)

Table 1: Analysis of injuries

Playing position	Playing phase	Injury mechanism	Injury type & site
G Keeper	Saving	Ball Contact	Sprain/Wrist*+
G Keeper	Saving	Ball Contact	Sprain/Wrist
R Back	Breakaway	Sprint	Strain/Back*
L Back	Tackled	Body Contact	Contusion/Shin
L Half	Tackling	Body Contact	Sprain/Knee*+
L Half	Tackled	Body Contact	Contusion/Foot
C Half	Tackled	Body Contact	Contusion/Thigh
L Wing	Tackled	Body Contact	Sprain/Knee*+

* indicates reinjury
\+ indicates absence of protective taping

onset and occurred during matchplay. This gave rise to an injury rate of 10,5 injuries per 100 participants or 1 injury per 20,6 player-hours. An analysis of the nature of the injuries, extrinsic aetiological factors such as the playing position and phase of play during which they were incurred and the mechanism of injury, is reflected in Table 1.

Aetiological analysis of injuries

Two of the injuries were incurred by goalkeepers in the process of saving a shot at goal, where in both cases the force of the ball caused excessive dorsiflexion of the right wrist leading to ligamentous sprains of the radiocarpal joint. Another 5 of the injuries were also related to a defensive playing phase, being sustained in the process of either making a tackle or being tackled. In each case the injury mechanism involved body contact with an opponent. This resulted in 3 contusions and 2 sprains. The sites of contusion were the left thigh, right foot and left tibia, despite shin guards being worn in the last instance. Both of the tackle-related sprains were to the medial aspect of the respective left and right knees and appeared to be associated with valgus forces from the tackle and/or a resultant awkward fall over the opponent. The single remaining injury, was unrelated to defensive play and took place as the player turned and chased the ball during an attack, thereby incurring a strain of a muscle of the erector spinae group. A noteworthy observation when considering the injuries in totality, was that 4 of the 8 injuries were recurrent. These injuries were incurred to an anatomical site that had been injured in the same or previous season, prior to participation in the current tournament. Furthermore, 3 of the 4 reinjuries were sprains. In each case the respective joint had not been provided with the possible protection of supportive strapping.

The volume of data from this study may preclude absolute deductions concerning the incidence and aetiological patterns of injuries in youth soccer. However, the findings can be discussed in general within the context of reports by other researchers.

DISCUSSION

Injury incidence

In commenting on the injury patterns in youth sports, Goldberg[17] maintains that preadolescent and young adolescent soccer players have a low risk of injury. In this respect McCarroll *et al*[10] have reported injury rates of 1,9% for players aged 10 or younger, 3,1% for those aged 12 or younger and 5,3% for those aged 14 or younger. When the injury rate recorded in this study is expressed in alternative forms of 10,5% or 48,5 injuries per 1000 player-hour exposures, the injury incidence would thus appear to be comparatively higher, although this relation remains emphatically speculative.

In a study conducted along similar lines as this report, but involving elite international participants, Nilsson and Roaas[11] monitored 11 to 18 year old boys playing in two 5 day tournaments. Their method of injury recording incorporated every injury reported by the players, including blisters and abrasions, and in so doing documented an injury incidence of 14 injuries per 1 000 player-hours. It is probable that due to the format of such tournament-based studies, which involve fairly intense competition concluded over a short period of time and thus demanding a high match frequency, the findings may reflect a higher incidence of injury than that which a more ideal study lasting a complete season may document. A further contributing factor may be the sensitivity of the injury definition which in this study excluded minor problems such as abrasions but allowed for the inclusion of mild contusions that are not usually considered significant.

The above reasoning gains support by relating the results of another apparently more functional study by Sullivan *et al*[12] who monitored the injuries among 7 to 18 year olds in a youth soccer league during one season. In this report injuries were required to be sufficiently significant as to lead to time lost from practice or play before being included in the results, and documented an incidence of 0,5 injuries per 1 000 player-hours. By comparison,[18] when minor injuries were excluded, the injury rate in the tournament-based and less stringent injury definition study of Nilsson and Roaas,[11] was twice as high as that of the afore cited study of Sullivan *et al.*[12]

Anatomical site and type of injuries

As is the case in senior soccer,[1,7,9] when expressed as a percentage of total injuries, the lower extremities are affected in the majority of cases, comprising 64% to 68% of injuries to youths.[11,12] More specifically, Goldberg[17] reports that the ankle, knee and shin are injured most often among youths, with contusions followed by sprains being the most frequent type of injury. While the same types of injury were found in this study, the absence of ankle injuries was noticeable and could be related to the good condition of the field on which all matches were played, which in the opinion of the coaches and managers present, was well grassed and even surfaced. The incidence of upper body injuries in young soccer players, has however, been reported to be higher than among seniors and in this respect concern has been raised about the potential for head injury among youths resulting from repeated heading of the ball.[12,18] The mechanism of such injury is considered to be related to the increased ball-weight to head-weight ratio for younger players,[19,22] and as a result it is commonly propagated that youth leagues use a lighter weight ball. It should also be appreciated that leather balls gain weight when wet, producing increased ball-body impact forces which may be germane to injury, resulting in the current trend to construct balls from synthetic non-absorbent materials.[18,22]

Playing position

In the study on youth soccer by Sullivan *et al*[12] the authors documented the percentage of total injuries by position as 32% each for both strikers and backs, 18% for goalkeepers and 17% for midfielders. The interpretation of the incidence of injury by playing position, must take into consideration that players are unequally distributed among positions, but according to Keller *et al*[18] in their review of the medical aspects of soccer injury epidemiology, the above results reflect a disproportionate high number of injuries to goalkeepers as compared to midfielders. A local study among senior soccer players,[13] reported the same trend by noting that when corrected for the number of players per position, a 37% incidence of injury was documented among goalkeepers, and suggested that this could partly be due to the intensity of play in the goal area.

Phase of play

It would appear that the observation of 5 of the 8 injuries (63%) in this study being related to the tackle phase of the game, is a common finding. Surve *et al*[13] for example, found that 73% of injuries in senior players occurred collectively during fouls and fair tackles, while Ekstrand and Gillquist[1,20] reported that 30% of traumatic injuries were sustained due to foul play and noted that typically it is the player committing the foul who sustains the more serious injury.

CONCLUSION

In the final analysis, the question of severity of injury is considered more important than the frequency of sports-related injuries.[16] In this respect, there is agreement that serious injuries appear to be uncommon among young soccer players, and the proportion of fractures and dislocations in soccer is consistently low regardless of age.[17,18] In this study, none of the injuries sustained were of such severity to require immediate medical attention or referral, i.e. players suffering extreme pain and/or obvious deformity and dysfunction. This should not, however, diminish the importance of prophylaxis. The following universal guidelines as suggested by various researchers should thus form the basis of a soccer injury prevention programme:

- Disciplined play and strict refereeing against foul and over-robust tackling;[13,18]
- The compulsory use of shock absorbing shin guards, as recently ruled by FIFA, which preferably, protect the full length of the tibia as well as the malleoli;[18]
- The use of prophylactic taping and bracing of previously injured ankle joints in particular;[14,20]
- The provision of well maintained playing surfaces;[13,20]
- The adequate rehabilitation of injuries prior to resuming participation;[21] and
- Adequate conditioning and warm-up programmes preferably under the supervision of individuals with certified training in the sport scientific aspects of coaching.[8,13,20]

ACKNOWLEDGMENT

The Natal Education Departments' approval to conduct this study is hereby acknowledged.

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APPENDIX B

INFORMED CONSENT DOCUMENTATION

RUGBY INJURY RESEARCH PROJECT

Dear Parents

Rugby injuries among schoolboys concern all who support and are involved with the game i.e. parents, coaches, educators and sport scientists.

This year your son, together with his teammates, are asked to participate in a rugby injury prevention research project which has been approved by the Headmaster and the Natal Education Department.

It is envisaged that once the findings of this project have been analyzed, it may lead to future steps to reduce rugby injuries.

The purpose of this letter is two-fold. Firstly, to notify you of the above project and of the procedures that need to be followed. Secondly, and very importantly, your approval for your sons' participation in the project is required and must be indicated by signing the informed consent form attached.

It will be appreciated if you would ensure that this consent form is returned to the school on completion and that the further procedures, as described hereafter, are followed so as to facilitate the successful completion of the project.

Yours sincerely

J Raubenheimer

(Senior Coach)

RUGBY INJURY RESEARCH PROJECT

GENERAL PROCEDURES

This project entails that all rugby players:

1. Be evaluated to determine their medical and physical fitness before the start of the season; and

2. Be monitored for any injury that may occur during the season.

Both of the above phases of the project will be done in cooperation with:

1. Local medical doctors;
2. Rugby coaches of the school; and
3. Mr HJ van Heerden and Prof MF Coetsee of the Dept Human Movement Science at the University of Zululand, who have initiated and will coordinate the project.

PARENTAL PROCEDURES AND NOTIFICATION

Medical Fitness Examination - Before the Rugby Season

1. The player and his parents are requested to complete a Health History form; and

2. The player is requested to undergo a voluntary medical examination as arranged by the researchers and the medical doctors involved in the project.

Note: As arranged for this project, the medical examination will be conducted free of charge. In addition, this medical examination should not be seen as an attempt to interfere with any doctor-patient relationship that is already established.

Physical Fitness Test - Before the Rugby Season

This will be done by the rugby coaches in conjunction with and under the supervision of the researchers in charge. Such tests will involve muscle strength, flexibility, agility, body type, body fat, etc.

Monitoring of Injuries - During the Rugby Season

Injuries will be monitored by coaches and the researchers during the season. A specific injury reporting form will be used to record all injuries that take place during both practices and matches. In the event of their son being injured, parents are requested to enquire wether the injury was reported to, and recorded by his rugby coach.

Further Information or Enquiries

Parents who wish to know more details about the project are invited to phone the coordinating researchers at the Department of Human Movement Science, University of Zululand:

Mr Johan van Heerden Tel. 93911 x 254

Prof MF Coetsee Tel. 93911 x 354

INFORMED CONSENT FORM

I agree to my son ____ participating in a research project, concerned with the prevention of rugby injuries, the nature of which has been explained to me. I have had the opportunity to discuss the experimental procedures with the researchers. I do hereby voluntarily authorize and consent to the said evaluation procedures. I agree to any relevant findings being passed on to members of the research team, and to the use of this information in publication for research purposes with the name of the participant remaining confidential.

Signed:__________________ (parent/guardian) Date:_________

Signed:__________________ (participant) Date:_________

APPENDIX C

HEALTH HISTORY PROFORMA

HEALTH HISTORY QUESTIONNAIRE

To be completed by the player and parent

Name: ______________________ Initials: ______ Age (Yrs): ______

Team: ______________ Date: ______________ Home Tel: ________________

(Please circle the correct option)

1. Have any members of your family had a "heart attack", "heart problems" or died before the age of 50? Yes No

2. Have you ever fainted during exercise or had to stop exercising because of dizziness? Yes No

3. Have you ever injured any bone, joint or muscle? Yes No

4. Have you ever been "knocked out" or had concussion from a blow to your head? Yes No

5. Have you ever suffered from "heat-stroke", "heat-exhaustion" or heat-related illness? Yes No

6. Are you able to run (jog) twice around a field or athletics track (800 metres) without stopping to rest? Yes No

7. Do you have any continuous health problem (chronic illness) like asthma, diabetes or epileptic convulsions? Yes No

8. Are you taking any daily medication? Yes No

9. Have you had any problems with or have you lost the use of one of the following paired organs? (Indicate): Yes No

   Eyes___ Lungs___ Kidneys___ Testicle___ Other___

10. Have you ever had an illness, condition or injury that caused you:

   a) To spend the night in hospital? Yes No
   b) To visit the doctor more than once? Yes No
   c) To have an operation? Yes No
   d) To have an x-ray, plaster cast, sling or crutches? Yes No
   e) To miss school for longer than a week? Yes No
   f) To be told not to participate in sport? Yes No

NB. On the reverse side of this form write 1-2 sentences detailing each "yes" answer.

Signature (parent): ______________________

Signature (player): ______________________

DETAILS OF POSITIVE RESPONSES TO THE QUESTIONNAIRE

APPENDIX D

MEDICAL EXAMINATION PROFORMA

RUGBY INJURY RESEARCH PROJECT

Letter to Medical Practitioners involved in the study.

Recently the South African Teachers Federal Council have emphasized the necessity of preventing sports injuries among school children. In particular, rugby injuries among high school players pose a problem in our country.

It is generally accepted that in order to gain knowledge about and prevent sports injuries, it is necessary to conduct epidemiological studies to determine the incidence of injury and the risk factors associated with injury.

As a result we as Biokineticists at the Department of Human Movement Science at the University of Zululand (Prof MF Coetsee as supervisor and Johan van Heerden as project leader), have initiated and planned a rugby injury research project. The protocol for this study involves the cooperation of parents, medical practitioners, school rugby coaches, paramedical attendants and the researchers.

Included herewith is a brief background to the study and the methods and procedures to be followed by cooperating medical practitioners. If required, further details can be obtained from the undersigned:

Your cooperation in this regard is highly appreciated.

Prof MF Coetsee Ph D

HJ van Heerden MA

Tel. 93911 x 354

Tel. 93911 x 254

BACKGROUND TO THE STUDY

Previous Research on Schoolboy Rugby Injuries

Rugby injuries among schoolboys is of concern to all who support and are involved in the game i.e. parents, coaches, educators and researchers in Sports Medicine. In this respect, epidemiological research that has addressed injury among South African schoolboy rugby players in the Cape Province,[1,2] has concentrated on the association of extrinsic risk factors (phase of play, playing position etc.) with injury. This led to various rule changes being implemented as preventive measures. These studies suggested that an intrinsic lack of "fitness" may also contribute to injury.

Aim

The purpose of this project, is to conduct a prospective epidemiological study to identify potential intrinsic aetiological risk factors among schoolboy rugby players.

References:

1. Nathan M et al. (1983). The incidence and nature of rugby injuries experienced at one school during the 1982 rugby season. South African Medical Journal;64:132-137.

2. Roux C et al. (1987). The epidemiology of schoolboy rugby injuries. South African Medical Journal;71:307-313.

RESEARCH PROTOCOL

The project will consist of two phases, namely:

1) The evaluation of rugby players prior to the start of the season to identify potential intrinsic risk factors among them; and

2) The monitoring of injury during the rugby season to evaluate the association of the potential risk factors identified at baseline evaluation, with injury occurrence.

PREPARTICIPATION EVALUATION PHASE

The methods and procedures for this first phase of the study consist of the following:

1) An initial administering of a health history questionnaire which will be completed by the player and his parents; and

2) A subsequent preparticipation evaluation (PPE) of the players' medical and physical status through:

a) a medical examination conducted by cooperating medical practitioners; and

b) a musculoskeletal fitness evaluation conducted by the rugby coaches (field tests) and the researches utilizing the Dept Human Movement Science Biokinetics Laboratory.

The musculoskeletal fitness evaluation will include:

Somatotype, % body fat, flexibility, agility and muscle strength / power / endurance (isometric, isotonic and isokinetic evaluation).

MEDICAL EXAMINATION GUIDELINES

Scope and Content

Based on a review of the literature, it is evident that the PPE medical examination of youths requires that:

1. It be sports-related - emphasizing those aspects of the individuals health, which may predispose him to injury during the particular sport (in this case being rugby); and

2. The core content comprises a cardiovascular and orthopaedic examination, but that positive responses in the health history questionnaire may necessitate additional examination.

Medical Examination Proforma

A proforma is attached for recording the findings of the examination.

Disposition

On reviewing the prior completed health history and conducting the medical examination, the practitioner is required to indicate the individuals disposition according to the following options:

1. No participation;

2. Limited participation i.e. only in specific activities;

3. Clearance withheld i.e. subject to further evaluation or rehabilitation; or

4. Unlimited participation.

The recommendations of the American Academy of Paediatrics' Committee on Sports Medicine[3] for participation in competitive sports, are included herewith for use as a guideline in deciding on the disposition after examination. Their system of assessment broadly classifies sports as practised by youths, into contact and non-contact, depending on the degree of strenuousness and probability for collision. As such, the sport of rugby would thus fall into the "contact/collision" category and has been added to the applicable column.

The authors do emphasize that the primary goal of the PPE medical examination is not to disqualify youths from participating, but to ensure that individuals are medically fit for the demands of the prospective sports-related activity / specialist event or position.

Reference[3]: Pediatrics 1988;81(5):737-739.

MEDICAL EXAMINATION PROFORMA

Name: ______________________________ Initials: _______ Age: _______

Tel No (Home): _________________________ Date: ____________________

Position(s) played: ____

CARDIOVASCULAR / RESPIRATORY (Inspection/Auscultation)

	Normal	:	Abnormal - Comments
Pulses	______	:	________________________
Heart Rate	______	:	________________________
Heart Rhythm	______	:	________________________
BP:(_____/_____)	______	:	________________________
Lungs	______	:	________________________
Other	______________________________		

ORTHOPAEDIC (Figure A) **Mass(kg):** ______ **Stature(cm):** _______

NECK Comments

____ Normal
____ Limited ROM - Direction? ____________________
____ Pain in ROM - Direction? ____________________
____ Other: ______________________________

SPINE

____ Normal
____ Kyphosis
____ Scoliosis
____ Lordosis
____ Limited Motion - Direction? ____________________
____ Pain in Motion - Direction? ____________________
____ Other: ______________________________

SHOULDER (Bilateral)

____ Normal
____ Limited ROM - Side/Direction? ____________________
____ Pain in ROM - Side/Direction? ____________________
____ Atrophy - Muscle(s)? ____________________
____ Other: ______________________________

ELBOW (Bilateral)

____ Normal
____ Hyperextension (>180 degrees) Side? ____________
____ Flexion Contracture (<180 degrees) Side? ____________
____ Other: ______________________________

HIPS (Bilateral)

____ Normal
____ Pelvis Not Level
____ Unequal Leg Length - Short Side? ____________________
____ Limited ROM - Side/Direction? ____________________
____ Pain in ROM - Side/Direction? ____________________
____ Other: ______________________________

KNEE (Bilateral)

Alignment

_____ Normal (i.e. 0-14 degrees valgus)
_____ Genu valgus (>15 degrees) - Side? ____________
_____ Genu varus - Side? ____________
_____ Genu recurvatum - Side? ____________

Range Of Motion

_____ Normal
_____ Limited ROM - Side/Direction? ____________
_____ Pain in ROM - Side/Direction? ____________

Stability / Ligamentous Laxity (Compare with opposite leg)

_____ Normal
_____ Positive Abduction / MCL Stress Test - Side? ____________
_____ Positive Adduction / LCL Stress Test - Side? ____________
_____ Positive Anterior / ACL Drawer Test - Side? ____________
_____ Positive Posterior / PCL Drawer Test - Side? ____________

Palpation

_____ Normal
_____ Effusion - Side? ____________
_____ Asymmetry (quadricep atrophy) - Side? ____________
_____ Scarring (previous surgery) - Side? ____________
_____ Joint-line pain (meniscus) - Side? ____________
- M/L ? ____________
_____ Patella crepitation - Side? ____________
_____ Patella pain (Apprehension Test) - Side? ____________

Other Finding - Knee Joint ____________

____

____

ANKLE (Bilateral)

Range Of Motion

_____ Normal
_____ Limited ROM - Side/Direction? ____________
_____ Pain in ROM - Side/Direction? ____________

Stability / Ligamentous Laxity (Compare with opposite ankle)

_____ Normal
_____ Positive Anterior Drawer Sign - Side? ____________
_____ Positive Medial / Lateral Talar Shift - Side? ____________

Other Finding - Ankle Joint ____________

____

HEEL (Bilateral)

_____ Normal
_____ Excessive valgus (pronation) - Side? ____________
_____ Tender Achilles tendon - Side? ____________
_____ Other: ____________

FEET (Bilateral)

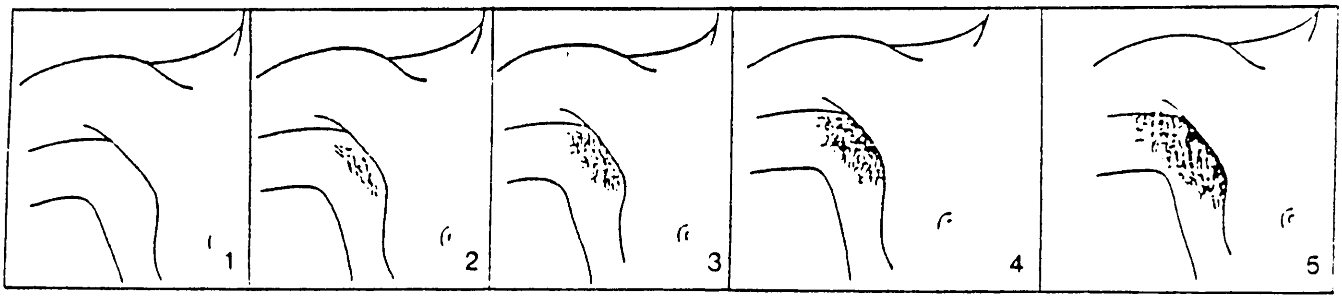
_____ Normal
_____ Pes planus (flat MLA) - Side? ____________
_____ Pes cavus (high MLA) - Side? ____________
_____ Other: ____________

ADDITIONAL AREAS OF EXAMINATION

EENT	Normal	:	Abnormal - Comments
Eyes/Vision	______	:	______
Ears	______	:	______
Nose	______	:	______
Throat	______	:	______
ABDOMINAL ORGANS			
Liver	______	:	______
Spleen	______	:	______
Hernia	______	:	______
Other	______		
NEUROLOGIC			
Pupils	______	:	______
Reflexes	______	:	______
Other	______		
GENITALIA	______	:	______
SKIN	______	:	______
TEETH	______	:	______
URINE	______	:	______

MATURATION INDEX (Tanner Stage - Axial Hair Growth)

1. ___ 2. ___ 3. ___ 4. ___ 5. ___



OTHER: ______

DISPOSITION (Based on health history and medical examination using Figure B as a guideline)

1. No participation:____

   (Reason):______________________________

   ____

2. Limited participation:____

   (Reason):______________________________

   ____

3. Clearance withheld:____

   (Reason):______________________________

   ____

4. Unlimited participation:____

   Remarks:______________________________

   ____

   ____

   ____

   ____

Examining Physician: ______________________________

Telephone Number(s): ______________________________

____

FIGURE A

ORTHOPAEDIC SCREENING EXAMINATION

INSTRUCTION	OBSERVATION
1. Stand facing examiner	*Acromioclavicular joints, general habitus.*
2. Look at ceiling; floor; over both shoulders ; and touch ears to shoulders.	*Cervical spine motion.*
3. Shrug shoulders (examiner resists)	*Trapezius strength.*
4. Abduct shoulders 90° (examiner resists @ 90°)	*Deltoid strength.*
5. Full external rotation of arms	*Shoulder motion.*
6. Flex and extend elbows	*Elbow motion.*
7. Arms at sides, elbows flexed at 90°; pronate and supinate wrists	*Elbow and wrist motion.*
8. Spread fingers; make a fist	*Hand or finger motion and deformities.*
9. Tighten (contract) quads; relax quadriceps	*Symmetry, knee and ankle effusion.*
10. "Duck walk" four steps (away from examiner)	*Hip, knee and ankle motion.*
11. Back to examiner	*Shoulder symmetry; scoliosis.*
12. Knees straight, touch toes	*Scoliosis, hip motion, hamstring tightness.*
13. Raise up on toes, raise heels	*Calf symmetry, leg length.*

After Dyment (1986)

FIGURE B

RECOMMENDATIONS FOR PARTICIPATION IN COMPETITIVE SPORTS

CONDITION	CONTACT		NON-CONTACT		
	CC	LCI	STR	MSTR	NSTR
ATLANTOAXIAL INSTABILITY	N	N	Y*	Y	Y
* Swimming - no butterfly, breast stroke or diving starts					
ACUTE ILLNESS	*	*	*	*	*
* Needs individual assessment					
ACQUIRED IMMUNODEFICIENCY SYNDROME	*	*	Y	Y	Y
* Private decision between the player and his physician.[1]					
CARDIOVASCULAR					
Carditis	N	N	N	N	N
Hypertension : Mild	Y	Y	Y	Y	Y
Moderate	*	*	*	*	*
Severe	*	*	*	*	*
Congenital heart disease	+	+	+	+	+
* Needs individual assessment					
+ Patients with mild forms can be allowed a full range of physical activities; patients with moderate or severe forms, or who are post-operative, should be evaluated by a cardiologist before participation.					
EYES					
Absence or loss of function in one eye	*	*	*	*	*
Detached retina	+	+	+	+	+
* Approved eye guards may allow participation in most sports, but must be judged on an individual basis.					
+ Consult ophthalmologist					
INGUINAL HERNIA	Y	Y	Y	Y	Y
KIDNEY : ABSENCE OF ONE	N	Y	Y	Y	Y
LIVER : ENLARGED	N	N	Y	Y	Y

[1] After the American Academy of Paediatrics (1991), Committee on Sports Medicine and Fitness

FIGURE B: CONTINUED

CONDITION	CONTACT		NON-CONTACT		
	CC	LCI	STR	MSTR	NSTR
ORTHOPAEDIC DISORDERS	*	*	*	*	*
* Needs individual assessment					
NEUROLOGIC					
History of serious head or spine trauma, repeated concussions or craniotomy	*	*	Y	Y	Y
Convulsive disorder: Controlled	Y	Y	Y	Y	Y
Uncontrolled	N	N	Y+	Y	Y++
* Needs individual assessment + No swimming or weightlifting ++ No archery or riflery					
OVARY : ABSENCE OF ONE	Y	Y	Y	Y	Y
RESPIRATORY					
Pulmonary insufficiency	*	*	*	*	Y
Asthma	Y	Y	Y	Y	Y
* May be allowed to compete if oxygenation remains satisfactory during a graded stress test					
SICKLE CELL TRAIT	Y	Y	Y	Y	Y
SKIN					
Boils, herpes, impetigo, scabies	*	*	Y	Y	Y
* No gymnastics with mats, martial arts, wrestling, or contact sports until not contagious					
SPLEEN : ENLARGED	N	N	N	Y	Y
TESTICLE : ABSENCE OR UNDESCENDED	Y*	Y*	Y	Y	Y
* Certain sports may require protective cup					

KEY : CC = Contact/collision LCI = Limited contact/impact
STR = Strenuous MSTR = Moderately strenuous
NSTR = Non - strenuous Y = Yes N = No

After the American Academy of Paediatrics (1988), Committee on Sports Medicine.

APPENDIX E

COACHES' COMPENDIUM

RUGBY INJURY RESEARCH PROJECT

COACHES' MANUAL

CONTENTS

Further Information & Enquiries

Coaches who are unsure about any aspect of the procedures of the project are encouraged to contact the researchers:

Mr Johan van Heerden (Researcher) Tel (W) 93911 x 254
Tel (H) 921363

Professor MF Coetsee (Supervisor) Tel (W) 93911 x 354

RUGBY INJURY RESEARCH PROJECT

TO ALL RUGBY COACHES

The South African Teachers Federal Council have emphasized the necessity of preventing sports injuries among school children. In order to gain knowledge about the prevention of sports injuries, it is necessary to study the incidence and risk factors associated with injury.

Subsequently, a rugby injury research project is to be carried out with the approval of the Headmaster, and the Natal Education Department. The initiators of this project are Mr Johan van Heerden (researcher) and Prof MF Coetsee (supervisor), of the Department of Human Movement Science at the University of Zululand.

Cooperation between the researcher and yourselves as rugby coaches, parents, Medical Doctors from the community and paramedical attendants are of vital importance in the successful completion of this project. Mr Raubenheimer as master in charge of rugby, will act as coordinator between the school and the researcher and will convey specific information regarding the project. Following this covering letter, is a COACHES' MANUAL explaining the methods and procedures to be followed during the project. Prior to the start of the project, a meeting will be called where you will be briefed further and details can be discussed.

Your cooperation as members of the research-team will not be taken for granted and as a token of appreciation for your efforts, a remuneration will be forthcoming.

Headmaster - Mr G Smith: ______________________________

Researcher - J van Heerden: ______________________________

Supervisor - Prof MF Coetsee: ______________________________

BACKGROUND TO THE PROJECT

Previous Research

Rugby injuries among schoolboys is of concern for all who support and are involved in the game i.e. parents, coaches, educators and sport scientists. Research that has addressed injury among South African schoolboy rugby players in the Cape Province, has concentrated on extrinsic risk factors such as phase of play and playing position as causes of injury. This has led to various rule changes being implemented as preventive measures. These studies suggested that intrinsic factors such as "unfitness" may also contribute to injury.

Aim of this project

This project entails that all rugby players:

1. Be evaluated to determine their medical and physical fitness before the start of the season; and

2. Be monitored for any injury that may occur during the season.

PROCEDURES

PARENTAL CONSENT

Every players' parents will receive a covering letter informing them of the project and to which a consent form for their sons' participation therein will be attached. This consent form must be completed and signed and then returned to the rugby coach.

MEDICAL EVALUATION - Before the Rugby Season

1. Health History Questionnaire

The player and his parents complete the Health History Questionnaire which is also attached to the covering letter, and then it is returned to the coach together with the informed consent form.

2. Medical Examination

Prior to the start of the rugby season, in the first week of the second term, a team of Medical Doctors will conduct a voluntary medical examination of the players. The Health History Questionnaire must be presented to the examiner during the medical examination.

FITNESS TEST - Before the Rugby Season

The fitness evaluation will be conducted by the researcher in cooperation with the rugby coaches.

The following variables are to be measured:

FIELD-TESTS	:	LABORATORY TESTS
* **Strength**	:	* **Strength**
Push-ups (upper body)	:	Grip strength (upper body)
Sit-ups (abdominal)	:	Knee extension/flexion*
Vertical Jump (legs)	:	* At HMS Lab - Unizul
* **Flexibility**	:	* **Anthropometry**
Gross Tests:	:	Body Stature
Scratch test (shoulders)	:	Body Mass
Toe touch (hamstrings)	:	% Body Fat
* **Agility**	:	Lean Body Mass
Zig-Zag run	:	Somatotype

FIELD - TEST INSTRUCTIONS

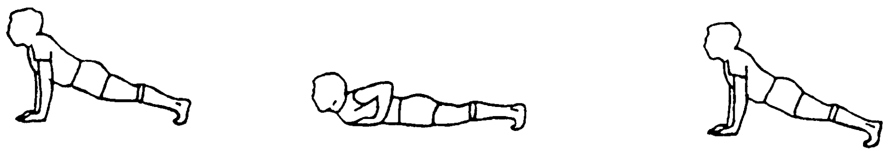
Muscle Strength and Endurance

*** Push-up Test**

Equipment: Stopwatch

Description: The standard push-up movement is executed from the floor. A front lying position is taken with the hands at the sides of the chest. The body is raised to the starting position by extending the arms completely while keeping the body in a straight line. The chest must touch a partners fist held on the ground each time on the down phase and arms must be fully extended on the return (up) phase. A push-up thus constitutes one down-and-up movement starting and ending in the raised position. The back must be kept straight throughout the movement. No partial credit is allowed and the exercise must be done continuously.

Scoring: The total number of valid push-ups completed in 60 seconds is recorded.



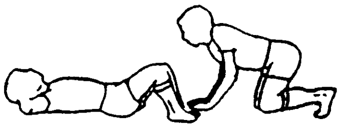
*** Bent-Knee Sit-up Test**

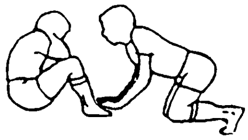
Equipment: Stopwatch

Description: The subject lies on the back with knees bent at 90 degrees, hands behind the neck with fingers interlaced, and elbows pointed forwards. The feet are flat on the surface, slightly separated and parallel to each other, and held in place by a partner. The abdominal muscles are tightened, the head and elbows brought forward, and the elbows touched to the legs. This action constitutes one sit-up. The subject returns to the starting position and repeats the exercise.

To be counted as a valid sit-up the subject must: i) keep the fingers clasped behind the neck; and ii) return to the starting position with the shoulder blades touching the floor, before sitting-up again.

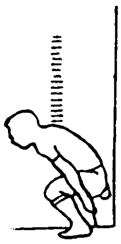
Scoring: The total number of valid sit-ups completed in 60 seconds is recorded.

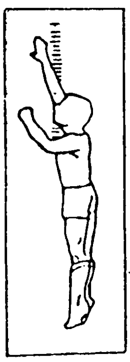




*** Vertical Jump Test**

Equipment: Wall, tape-measure, chair, chalk & duster.
Footwear to be standardized.





Description: The player stands side-on against the wall and his reach height is determined: With both feet flat on the floor and heels together he reaches up with his dominant hand and makes a mark against the wall. To perform the jump, the knees are bent and then he jumps as high as possible vertically with maximal effort and makes a mark against the wall. The person may not move his feet in preparation for the jump. the difference between the reach height and the jump height is measured to the nearest cm.

Three jumps are permitted. The first jump is performed sub-maximally and serves as a familiarization and specific warm-up for the test. The remaining two jumps are performed with maximal effort directly after each other with 10 seconds rest in between.

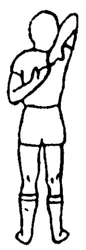
Scoring: The distance achieved with the last two efforts are measured and recorded to the nearest cm.

Flexibility

*** Scratch Test**

Description: The right elbow is raised and the right hand reaches down between the shoulder blades. The left hand is placed in the small of the back with the palm facing away from the back. The subject attempts to overlap the fingers of the two hands. The test is then repeated, reversing the positions of the hands.

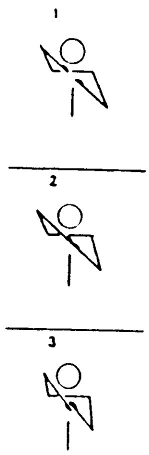
Scoring: The score is recorded by observing the distance between the hands according to numerical scores ranging from 1 - 3, indicating the amount of finger overlap, where:



1 = Fingers not touching;

2 = Fingers touching; and

3 = Fingers overlapping.



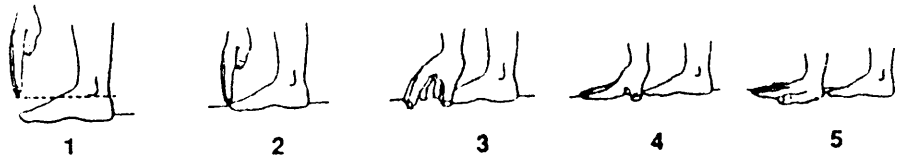
*** Standing Toe - Touch**

Description: The subject assumes an erect standing position either barefoot or wearing socks and with feet together.

The arms should hang by the sides. Keeping the knees straight throughout the test, the subject slowly leans downward towards the toes, attempting to touch the floor with the palms of the hand.

Scoring: Numerical scores ranging from 0 - 5, are recorded according to the finger placement on the floor, where:

0 = Fingertips not in line with the ankles;
1 = Fingertips in line with the ankles;
2 = Fingertips touching the toes;
3 = All fingertips touching the ground;
4 = All fingers (but not palms) flat against the floor; and
5 = Palms flat against the floor.



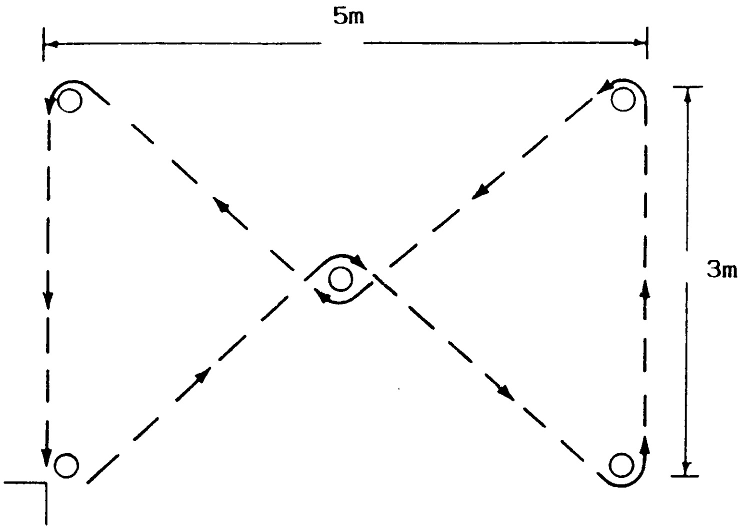
Agility

*** Zig-Zag Run Test**

Equipment: Stopwatch; 5 markers outlining the test course as in the sketch below.

Description: At the signal the subject begins from behind the line and runs the outlined course as fast as possible. Three trials are given directly after each other with a 10 second rest period between trials. The first trial is carried-out at three-quarter speed to familiarize the subject with the procedure and to serve as a specific warm-up. Footwear is to be standardized for all subjects.

Scoring: The subjects' performance is measured as the elapsed time to the nearest tenth of a second. The score is recorded as the mean of the last two trials.



NOTES

MONITORING OF INJURIES - During the Rugby Season

Once the rugby season has started formally, the injury monitoring phase will commence. All injuries to players occurring during both practices and matches are recorded.

INJURY RECORDING PROCEDURES

Definition of Injury

All injuries that are incurred by players which comply with the following are to be recorded:

An injury is defined as any traumatic condition occurring during a match or practice, which:

i) necessitates the complete cessation of participation in the match/practice; and/or

ii) requires first aid treatment during or after the match / practice.

2. DATA COLLECTION INSTRUMENTS

Injuries are to be recorded using an Injury Recording Form which will be distributed among coaches.

INJURY RECORDING FORM

The Injury Recording Form consists of four parts and should be completed as follows in the event of an injury:

Part 1 - Player Identification

To be completed by player, coach or parent.

Part 2 - Injury Description

To be completed by:

i) medical/paramedical attendants or the researcher during matches; or

ii) by coaches in the absence of field-side medical / para-medical attendants during matches and/or practices.

Part 3 - Aetiology / Factors related to injury

To be completed by the researcher or coach who then:

i) either retains the injury recording form if no further medical treatment or examination is needed (form will be collected by the researcher / coordinator); or alternatively

ii) the coach ensures that the injury recording form is left in the possession of the injured player or accompanying person (coach/parent) so that the examining doctors' diagnosis can be recorded on the reverse-side of the injury recording form.

Part 4 - Doctors Report (Overleaf)

If the injured player is referred to a doctor or the hospital - the medical examiner completes this section of the recording form, and it is handed in to the coach by the player or accompanying person on their return to the competition venue/school.

GENERAL COMMENTS - INJURY RECORDING

In particular, coaches acting as injury recorders are requested to note the following in order to prevent under-reporting of injuries:

1. Remind their players of the injury recording procedure and to impress on them the importance of reporting their injuries.

2. Ensure that injuries are recorded in the following cases where injuries may otherwise be missed:

   a) Injuries sustained during practices;

   b) If a player is injured during a practice or match but does not receive treatment at the time and only reports the injury afterwards;

   c) If a player is injured during competition and receives treatment but returns to competition thereafter.

3. Ensure that injuries sustained during away-matches, during the last week of a term or at the end of the season are recorded and forms handed in.

4. In the event of any doubt - the researcher / coordinator should be consulted.

NOTES

APPENDIX F

INJURY RECORDING PROFORMA

INJURY RECORDING FORM

1. PLAYER IDENTIFICATION : **DATE** ___ / ___ / ___

Surname: ______________ Initials: _____ Age(Yrs): _____

Position: ______________ Home Tel: ______________

Team (Mark - X): 1st 2nd 3rd 15A 15B 15C 14A 14B 14C

2. INJURY DESCRIPTION (Mark - X)

Anatomical Site of Injury: Left ___ Right ___ Both ___ NA ___

Head ______	Neck ______	Upper arm ____	Hip ______
Face ______	Chest ______	Elbow ______	Thigh:F__B__
Eye ______	Ribs ______	Forearm ______	Knee ______
Nose ______	Breastbone____	Wrist ______	Knee-cap____
Ear ______	Abdomen ______	Hand ______	Lower-leg __
Mouth ______	U-Back ______	Thumb ______	Ankle ______
Teeth ______	L-Back ______	Finger ______	Achilles ___
	Shoulder ______	**Other** ______	Foot ______
	Collarbone____	______	Toe ______

Injury Classification

Bruise ("lamey") ___	Cut ______
Muscle pulled ______	Scrape ______
Ligament sprain ____	Winded ______
Closed fracture ____	Internal ____
Open fracture ______	Concussion ___
Joint dislocation __	Other ______

Treatment Rendered

Ice ______	Sling _____
Splint ______	Crutches __
Neck-brace __	CPR ______
Crepe-bandage ______	
Adhesive-strapping ______	
Other ______	

Injury Disposition (Action taken)

* No further play ______
  Referred - coachs'care ___
  Referred - doctor ______
  Referred - hospital ______
* Limited return with disability ___
* Full return without disability ___
* Other ______________

3. FACTORS RELATED TO INJURY (Mark - X)

Injury Onset: Sudden/Acute ___ Gradual/Chronic ___

Period of Play: Match __ Practice __ 1st H __ 2nd H __ am __ pm __

Phase of Play: Scrum __ Loose-scrum __ Line-out __ Tackling __
Being Tackled __ Open-play __ Other ______

Position Played: ______________

Status: New injury ___ Reinjury ___ (this ___ or last ___ season)

Briefly explain how injury occurred ______________

____

Surface Condition(X): Hard Soft Muddy Wet Dry Slippery Even Uneven

Footwear(X): Running-Shoes/Boots - Highcut/Lowcut - Multistud? Y/N

Protective Equipment(X if worn/used): Gumguard ___ Shinpads ___

Brace ___ Elastic-Guard ___ Adhesive-strapping ___ Other ______

Warm-up before playing? (X): Y / N ; If yes - how long?: ____ mins

Was stretching of the specific injured area included ? Y / N

NB - IF EXAMINED BY OR REFERRED TO A DOCTOR/HOSPITAL - PTO

NOTE - THIS FORM SHOULD BE COMPLETED BY THE EXAMINING DOCTOR AND HANDED TO YOUR COACH ON RETURNING TO SCHOOL

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4. DOCTORS REPORT ON SPORTS INJURY SUSTAINED

Specific diagnosis: ______________________________

____

Severity: Mild - 1st Degree ______ (No limitations expected; back to sport in 3 days)

Moderate - 2nd Degree ______ (Sequela to resolve; back to sport in 4 - 14 days)

Severe - 3rd Degree ______ (Long term sequela; Can't return in same capacity)

Disposition: No limitation ______ or

No participation for ______ days or ______ weeks

Expected return to participation (Date) ______

Diagnostic Procedures and Treatment:

Physical Examination ______ X - ray ______

Splint ______ Bandage ______

Crutches ______ Cast ______

Other ______________________________

Prescriptions: Analgesic ______________________

Anti-inflammatory ______________________

Other ______________________

Other Recommendations: ______________________________

____

Signature: ______________________ Date: ______________

Doctors Name: ______________________________

NB. Tel No: ______________________

____

APPENDIX G

RULE-REVISION COMPENDIUM

REVIEW OF PERTINENT REVISIONS TO THE LAWS OF RUGBY

Revisions to the laws of rugby which are pertinent in the context of this study, were introduced on three occasions:

i) 1988 - Instituted by the International Rugby Board and applicable to rugby at senior and junior levels;

ii) 1990 - Proposed as experimental laws by the South African Rugby Board for application at high school level and approved by the International Rugby Board;

iii) 1992 - Instituted by the International Rugby Board and applicable to rugby at senior and junior level (in addition to the preceding laws applicable to high school rugby).

1988 RULE REVISIONS

Referee - Law 6A (7)
Play may continue during minor injuries with a medically trained person being permitted to come onto the playing area to attend the player or the player going to the touch line.

Touch Judges - Law 6B (6)
...the touch judge *shall (it is mandatory)* report incidents of foul play.

This law was introduced as deterrent to foul play and misconduct under circumstances where the referee may be unlikely to observe it. Thus it is intended that the penalty be severe.

Fair catch (Mark) - Law 16 Note 2
If an opponent unfairly charges the catcher *in the playing area* after the referee has blown his whistle for a fair catch, a penalty kick shall be awarded.

Tackle, lying with or near the ball - Law 18 (1)

a) A tackled player must immediately pass or release the ball and get up or move away from the ball.

b) A player who goes to ground to gather a ball or with the ball in his possession but who is not tackled, must immediately get onto his feet with the ball in his possession or pass/release the ball or move away from the ball.

c) Any other player must be on his feet before he can play the ball.

The rewrite of the law (18 & 19 combined) serves to clarify and not alter the law. Note (5): Danger may arise if a tackled player fails to pass or release or move away from the ball at once or is prevented from doing so. In such cases the referee should not delay in awarding a penalty kick.

Scrummage (Engagement) - Law 20 (2)
In the interests of safety each front row should touch on the upper arms and then pause prior to engagement in the sequence: crouch - touch - pause - engage.

To minimize the force of impact on engagement of the front rows, which has been identified as the point of most serious injury in scrums over recent years. This is considered to be a vital safety measure.

Scrummage (Formation and execution) - Law 20 (4 & 5c)
While the scrummage is in progress a minimum of five players shall remain bound in the scrummage until it ends. ... the two players in the second row (locks) must remain bound to each other until the scrummage ends.

In the interests of safety, the law was previously changed to require a minimum of five players to form a scrummage. These amendments are to clarify the intention that these five remain bound for the duration of the scrum, thus avoiding a potentially dangerous situation.

Scrummage (Execution) - Law 20 (18)
A scrummage must not be wheeled beyond a position where the middle line becomes parallel to the touch line. ... the scrummage will be reformed at the original mark.

A scrummage is likely to become destabilised on wheeling, with a consequent increase in the likelihood of a scrum collapse and the danger of injury. In the interests of maintaining a more stable scrum it is intended that play should be stopped if the scrum wheels more than 90°.

Foul Play - Law 26 (Penalty - Note 3)
... tackling or attempting to tackle a player around the neck or head *or above the line of the shoulders* must be punished severely *and a penalty awarded in all such cases.*.

To reinforce the need to deter and penalize any form of high tackle, which medical review shows to be responsible for many facial and neck injuries.

1990 RULE REVISIONS (Schoolboys)

Scrummage (Engagement) - Law 20 (2)
Every scrummage shall be ... stationary with the middle line parallel to the goal lines until the ball has been put in. Before commencing engagement, each front row must be in a crouched position with heads and shoulders no lower than their hips and so that they are not more than one arms' length from their opponents' shoulders.

The front row will at the referees' command, go down in three phases:

i) a front row of three players;
ii) a second row of two players; and
iii) the remaining players taking part in the scrummage.

At all times in this process the players who go down in scrummage must be stationary. Should a team opt for only five players in the scrummage, the referee shall still give the other team chance to go down with more than five players before the ball is put into the scrummage.

Scrummage (Formation and execution) - Law 20 (4)
A minimum of five players from each team shall be required to form a scrummage. Each front row shall have three players in it at all times. The head of a player in the front row shall not be next to the head of a player in the same team.

While the scrummage is in progress, all the players taking part in the scrummage shall remain bound until it ends.

Scrummage (Possession) - Law 20 (7)
When an infringement occurs the team not responsible shall put in the ball. *In all other circumstances, unless otherwise provided, the ball shall be in put in by the team not carrying the ball prior to the stoppage or by the team with the ball at its feet prior to the stoppage or,* if the referee is undecided, by the attacking team.

Scrummage (Duration) - Law 20 (19)
No player may deliberately prevent the ball from emerging from a scrummage.

Touch and Line-out (Throw-in) - Law 23B (10)
The ball may be brought into play by a quick throw-in or at a formed line-out. The player must throw-in the ball such that it is *within the formation of formed by the outer shoulders of the players in the line-out.*

Off-side at Scrummage - Law 24B (2)
A player is off-side if he, being the player of either team who puts the ball in the scrummage, *advances beyond the centre line of the scrummage,* or if he is the immediate opponent of the player putting in the ball, takes up a position on the opposite side of the scrummage in front of the off-side line.

Foul play - Law 26 (Penalty)
vii) For a grievous offence of such a nature as would warrant sending off the field or to the cooler, the referee will award the non-offending team a penalty kick anywhere along the 22 m line, or if the offence occurs within the opposing teams' 22 m area, the non-offending team will have the option of a penalty at the place of infringement or anywhere along the 22 m line.

1992 RULE REVISIONS

Method of Scoring - Law 11

The scoring value of a try is five points.

Scrummage (Possession) - Law 20 (7)
In a ruck and/or maul when the ball becomes unplayable or stationary, the team not in possession at the start thereof will put the ball into the ensuing scrummage.

This is essentially an extension to senior level of the same rule which had formerly been stipulated and applied for high school rugby during 1990.

Scrummage (Execution) - Law 20 (14/16)
It is illegal to intentionally lift an opponent off his feet or force him upwards out of a scrum.

Touch and Line-out (Throw-in) - Law 23B (6)
When a player receives the ball outside his 22 m area and runs behind the 22 m line to kick for touch, he may not gain ground from the kick.

Touch and Line-out (Throw-in) - Law 23B (7)
When a penalty is kicked directly into touch the same team will have the throw-in.

Touch and Line-out (Throw-in) - Law 23B (9)
At a quick throw-in the ball may be thrown from any point along the touchline nearest to the defending teams' goal line, provided the player uses the same ball and retrieves it himself.

Touch and Line-out (Competing) - Law 23B (15)
A player jumping for the ball must use both hands or his inside arm.

Touch and Line-out (Formation) - Law 23B (18)
The former half metre space required between lines of players is increased to one metre.

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