

**UNIVERSITY OF ZULULAND**

**THE APPLICATION OF PROPHYLACTIC KNEE BRACING IN  
RELATION TO SELECTED PROPRIOCEPTIVE AND FITNESS AND  
SKILL PARAMETERS IN FIRST LEAGUE SOUTH-AFRICAN  
RUGBY PLAYERS**

By

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for the degree

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## **DEDICATION**

**This dissertation is dedicated to my parents.**

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## SYNOPSIS

**TITLE** : The Application of Prophylactic Knee Bracing in relation to selected Proprioceptive and Fitness and Skill parameters in First League South African rugby Players.

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In rugby and other sports involving rapid change in direction and physical contact, there has been a high incidence of knee injuries in match situations as well as in training sessions. Ample literature is available on the effect of braces for the prevention and recurrence of injuries. However, due to different research fields/subjects (American football, soccer and baseball) and methodologies, results are not always applicable to rugby union. The primary focus of the present study was to evaluate selected parameters important in modern rugby, and the effect of prophylactic knee bracing on speed, agility, strength, proprioception and economy of running. These parameters all play an important role in performance on the rugby field. The questions addressed are: are any of these parameters affected by wearing a prophylactic knee brace, and could forwards and backs be affected differently.

Thirty subjects aged 21 – 30 with the mean age of  $24,33 \pm 4,98$  years volunteered to participate in this study. Subjects were evaluated with respect to their anthropometric, proprioceptive, fitness and skill responses. The data were statistically analyzed by a one way ANOVA for significant differences in the following: braced and non-braced conditions for the combined group, backs and forwards separately. An independent t-test was employed to analyse the difference between backs and forwards. Both,  $p < 0.05$  and  $p < 0.01$  level of probability are indicated, although  $p < 0.05$  was the criteria for refuting the null hypothesis.

Anthropometric results illustrated that forwards and backs were significantly ( $p < 0.01$ ) different in their stature, mass, bodyfat, upper thigh girths and significantly ( $p < 0.05$ ) different in their above knee and calf girth and the mid thigh calf ratios (MTCR). Fitness and skill responses indicated that speed was insignificantly ( $p > 0.05$ ) influenced with prophylactic bracing for combined subjects, forwards and backs. However, speed was slower with bracing, but the difference was insignificant ( $p > 0.05$ ). Forwards' speed results were slower than results of the backs but the speed difference between forwards and backs illustrated an insignificant ( $p > 0.05$ ) difference for both variables (braced and non-braced conditions). Agility performance was insignificantly ( $p > 0.05$ ) decreased with brace application for the combined group, forwards and the backs. Forwards' agility performance was significantly ( $p < 0.05$ ) worse than backline players' performance in both variables, braced and non-braced conditions. Proprioception responses indicate that proprioceptive ability improved significantly ( $p < 0.01$ ) with prophylactic bracing for combined subjects and backs, however the forwards' performance also increased with bracing, but the increase was only significant at ( $p < 0.05$ ). Forwards' proprioceptive results in both conditions were worse than results of the backs, and the difference illustrated to be significant ( $p < 0.01$ ) for both variables.

For strength, prophylactic bracing illustrated no significant influence on flexion and extension of the knee ( $p>0.05$ ) for the combined group, backs or forwards. However, a significant ( $p<0.01$ ) difference was found between backs and forwards in peak strength (Nm) but not in relative strength ( $\text{Nm} \cdot \text{kg}^{-1}$ ). Economy of running performance for the combined subjects was not significantly ( $p>0.05$ ) influenced for levels 1-8, but was significantly ( $p<0.05$ ) influenced in level 9. Backline players illustrated an significant difference from levels 5-9 and the forwards only a significant difference ( $p<0.05$ ) at level 9 with brace application.

In conclusion the major two questions of the present study is to investigate if rugby players should use prophylactic knee bracing to prevent or reduce injuries to the knee, and will the brace affect forwards differently from backline players. From the results one could conclude in saying that bracing would not hamper performance on the rugby field significantly. But one should remember that each rugby player has a unique morphological composition and therefore one would suggest that rugby players evaluate or compare the involving factors, and experiment with prophylactic braces. The individual should, after reading the arguments, be in a better position to make an informed decision whether to use prophylactic braces or not.

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**KEY WORDS : ANTHROPOMETRIC; PROPRIOCEPTION; PROPHYLACTIC KNEE BRACING; RUGBY PLAYERS**

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## SINOPSIS

- TITEL** : Die Applikasie van Profalaktiese Kniestutte in verhouding met selektiewe Proprioepsie, Fiksheid en Vaardighede parameters in Eerste Liga Suid Afrikaanse rugby Spelers.
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Kniebeserings tydens oefeninge en wedstryde in rugby en ander sportsoorte wat vinnige verandering in rigting (ratsheid) en fisiese kontak vereis, is baie algemeen. Heelwat literatuur is beskikbaar oor die effek van kniестutte vir die voorkoming van beserings en herbeserings. As gevolg van die uniekheid van die navorsingsvelde, proefpersone (Amerikaanse rugby, sokker en sagtebal) en navorsingsmetodes, is resultate nie altyd van toepassing op rugby unie nie. Die primêre fokus van die huidige studie is om die volgende parameters, belangrik in rugby unie, te evalueer: die effek van profalaktiese kniестutte op spoed, ratsheid, krag, proprioepsie en ekonomie van hardloop. Laas genoemde parameters speel almal 'n belangrike rol in prestasie op die rugby veld. Die vrae is, of enige van die parameters beïnvloed word deur die gebruik van kniестutte, en of voor- en agterspelers verskillend beïnvloed sal word.

Dertig proefpersone met ouderdomme 21- 30 jaar met 'n gemiddelde ouderdom van  $24.53 \pm 4.98$  jaar het uit vrye wil aan die studie deel geneem. Proefpersone se antropometriese komposisie, proprioepsie, fiksheid en vaardigheids response is gemeet. Die data is statisties geanaliseer met 'n eenrigting KOVARO vir beduidende verskille tussen; stut draend en nie stut draende kondisies vir die gekombineerde groep, agterspelers en voorspelers. 'n Onafhanklike t-toets is gebruik om beduidende verskille tussen voorspelers en agterspelers te bepaal. Al twee vlakke ( $p < 0.05$  en  $p < 0.01$ ) van beduidenheid word aangetoon. Die vlak ( $p < 0.05$ ) is gebruik vir die verwerping van die nulhipoteses.

Die antropometriese resultate illustreer dat voor- en agterspelers beduidend ( $p < 0.01$ ) verskil, ten opsigte van hul liggaamslengte, liggaamsmassa, liggaamsvet, beenlegte, bo-been en middel-bo-been omtrekke, en beduidend verskil ( $p < 0.05$ ) in hul bo-knie en kuit omtrekke. Daarom is verskille ook beduidend in hul middel-bo-been kuit ratio (MBKR). Fikshied- en vaardigheid reponse het getoon dat spoed nie beduidend ( $p > 0.05$ ) af geneem het met die profalaktiese kniestut, vir die gekombineerde groep, agterspelers en die voorspelers. Alhoewel spoed wel afgeneem het met die kniestut was die afname in spoed nie beduidend. Voorspeler spoed was stadiger as die van die agterspelers. Alhoewel, daar 'n spoed verskil tussen voor- en agterspelers bestaan, was die verskil nie beduidend vir, stut draend en nie stut draend. Ratsheid resultate het getoon dat die stut nie 'n beduidende ( $p > 0.05$ ) afname in die ratsheid prestasie van die gekombineerde groep, agterspelers en die voorspelers tot gevolg het nie. Die ratsheid prestasie van die voorspelers was beduidend ( $p < 0.05$ ) swakker as die agterspelers se prestasie in albei kondisies. Proprioepsie prestasie het beduidend ( $p < 0.01$ ) verbeter met die kniestut, vir die gekombineerde groep en die agterspelers, die voorspelers se proprioepsie prestasie het ook verbeter, maar was slegs beduidend by ( $p < 0.05$ ). Voorspelers se proprioepsie prestasie was swakker as die van die agterspelers, maar die verskil was nie beduidend vir, stut draend en nie stut draend.

Die krag resultate toon dat die stut geen beduidende effek op fleksie en ekstensie prestasie van die knie gehad het, vir die gekombineerde groep, voor- en die agterspelers. Daar was wel 'n beduidende ( $p < 0.05$ ) verskil in krag tussen die voor- en agterspelers in piek krag (Nm), maar geen beduidende verskil in relatiewe krag ( $\text{Nm} \cdot \text{kg}^{-1}$ ) nie. Ekonomie van hardloop resultate toon dat daar geen beduidende ( $p > 0.05$ ) afname is in ekonomie van hardloop as 'n stut gedrae word, vir vlakke 1-8 vir die gekombineerde groep, maar wel 'n beduidende ( $p < 0.05$ ) afname in ekonomie van hardloop vir vlak 9. Agterspeler resultate wys 'n beduidende ( $p < 0.05$ ) afname in ekonomie van hardloop vir vlakke 5-9, en voorspelers slegs 'n beduidende ( $p < 0.05$ ) afname in vlak 9.

By die afhandeling van die studie is die belangrikste twee vrae, om te bepaal of rugby spelers kniestutte moet gebruik vir die voorkoming of vir die afname in knie beserings, en of knie stutte voorspelers verskillend van agterspelers sal beïnvloed. Resultate toon dat profalaktiese kniestutte nie rugby prestasie op die veld beduidend sal benadeel nie. Maar ons moet onthou dat elke rugby speler van morfologiese komposisie kan verskil. Rugby spelers word daarom aanbeveel om verskeie faktore in ag te neem en te vergekyk tydens eksperimentering met profalaktiese kniestutte. Spelers kan dan 'n ingeligte besluit neem om 'n stut te gebruik al dan nie.

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**SLEUTELTERME : ANTHROPOMETRIESE; PROPRIOSEPSIE;  
PROFALAKTIESE KNIESTUTTE; RUGBY SPELERS**

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## TABLE OF CONTENTS

TITLE PAGE	I
DEDICATION	II
ACKNOWLEDGEMENTS	III
SYNOPSIS	V
SINOPSIS	VIII
TABLE OF CONTENTS	XI
LIST OF TABLES	XVI
LIST OF FIGURES	XVI
<b>CHAPTER 1 : INTRODUCTION</b>	
PROLOGUE	1
STATEMENT OF THE PROBLEM	2
AIMS OF THE STUDY	3
RESEARCH HYPOTHESIS	4
DELIMITATIONS	6
LIMITATIONS	6
<b>CHAPTER 2</b>	
LITERATURE REVIEW	8
INTRODUCTION	8
ANATOMY OF THE KNEE	9
BRACING OF THE KNEES	14
PHYSICAL EFFECTS OF BRACING	18
External compression	18
Muscle blood flow	21

Blood Lactate	22
Electromyography (EMG) activity	23
<b>EFFECTS OF BRACING ON PERFORMANCE</b>	<b>25</b>
<b>SPEED</b>	<b>25</b>
Introduction	25
Bracing and Speed	26
<b>STRENGTH</b>	<b>30</b>
Introduction	30
Bracing and Strength	32
<b>PROPRIOCEPTION</b>	<b>35</b>
Introduction	35
Bracing and Proprioception	35
<b>AGILITY</b>	<b>39</b>
Introduction	39
Bracing and Agility	40
<b>ECONOMY OF RUNNING</b>	<b>42</b>
Introduction	42
Bracing and Economy of Running	44
Assessment of Economy of Running	45
<b>FACTORS THAT AFFECTS ECONOMY OF RUNNING</b>	<b>46</b>
Children vs. Adults	46
Male vs. Female	47
Training	47
Stride length and frequency	49
Fatigue	50
Body Mass	51
<b>CHAPTER 3</b>	
<b>METHODOLOGY</b>	<b>52</b>
<b>SUBJECT CHARACTERISTICS</b>	<b>52</b>
<b>INFORMED CONSENT</b>	<b>52</b>

<b>INSTRUMENTS</b>	<b>53</b>
Anthropometric measurements	53
Speed Test	53
Agility Test	53
Proprioception Test	54
Strength Test	54
Economy of Running Test	55
<b>PROCEDURES</b>	<b>56</b>
Pilot Study	57
<b>DESIGN AND ANALYSIS</b>	<b>58</b>
<b>ANTHROPOMETRIC MEASURES</b>	<b>58</b>
Stature	58
Leg Length	59
Body Mass	59
Body composition: Skinfold measurements	59
Percentage Body Fat	64
Girth measurements	64
<b>FITNESS AND SKILL MEASUREMENTS</b>	<b>65</b>
Speed	65
Agility	66
Proprioception	70
Strength	72
Economy of Running	74
<b>STATISTICAL ANALYSIS AND TREATMENT OF DATA</b>	<b>76</b>
<b>CHAPTER 4</b>	
<b>RESULTS AND DISCUSSION</b>	<b>77</b>
<b>SUBJECT CHARACTERISTICS</b>	<b>77</b>
<b>ANTHROPOMETRIC RESULTS</b>	<b>78</b>
Stature	78
Body Mass	81

Body Composition	83
Girths	84
<b>RESULTS OF FITNESS AND SKILL COMPONENTS</b>	<b>86</b>
<b>EFFECT OF BRACING ON SPEED</b>	<b>86</b>
Combined Speed	87
Speed for Backline players	91
Speed for Forward	92
Speed of Forwards versus Backline players	92
<b>EFFECT OF BRACING ON AGILITY</b>	<b>94</b>
Combined Agility	95
Agility for Backline players	98
Agility for Forwards	98
Agility of Forwards versus Backline players	99
<b>EFFECT OF BRACING ON PROPRIOCEPTION</b>	<b>100</b>
Combined Proprioception	101
Proprioception for Backline players	104
Proprioception for Forwards	105
Proprioception of Forwards versus Backline players	105
<b>EFFECT OF BRACING ON STRENGTH</b>	<b>108</b>
Combined Isokinetic Knee Extension	108
Isokinetic Knee Extension of Backline players	111
Isokinetic Knee Extension of Forward players	112
Combined Isokinetic Knee Flexion	112
Isokinetic Knee flexion of Backline players	114
Isokinetic Knee flexion of Forward players	116
Forwards versus Backline Isokinetic Knee Extension	117
Forwards versus Backline Isokinetic Knee Flexion	119
<b>ECONOMY OF RUNNING RESULTS</b>	<b>122</b>
Economy of Running for Combined subjects	122

Economy of Running for Backline players	127
Economy of Running for Forward players	130
<b>CHAPTER 5</b>	
<b>CONCLUSION AND RECOMMENDATIONS</b>	<b>133</b>
Morphological Composition	133
<b>POSITIVE EFFECTS OF BRACING</b>	<b>134</b>
Valgus Forces	134
Strength Performance	135
Improved Proprioception	135
Psychological Effect	136
<b>NEGATIVE EFFECTS OF BRACING</b>	<b>136</b>
Decreased Speed	136
Decreased Agility	137
Decreased Economy of Running	137
Psychological Effect	138
<b>RECOMMENDATIONS TO THE MANUFACTURERS</b>	<b>141</b>
<b>RECOMMENDATIONS TO FUTURE RESEARCHERS</b>	<b>137</b>
<b>APPENDICES</b>	
Appendix A – Informed Consent Documentation	143
Appendix B – Anthropometric Scoring Sheet	148
Appendix C – Speed Testing Scoring Sheet	151
Appendix D – Agility Testing Scoring Sheet	153
Appendix E – Proprioception Scoring Sheet	155
Appendix F – Isokinetic Strength Test, Akron Report	157
Appendix G – Economy of Running Scoring Sheet	159
<b>REFERENCES</b>	<b>161</b>

## LIST OF TABLES

TABLE	PAGE
i. Anthropometric results: means and standard deviations for stature, leg length, mass and body fat for all groups.	78
ii. Anthropometric Girth results: means and standard deviations for all groups.	84
iii. Means and standard deviations for time to complete the 30-meter speed test (Braced versus Non-Braced) for all groups.	87
iv. Means and standard deviations for time to complete the 30-meter speed test for backs and forwards in both variables Braced versus Non-Braced.	93
v. Means and standard deviations for time to complete the modified SEMO agility test for all groups.	95
vi. Means and standard deviations for time to complete the modified SEMO agility test for backs and forwards.	99
vii. Means and standard deviations for time unbalanced on the two minute Wilknox Quad Time Logger for all groups.	101
viii. Means and standard deviations for time unbalanced on the two minute Wilknox Quad Time Logger for backs and forwards.	106
ix. Means and standard deviations for Extension Torque in the Akron Isokinetic Strength test for all groups.	108

x.	Means and standard deviations for Flexion Torque in the Akron Isokinetic Strength test for all groups.	113
xi.	Means and standard deviations for Peak Extension Torque in the Akron Isokinetic Strength test for backs and forwards.	117
xii.	Means and standard deviations for Relative Extension Torque in the Akron Isokinetic Strength test for backs and forwards.	117
xiii.	Means and standard deviations for Peak Flexion Torque in the Akron Isokinetic Strength test for backs and forwards.	119
xiv.	Means and standard deviations for Relative Flexion Torque in the Akron Isokinetic Strength test for backs and forwards.	120
xv.	Means and standard deviations for exercise heart rates in the economy of running test for the Combined subjects.	123
xvi.	Means and standard deviations for exercise heart rates in the economy of running test for Backline players.	128
xvii.	Means and standard deviations for exercise heart rates in the economy of running test for Forwards.	131

## LIST OF FIGURES

FIGURE		PAGE
1.	Anatomy of the Knee (A) Quadriceps & Patella, (B) Anterior view of knee joint.	11
2.	Anatomy of the Knee (A) Lateral view of knee joint, (B) Hamstring muscles	12
3.	Anatomy of the Knee (A) Gastrocnemius and (B) Soleus muscles.	13
4.	The basic design of a Knee brace (A) Anterior view, (B) Lateral view of the thigh and calf cuffs (C) Single hinge and (D) Double hinge brace.	16
5.	Prophylactic Knee brace of the present study (A) Anterior view prior to application and (B) Anterior view after application.	17
6.	External compression elevates the intramuscular pressure beneath the thigh and calf straps.	20
7.	Anthropometric measurements (A) Height and (B) Weight	61
8.	Anthropometric measurements (A) Triceps skinfold, (B) Middle Thigh girth.	62
9.	Anthropometric measurements (A) Skinfold and (B) girth sites.	63
10.	Starting position of the 30 meter sprint for the speed test and SEMO agility test.	67
11.	Agility course for the modified SEMO agility test.	69
12.	Proprioception test on the Wilknox Quad Time Logger.	71

13.	The Akron Isokinetic tester (A) Anterior view and (B) Lateral view of tester.	73
14.	Heart rate monitoring in the 20 MST protocol test run.	75
15.	Anthropometric mean results (A) Stature, (B) Mass for subjects of the present study, the NSW super 12 side and the Australian National side.	79
16.	Anthropometric mean results (A) Body fat of the present study and (B) Middle thigh calf ratio (MTCR) of subjects in the present study.	80
17.	Speed for (A) Braced and Non-Braced of individual subjects and (B) Braced and Non-Braced time for different groups.	89
18.	Agility for (A) Braced and Non-Braced of individual subjects and (B) Braced and Non-Braced time for different groups.	97
19.	Proprioception for (A) Braced and Non-Braced of individual subjects and (B) Braced and Non-Braced time for different groups.	103
20.	Extension torque for (A) Braced and Non-Braced for individual subjects and (B) Braced and Non-Braced for different groups.	110
21.	Flexion torque for (A) Braced and Non-Braced for individual subjects and (B) Braced and Non-Braced for different groups.	115
22.	Torque recorded for (A) Knee flexion and (B) Knee extension for backs and forwards.	121

23. Mean heart rates for (A) Braced and Non-Braced of individual subjects  
and (B) Braced and Non-Braced for backs. 126
24. Mean heart rates for Braced and Non-Braced for the forwards in the MST. 132

# CHAPTER 1

## INTRODUCTION

### PROLOGUE

The origin of the game rugby is controversial. According to common belief, in 1823 rugby started, when a man called William Web Ellis, who was playing soccer, decided to pick up the ball and started to run (Van Der Merwe, 1990). This is seen across the world as the beginning of rugby. Sport Historians believe that this is not true as aspects of rugby already existed in games across the world. For example, the Chinese and other nations played a similar game about 200 years ago that included skills which are used in today's modern game (Van Der Merwe, 1990).

After all the controversial statements of how the game developed, a memorial stone at the rugby school of Warwickshire, England, can still be read today: "This stone commemorates the exploit of William Web Ellis who, with a fine disregard for the rules of football as played in his time, first took the ball in his arms and ran with it, thus originating the distinctive feature of the rugby game. AD 1823."

The rules of rugby changed many times during the years, but in the last 100 years the basic rules have stayed more or less the same. Today rugby is played with 15 players on the field and seven players on the reserve bench for each side. The most basic rule of the game is the same since the start of the game and that is to ground the ball behind the opponent's line. A standard rugby match lasts eighty minutes, and is divided and played in two halves consisting of forty minutes each. Rest periods of ten minutes between halves are given.

Rugby places high physical and physiological demands on the players. Due to factors such as different playing positions and skills required, the functional and physiological demands of different positions differ, although all positions in rugby require speed, agility, strength, proprioception and economy of running. Shortcomings in any of the mentioned could lead to injury or poor performance in rugby.

Rugby is played mainly by men and a very high level of skill, talent and ability is required to become an elite player in this sport. According to the IRB (International Rugby Board 2001) ninety-two countries in the world play rugby, ranging from social to highly competitive international level. Lately women have started to participate in the game as well.

In the last ten years sport in general, and especially rugby, has become increasingly professional, resulting in players being paid to participate in the sport. While large companies have seen the marketing potential, through worldwide media television, by sponsorship involvement, players saw the opportunity to make rugby a career. As the competition between companies to sponsor rugby teams has increased, so has the money involved in the sport increased. All these factors have led to the great competitiveness between players to become the best player in their club, province and country. All this has resulted in the game of rugby becoming more professional especially at international level with improved training techniques, placing greater physical demands on the players.

## **STATEMENT OF THE PROBLEM**

In rugby and other sports involving rapid change in direction and physical contact, there has been a high incidence of knee injuries in match situations as well as in training sessions. Ample literature is available on the effect of braces for the prevention and recurrence of injuries.

However, previous research leads to the conclusion that results are controversial (Montgomery & Kozirus, 1989; Baker et al., 1989; Sitler et al., 1990; Anderson et al., 1992; Johnston et al., 1991).

Beyond the need for objective evidence of protection offered by knee braces, it is also necessary to show that they do not hamper performance, or that any detriment to performance is acceptable in light of decreased injury rates or severity (Johnston & Paulos, 1991). The primary focus of the present study is to evaluate fitness and skill components important in rugby, and the effect of prophylactic knee bracing on such as speed, agility, strength, proprioception and economy of running. These all play a very important role in performance on the rugby field. The question is, will any of these physical parameters benefit from knee braces, or will braces have a negative effect on them.

## **AIMS OF THE STUDY**

The aim of this study is to determine whether prophylactic bracing of the knee has an affect on performance factors such as, speed, agility, strength, proprioception, and the economy of running. Therefore, if an individual would like to brace his/her knee as a preventive measure, the results of this study could benefit the player in helping him/her to weigh up the positive and negative factors.

According to the problem stated above, different parts in this investigation have been identified, such as:

- ❖ A 30-meter timed sprint test, both with and without a knee brace.
- ❖ An agility test with and without bracing.
- ❖ A proprioception test where unbalanced times are recorded.
- ❖ Leg flexion and extension of the knee with and without knee bracing.
- ❖ A 20-meter shuttle run test (20 MST), with and without bracing for the purpose of determining the economy of running.
- ❖ Weighing positive effects of prophylactic knee bracing against the negative effects.

## RESEARCH HYPOTHESES

Bracing of knees to prevent injury in rugby players will not affect individual performance, and therefore has no effect on the performance of the team he/she is playing for.

### Hypothesis 1

No difference exists between bracing the knee and not bracing the knee with regard to selected functional measures of speed.

Stated statistically the null-hypothesis is:

$$H_0: \mu_b(s) = \mu_n(s)$$

Where:

b = braced knee,

n = no brace,

(s) = functional analysis of speed.

### Hypothesis 2

No difference exists between bracing the knee and not bracing the knee with regard to selected functional measures of agility.

Stated statistically the null-hypothesis is:

$$H_0: \mu_b(a) = \mu_n(a)$$

Where:

b = braced knee,

n = no brace,

(a) = functional analysis of agility.

### **Hypothesis 3**

No difference exists between bracing the knee and not bracing the knee with regard to selected functional measures of strength.

Stated statistically the null-hypothesis is:

$$H_0: \mu_b(st) = \mu_n(st)$$

Where:

b = braced knee,

n = no brace,

(st) = functional analysis of strength.

### **Hypothesis 4**

No difference exists between bracing the knee and not bracing the knee with regard to selected functional measures of proprioception.

Stated statistically the null-hypothesis is:

$$H_0: \mu_b(p) = \mu_n(p)$$

Where:

b = braced knee,

n = no brace,

(p) = functional analysis of proprioception

### **Hypothesis 5**

No difference exists between bracing the knee and not bracing the knee with regard to selected functional measures of economy of running.

Stated statistically the null-hypothesis is:

$$H_0: \mu_b(e) = \mu_n(e)$$

Where:

b = braced knee,

n = no brace,

(e) = functional analysis of economy of running

## **DELIMITATIONS**

1. In the present study 30 men age 20-32 years, were selected from injury free volunteers. Provincial and National players were not considered for this study due to the limited time available for them to complete the tests.
2. First league male rugby players were recruited from three teams, all from the Zululand area, the Empangeni Rhinos I, II and Richards Bay Technical College I.
3. Subjects were given five minutes recovery between trials of each test and two days between the different tests.

## **LIMITATION**

The following limitations must be considered while examining the implications and subsequent conclusions drawn from these experimental results.

1. The sample used was restricted to three teams in the Zululand area, two of which were from the Empangeni Rhinos and the other one from the Richards Bay Technical College. It is recognized that the subjects used were of a relatively small number ( $n=30$ ) and were furthermore representative of only a small geographic area and demographic sample, with regards to South Africa as a whole.
2. Other than voluntary compliance with a request to maintain normal eating and exercise habits during the course of the study, there was no control over these external influences.
3. Player's habituation was not necessarily the same (The time needed to get used to the brace might have differed). All subjects wore the brace during a fifteen-minute warm-up before the tests were started.

4. Emotional state and motivation might have varied from player to player, and could have led to players not performing to their full potential.
5. Subjects were not tested at the same time and also on different days, and the effect of environmental changes might have influenced the performance of subjects (hot, cold and windy).
6. Due to time limit and costs of braces it was impossible to have the braces custom made and fitted for each subject, however three sizes small, medium and large were available.

## CHAPTER 2

### LITERATURE REVIEW

#### INTRODUCTION

Approximately 13% of high school and college football injuries are to the knee (Powell, 1985; Pritchett, 1992). With well over 1,000,000 Americans participating in organized contact football each year, the potential for lost playing time and the cost of providing medical care for knee injuries, not to mention the impact on a young athletic individual's life, make the pursuit of injury reducing factors worthwhile (Johnston & Paulos, 1991).

A variety of protective and supportive knee devices have been devised because of the high incidence of injuries to this joint. Indeed, support braces can enable individuals with knee ligament instability to participate successfully in athletics (Anderson, 1979; Houston & Goemans, 1982). Although it has been shown that leg support braces can improve walking parameters in hemiparetic and arthritic patients, the extent to which knee braces influence performance characteristics of the supported leg has not been evaluated in an athlete population at least up until 1982 (Houston & Goemans, 1982). This has created a large market for protective measures to improve knee stability. In 1979, the use of knee braces was introduced for prophylactic (preventive) purposes. Since then the use of knee braces has gone through a period of widespread popularity, followed by increasing skepticism as to their effectiveness (Hansen, 1985; Garrick, 1987; Johnston & Paulos, 1991).

## **ANATOMY OF THE KNEE**

The knee joint is the largest joint in the body and is very complex. It is primarily a hinge joint. The combined function of weight bearing and locomotion place considerable stress and strain on the knee joint. Powerful knee joint extensor and flexor muscles, combined with a strong ligamentous structure, provide a strong functioning joint in most instances (see Figure 1A) (Marieb & Mallatt, 1996).

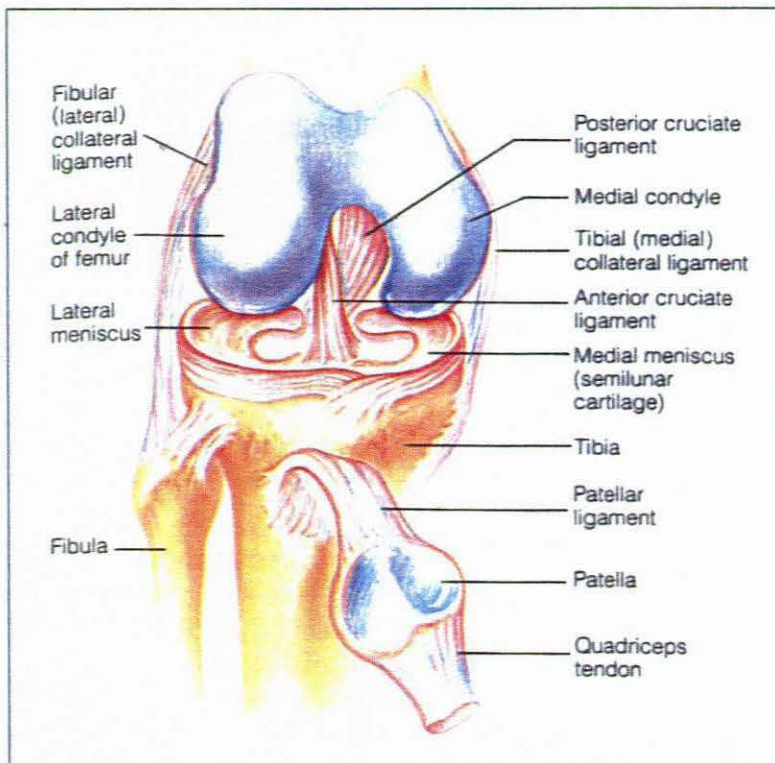
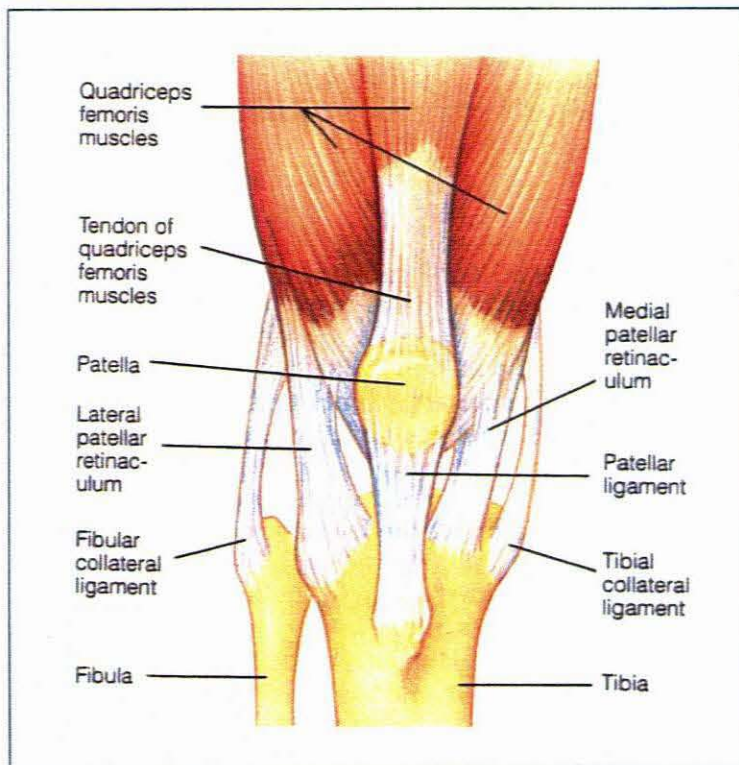
The enlarged femoral condyles articulate on the enlarged condyles of the tibia, somewhat in a horizontal line. Since the femur projects downward at an oblique angle, its medial condyle is slightly longer. The top of the medial and lateral tibial condyles, known as the medial and lateral tibial plateaus, serves as receptacle for the femoral condyles. The tibia is the medial bone in the leg bearing most of the weight of the lower leg. The fibula serves as the attachment for very important knee joint structures, although it does not articulate with the femur or patella and is not part of the knee joint. The patella is a sesmoid bone imbedded in the quadriceps muscle group and patella tendon. Its location helps provide a better angle of pull and thus a greater mechanical advantage for the quadriceps muscle in their work as knee extensors (see Figure 1B) (Marieb & Mallatt, 1996).

The knee joint is classified as a ginglymus joint because of its hingelike functioning into flexion and extension. However, it is sometimes referred to as a trocboinglymus joint because of the internal and external rotation movements that can occur during flexion. The ligaments provide static stability to the knee joint, and contractions of the quadriceps and hamstring muscles produce dynamic stability. Cartilage forms the cushion between the bones (see Figure 1B & 2A). The medial semilunar cartilage, or more technically, the medial meniscus, is located on the medial tibial plateau to form a receptacle for the medial condyle; whereas the lateral meniscus sits on the lateral tibial plateau to receive the lateral femoral condyle. Both of these menisci are thicker on their outside border and taper down to a very thin inside border. They can slip about slightly and are held in place by various small ligaments.

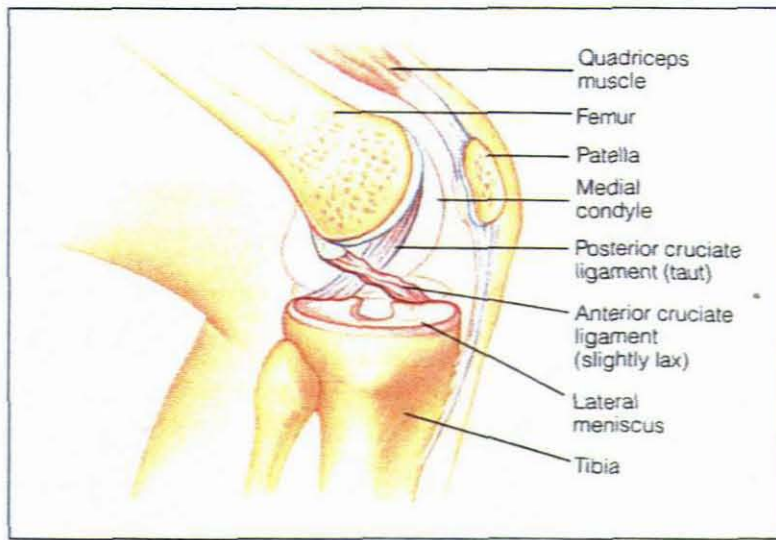
The medial meniscus is the larger of the two and has much more open "C" appearance than the rather closed "C" lateral meniscus configuration (Marieb & Mallatt, 1996).

Two very important ligaments of the knee are the anterior and posterior cruciates, so named because they cross within the knee between the tibia and the femur. These ligaments are vital in respectively maintaining the anterior and posterior stability of the knee joint, as well as the rotatory stability. On the medial side of the knee is the medial collateral ligament, which maintains medial stability by resisting valgus forces or preventing the knee joint from being abducted. On the outside of the knee, the lateral collateral ligament joins the fibula and the femur (see Figure 1B & 2A) (Marieb & Mallatt, 1996).

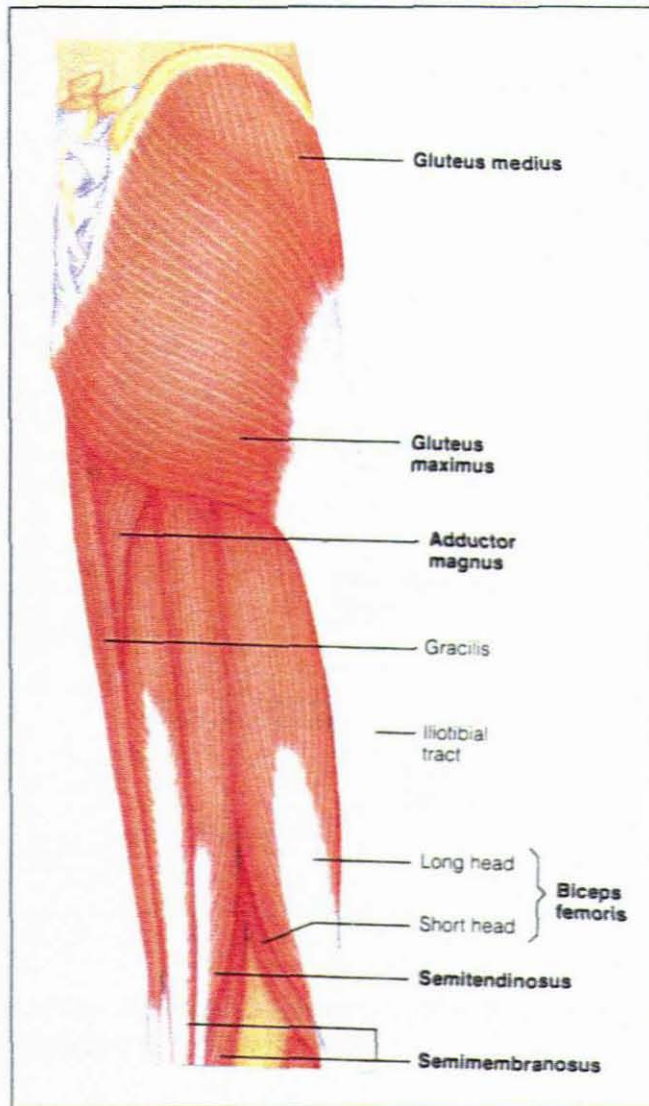
The knee joint is well supplied with synovial fluid from a synovial cavity, which lies under the patella and between the surfaces of the tibia and the femur. Commonly, this synovial cavity is called the "capsule of the knee". More than ten bursae are located in the knee, some of which are connected to the synovial cavity. Bursae are located where they can absorb shock or prevent friction. The knee can usually extend to 180 degrees or a straight line, although it is not uncommon for some knees to hyperextend up to ten degrees or more. When the knee is in full extension or 0 degrees of flexion, it can move from there to about 140 degrees of flexion. With the knee flexed 30 degrees or more, approximately 30 degrees of internal rotation and 45 degrees of external rotation can occur. Flexion is bending or increasing the angle of the knee characterized by the heel moving towards the buttocks and extension is the straightening or increasing of the angle between the femur and lower leg. Whereas external rotation is a rotary movement of the lower leg laterally away from the midline of the body and internal rotation is then movement of the lower leg towards the midline (Marieb & Mallatt, 1996).



**Figure 1. Anatomy of the Knee (A.) Quadriceps & Patella and (B.) Anterior view of the knee joint (Marieb & Mallatt, 1996).**

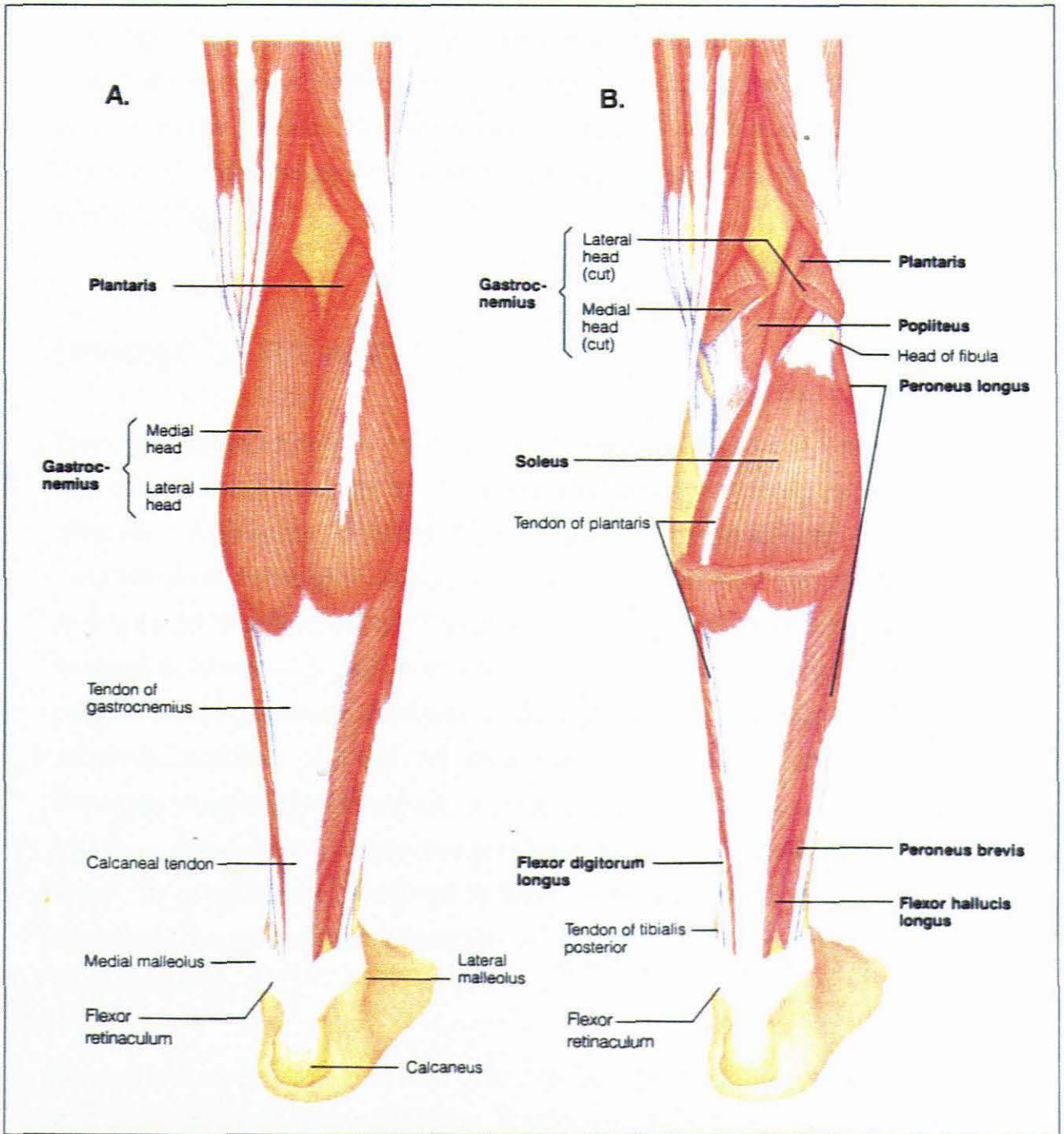


A.



B.

Figure 2. Anatomy of the Knee (A.) Lateral view of the knee joint and (B.) Hamstring muscles (Marieb & Mallatt, 1996).



**Figure 3. Anatomy of the Knee (A.) Gastrocnemius and (B.) Solius muscles (Marieb & Mallatt, 1996).**

The muscle group that extends the knee is known as the quadriceps and consists of four muscles: the rectus femoris, the vastus lateralis, the vastus intermedialis, and the vastus medialis. The hamstring muscle group is responsible for knee flexion and consists of three muscles: the semitendinosus, the semimembranosus, and the biceps femoris. The gastrocnemius muscle, which is part of the knee and ankle joint, also assists with knee flexion (see Figure 2B, 3A & B) (Marieb & Mallatt, 1996).

## **BRACING OF THE KNEES**

Bracing of knees lies within the field of knowledge known as orthotics, and braces and other devices designed to straighten, strengthen, or protect joints are called orthoses. Classically, orthoses fall into one of four categories: 1) supportive (stabilize joints for weight-bearing), 2) functional ("motorized," i.e., contain a coil or spring as, for example, in controlling foot drop), 3) corrective (attempt to correct a skeletal deformity, e.g., club foot), and 4) protective (prophylactic, attempting to prevent injury) (American Academy of Orthopedic Surgeons, 1985). Orthopedic surgeons commonly deal with the prevention and treatment of knee injuries. The American Academy of Orthopedic Surgeons (1985) placed existing knee braces into three categories: 1) functional (designed to provide stability for the unstable knee), 2) rehabilitative (designed to allow protected motion of injured or post-operative knees), and 3) prophylactic (designed to prevent or reduce the severity of knee injuries).

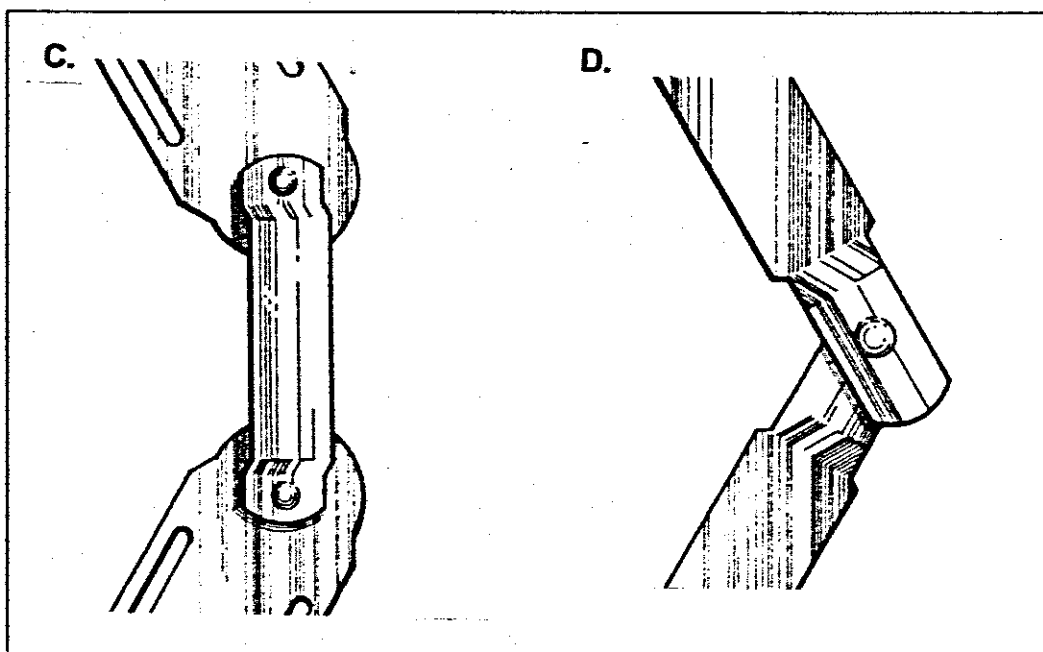
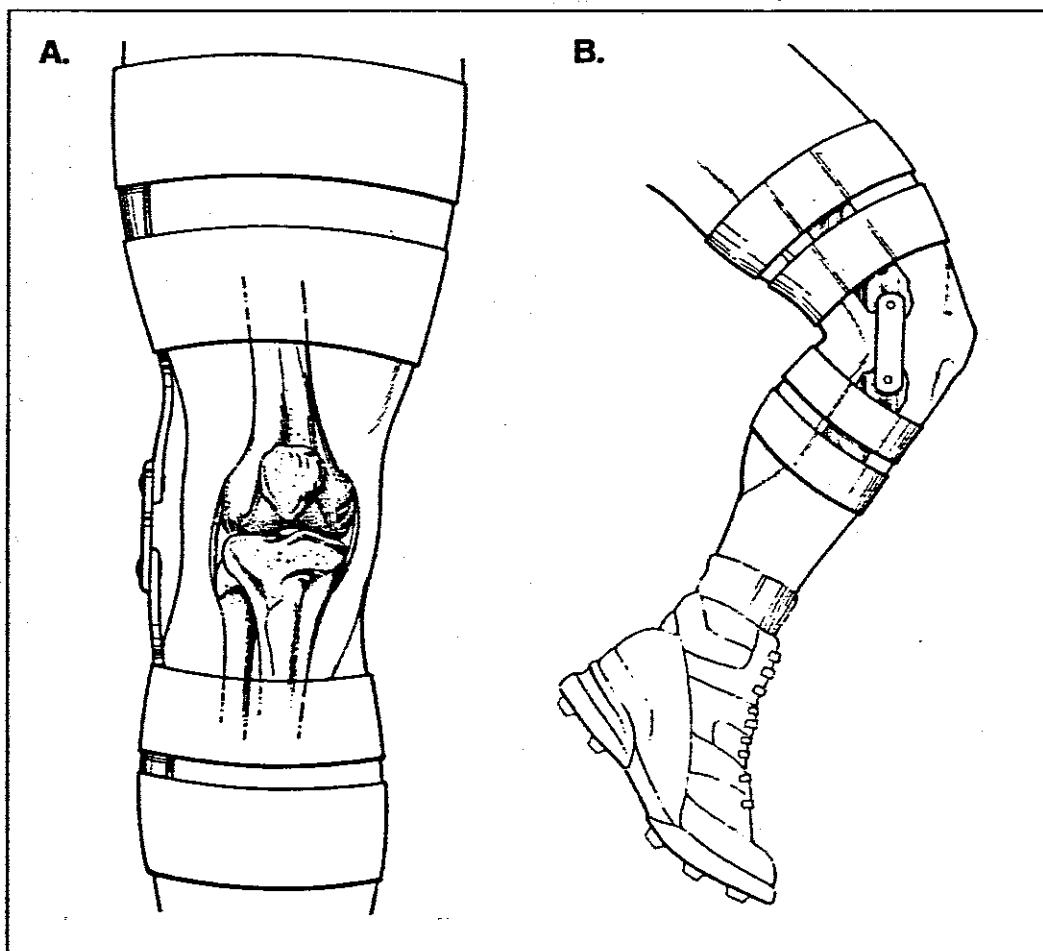
Bracing and taping have long been standard treatments for improving joint stability and allowing injured athletes to return to competition. However, in the last decade prophylactic bracing of the knee has gained tremendous popularity. Many team physicians and coaches have prescribed or required brace wearing by athletes in hopes of preventing injury and improving performance (Sforzo et al., 1989). Prophylactic knee braces are designed to prevent or reduce the severity of knee injuries by absorbing valgus producing forces (Millet et al., 1988). Trauma

resulting in valgus stress to the knee can create a medial joint opening, injure the medial collateral ligament, rupture the anterior cruciate ligament, rupture the posterior cruciate ligament, or tear a meniscus (Paulos et al., 1987). Valgus stress injuries can involve contact and non-contact stresses to the knee joint.

It is generally agreed that functional and rehabilitative knee braces accomplish, to a significant degree, the goals for which they are designed (Zeman, 1984; Goldberg, 1989). The question of whether or not so called protective or prophylactic bracing of the knees of competitive athletes is efficacious, however, is more difficult to answer. Opinion ranges from the belief that braces reduce the injury rate, to the belief that they not only do not work, but also may actually contribute to an increase in the injury rate.

Sport braces should be designed to give dynamic stability to sportsmen (Stephens, 1995). Although individual braces differ as to details, the basic designs are similar, consisting essentially of thigh and calf cuffs connected by hinged bars, which allow for flexion and extension of the knee (Figures 4A & B). They usually contain a single lateral bar that may have a single or double axis, i.e., single-hinged or double-hinged respectively (Figures 4C & D). Double-hinged braces have a two to three inch central piece with hinges at the distal femur and one at the proximal tibia. There may also be a medial bar. Although there has been experimentation with stops to limit hyperextension or to control rotational forces, all currently manufactured braces are designed simply to increase resistance to valgus stress upon impact and to direct impact loads away from the knee joint (Rovere & Bowen, 1986).

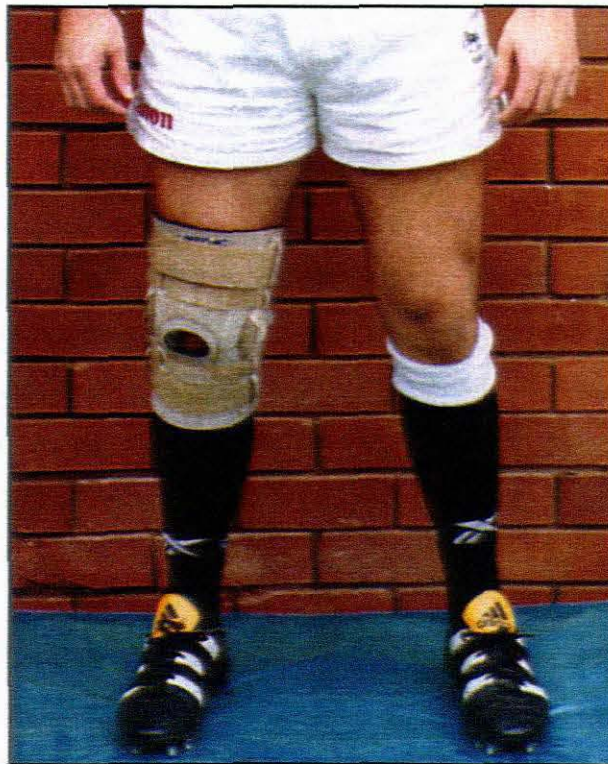
These braces that should support the knees by increasing stability, absorbing forces from all sides and thus prevent injuries (Deppen, 1994), were and still are very appealing to players and coaches, but are less appealing to those with the physical responsibility of finding the money to pay for these braces. These braces are expensive and the question of their effectiveness is also controversial.



**Figure 4. The basic design of Knee Braces (A.) Anterior view (B) Lateral view of Thigh and Calf cuffs (C) Double hinge and (D) Single hinge (Schneider and Fogel, 1991).**



A.



B.

**Figure 5.** Prophylactic Knee Brace used in present study (A.) Anterior view prior to application and (B) Anterior view after application.

While some studies have supported their use in restricted circumstances, others have actually suggested that knee braces may increase the rate of injury at the knee and ankle joint (Anderson et al., 1992). No final conclusion can be drawn from all the research done in the past. An important question to answer is, if you brace knees to prevent injury, do these prophylactic knee braces affect functional performances such as speed, agility, strength, proprioception and economy of running in any way.

In the present study, the possible influence/effect of prophylactic knee bracing (see Figure 5A & B) on speed, agility, strength, proprioception and economy of running of first league rugby players, was investigated.

## **PHYSICAL EFFECTS OF BRACING**

### **External compression**

When a knee brace is applied it compresses the soft tissues of the thigh and calf. This compression is called external compression and is pre-requisite for the knee brace to mechanically protect the knee joint, because to stabilize the knee the knee brace should fit and be stable around the knee. External compression creates forces that compress the tissues at a right angle. These forces are vectors and they have a magnitude and a direction, act on a well defined area and create an elevated hydrostatic pressure in the tissues beneath the straps of the brace (Aston, 1975; Jerosch, 1996; Styf, 1999).

The tensile forces of the straps used at brace application must be optimized to avoid abnormally increased intramuscular pressure. The tensile force used at tensioning the thigh strap is transformed to a larger cross sectional area compared to the leg strap (Styf, 1999). In general, the law of Laplace ( $p=T/r$ ) states that the hydrostatic pressure ( $p$ ) in a vessel is directly proportional to the tensile force ( $T$ ) and indirectly proportional to the radius ( $r$ ) of the vessel. Laplace's law has also been applied to the curvature of muscle fibres in biomechanical studies.

If the tensile force of the thigh strap ( $T_{thigh}$ ) and the leg strap ( $T_{leg}$ ) are kept equal, pressure in the thigh muscle increases less than in the lower leg muscles because the thigh has a larger radius ( $R$ ) of the cross sectional area than the lower leg ( $r$ ) (Styf, 1999).

External compression by the knee brace elevates the intramuscular pressure at rest (pressure in the muscle) in the calf, thigh muscles and the muscle relaxation pressure during exercise beneath the brace. Muscle relaxation pressure is the pressure in the relaxed muscle between contractions (Styf, 1999). The pressure increase correlates well with the tensile force of the straps at brace application (Styf, 1999). The intramuscular pressure increase may possibly be the reason for premature leg muscle fatigue that has been reported in other experimental studies on individuals using knee braces (Regalbuto et al., 1989). In a report by Styf (1990), knee bracing protected knee ligaments by reducing the strain values for anterior directed loading on the tibia. This was also true for the internal-external rotation of the tibia. Knee flexion from 0 degrees to 120 degrees is accompanied by 8 to 9 mm of femoral roll back and by 15 to 20 degrees of internal tibial rotation (Styf, 1999). Single, dual or multiple hinged braces that do not conform with the roll back and rotation of the joint will exert adverse mechanical effects (Styf, 1999).

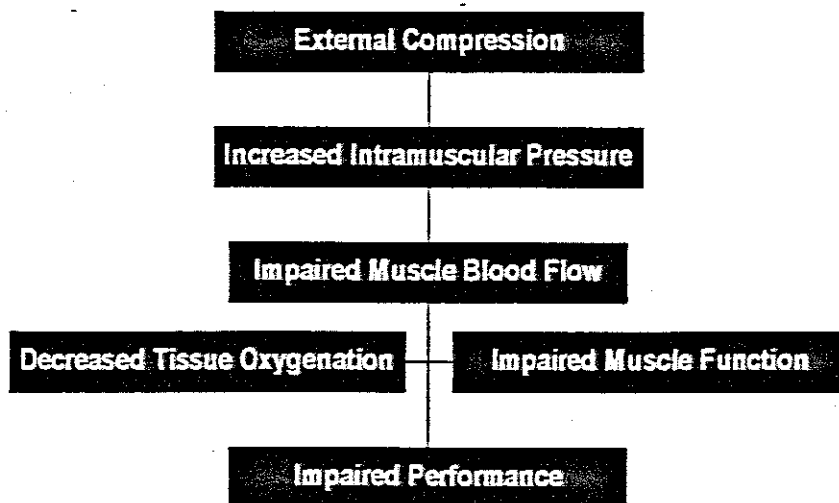
Regalbuto et al. (1989) concluded that forces and moments represented a mismatch between the motion of the brace and the motion of the knee. This could lead to adverse internal joint mechanics and discomfort. The forces were greatest along the long axis of the tibia and in an antero-posterior direction. How these thigh straps forces affect external compression has not been studied. However, in theory these forces could possibly increase the external compression of muscle tissue and thereby further elevate the intramuscular pressure.

According to Styf et al. (1994) muscle relaxation pressure in the anterior tibial muscle during exercise, increased from 7 to 25mm Hg in the unbraced leg due to an increased volume of up to 20% developed by muscle. Muscle relaxation pressure in the braced leg was significantly higher than in the unbraced leg at the start of exercise.

Intramuscular pressure increased from between 40 and 50mm Hg at the beginning of exercise to between 50 and 60mm Hg at the end of exercise (Lapidus, 1984; Lundin & Styf, 1998; Styf et al., 1994).

Another possible explanation for the higher pressure in the tibialis anterior muscle of the lower leg compared with the quadriceps muscle in the thigh is the lower compliance of the anterior compartment of the leg. Also, the intravascular hydrostatic blood columns are greater in the lower leg compared with the thigh in the standing or sitting individual. Finally, if applied firmly the thigh straps may create venous stasis of the leg, which may effect intramuscular pressure in the leg (Styf,1999).

It can be concluded that external compression exerted on the lower leg and thigh muscles with knee bracing increases intramuscular pressure at rest and muscle relaxation pressure during exercise to abnormal levels. Adjustment of strap tension to high settings does not decrease the sagittal motion of instable knee joints. However, such adjustment increases intramuscular pressure (Larson, 1984; Regalbuto et al., 1989). The result of the increased intramuscular pressure is a significantly faster muscle fatigue elicited in the braced leg compared with the unbraced leg (See Figure 6).



**Figure 6.** External compression elevates the intramuscular pressure beneath the thigh and leg straps. Local muscle bloodflow is impaired by increased intramuscular pressure, which leads to decreased oxygen tension and impaired muscle function (Styf, 1999).

## **Muscle Blood Flow**

During exercise that requires an oxygen uptake of 4.0 liters per minute, the muscle's oxygen uptake increases nearly 70 times, to approximately 11 ml per 100 g of muscle per minute (or a total of 3400 ml per minute). To accommodate this oxygen requirement, the local vascular bed channels large quantities of blood through the active tissues.

In rhythmic activities such as running, swimming, or cycling, the blood flow fluctuates; it decreases during the muscle's action phase and increases during the relaxation phase. This provides a "milking action" that facilitates blood flow through the muscles and helps propel the blood back to the heart. Complementing this pulsatile flow is the rapid dilatation of previously dormant capillaries. Consequently, between 200 and 500 capillaries delivering blood to each square millimeter of active muscle, with as many as four capillaries in direct contact with each fibre (McArdle et al., 1996; Jerosch, 1996).

Strenuous muscular activities present a somewhat different picture for muscle blood flow. When a muscle generates approximately 60% of its force generating capacity, local blood flow is occluded due to the elevated intramuscular pressure. When this occurs, energy for continued effort at near maximal force production is generated from the intramuscular high energy phosphates and through the anaerobic reaction of glycolysis (McArdle et al., 1996).

Muscle blood flow is impeded during muscle contraction. Arterial inflow to muscle occurs only during muscle relaxation between contractions (Folkow et al., 1970). Increased muscle relaxation pressure could therefore impair muscle blood flow and also cause premature muscle fatigue. Muscle relaxation pressure in the braced leg increased to values between 30 and 50mm Hg in healthy individuals (Styf, 1999). Increased intramuscular pressure at rest to levels between 30 and 50 mm Hg in healthy individuals impedes muscle blood flow (Aston, 1966; Matsen et al., 1979; Ogata & Whiteside, 1982). Patients with chronic compartment syndrome have impeded muscle blood flow and symptoms of ischaemic leg pain when

muscle relaxation pressure during exercise increases to values between 35 and 55mm Hg (Styf & Korner, 1986; Styf et al., 1987). Increased pressure to 50mm Hg caused by external compression reduces exercise performance by 40% because of premature muscle fatigue (Eiken & Bjurstedt, 1987). Jerosch et al. (1995) reported an increasing number of athletes who experienced major complaints and oedema of the lower leg, possibly by venous stasis, when wearing knee braces during athletic activity. Intramuscular pressure beneath the brace was 25mm Hg in the sitting athlete and about 50mm Hg when the athlete's running speed was 8 km · hr<sup>-1</sup>.

### Blood Lactate

During more intense submaximal exercise, the minute ventilation takes a sharp upswing and increases disproportionately in relation to oxygen uptake. As a result, the ventilatory equivalent for oxygen may reach values as high as 35–40 liters of air per liter of oxygen consumed. During steady-rate exercise, aerobic metabolism is matched by the energy requirements of the active muscles. Under these conditions, there is little or no accumulation of blood lactate. The term lactate threshold refers to the highest exercise level (intensity) or level of oxygen uptake that is not associated with an elevation in blood lactate concentration above the pre-exercise level. The region in which blood lactate shows a systematic increase equal or above a level of 4.0 mmol · L<sup>-1</sup> is termed the point of onset of blood accumulation or simply OBLA. This implies a maximum exercise intensity that a person can sustain for a prolonged period. In reality, this maximum stable lactate level is probably quite variable among individuals (McArdle et al., 1996). Almost all of the lactic acid generated in anaerobic metabolism is buffered to lactate in the blood by sodium bicarbonate in the following reaction:



Blood lactate plays a very important role in performance of any prolonged exercise or sport, and it is quite likely that rugby would fall into this category. The higher an individual's lactate levels in the particular exercise or sport the more difficult to perform to his/her best. If lactate levels were to be influenced with the application of prophylactic knee bracing, it would have an effect on performance. Therefore it would be important to evaluate lactate levels with and without the application of prophylactic bracing.

Zettlerland et al. (1986) performed different tests such as knee extension, stair run tests and bicycle ergometer tests. The study found that blood lactate levels were markedly higher during the 15-minute bicycle ergometer exercise with prophylactic knee bracing, despite the identical workloads. This suggests that, with all other variables equal, the same prophylactic bracing significantly increased lactate levels. This points to a negative effect of prophylactic knee bracing on performance (Zettlerland et al., 1986).

These results demonstrate that benefits of prophylactic bracing in terms of knee support come at the expense of impaired maximal performance due to increased lactate levels, at least for young male athletes (Houston & Goemans, 1982). Houston & Goemans (1982) also reported on muscle performance of athletes with and without prophylactic knee bracing. They showed a lactate concentration that was 41% higher in subjects with prophylactic bracing and a significantly decreased maximal torque output. Though this study used custom prophylactic knee braces for subjects with anterior cruciate ligament (ACL) deficiency, similar impedance of performance could be postulated in players wearing prophylactic lateral braces (see Figure 5).

### **Electromyography (EMG) activity**

Electromyography signal provides a convenient means for studying the intricacies of neuromuscular physiology during various types of muscle action. Both the quality and quantity of the electrical activity generated in muscle influence the

EMG. During isometric actions, for example, the EMG signal is proportional to the muscle force generated. In dynamic actions, the situation is more complex because of changing force torque characteristics during different phases of the range of motion. In rapid, ballistic-type movements, the EMG is characterized by alternating bursts of electrical activity in the agonist and antagonist muscles. The EMG pattern in this situation is triphasic in nature: the first burst of electrical activity occurs in the agonist, followed by signals from the antagonist (during the time the agonist is electrically silent), and then another burst of activity in the agonist. Each phase of the EMG is associated with certain aspects of the muscle action. The first burst of the agonist creates the propulsive force that sets the limb in motion, the antagonist's first burst stops the limb, and the agonist's second burst is required for the final positioning of the limb (McArdle et al., 1996).

Nemeth et al. (1997) conducted an interesting study on Electromyographic (EMG) activity in expert downhill skiers using prophylactic knee braces after anterior cruciate ligament injuries that presented some useful insights for the present study. Subjects were tested without a brace and increased EMG levels were shown through the complete cycle (beginning-middle-end) of the upward and downward ski run. When the brace was worn on the injured leg, EMG activity during the mid-phase ski run of the injured leg was increased, but the activity in the uninjured leg decreased (Nemeth et al., 1997). So, it can be tentatively said that bracing of the injured leg influenced activity of the uninjured leg.

It was interesting to note that all six subjects felt safer and more stabilized wearing the prophylactic brace during competition. This study as well as one performed by Osternig and Robertson (1993) highlighted an important aspect of prophylactic knee bracing. If the brace was worn on an unstable knee, a positive effect was experienced both physiologically and psychologically. However, if a brace was worn on a stable knee, a lower EMG activity was experienced in both the biceps femoris and vastus medialis muscles, perhaps explaining higher injury rates experienced by college football players wearing knee braces.

# EFFECTS OF BRACING ON PERFORMANCE

## SPEED

### Introduction

In everyday language the terms speed and velocity are often used as synonyms, while the scientific meanings are different. Speed is an indication of how quickly motion takes place, i.e. how far an object moves in an specific time. The speedometer of a car, for example, measures how fast its motion is taking place. Speed is therefore the rate at which a distance is traversed or the rate that the body is propelled between two points. The word "rate" implies that something occurs in unit time, i.e. per hour or per second. The speedometer, however, gives no indication of the direction in which the motion takes place. Speed is therefore a scalar, which can be calculated from the relationship:

$$\text{Speed} = \frac{\text{distance traversed}}{\text{elapsed time}}$$

In everyday life speed is measured in kilometers per hour ( $\text{km} \cdot \text{hr}^{-1}$ ) e.g. motorcars and aircrafts, but in purely scientific work, however, speed must be given in the SI unit which is meters per second ( $\text{m} \cdot \text{s}^{-1}$ ) (Johnson & Nelson, 1986). In the present study speed relates to running speed or the speed of movement of parts of the body, for example the speed of leg movement is important for running speed.

Fast movement and quick reactions are prized qualities in sport. Coaches and the media frequently praise certain players or an entire team for their quickness. For example the world champions, the Australian rugby side are the talking point of the rugby world because of the quickness of all the players in the team. In most sports, the player who is extremely fast poses a constant threat of breaking away for that long run (Mannings, 1998). In baseball the fast runner causes hurried throws and adjustments in pitching and defensive strategy; the full court press is a potent weapon in basketball if a team has the speed to make it effective; and in

rugby speed is important in all aspects of the game. For example in defense the player should be able to tackle the opponents and be ready for their next attack, and in attack to out-sprint the opponents and not to be tackled, making speed an essential physical component of sport and rugby (Johnson et al., 1986). In rugby speed and quickness means running speed of the player, how quickly can he/she run from point A to point B. And this does not necessarily mean the fastest hundred-meter runner will be the fastest runner on the rugby field. Running speed in rugby is mostly associated with short sprints, the most effective rugby player is the player that is extremely quick over the first two to five meters and then maintaining that speed for at least 20-25 meters. For example, Breyton Paulse, the South African wing, is very quick over the initial two to five meters and that creates the opportunity for the longer sprints and try scoring opportunities. But when Paulse's speed was compared to his team players' speed over hundred meters, three to four team players performed better. Thus running speed in general is important in rugby but the initial speed over shorter distances (2-25 meters) is even more important.

Speed is much more complex than it might appear, speed of movement entails much more than mere running speed (Johnson & Nelson, 1986; Prentice, 1986). The speed with which a wrestler executes a reversal, the quickness of a boxer's jab, the explosive spring of the shot putter's move across the throwing circle, and the graceful swiftness of the swimmer and skater are but a few of the many different kinds of movement speeds that are involved in physical performance (Johnson & Nelson, 1986). But for rugby, running speed and the cadence of limbs are important to create scoring opportunities for the team and if knee bracing interferes with running speed then it interferes with the performance of rugby players.

### **Bracing and Speed**

If one investigates the influence of prophylactic knee bracing on speed performance it is obviously important to know which structures around the knee are

most likely to be influenced by the brace and thus influence speed. The anatomy of the knee illustrates the ligaments (medial, lateral collateral ligaments and the anterior and posterior cruciate ligaments) and muscles (hamstring, quadriceps and calf muscles) around the knee to stabilize the joint. For these structures to protect and stabilize the joint, they have to function without any interference internally or externally. For running speed all the above structures would be important because they influence the function of the knee. The quadriceps muscles extend and lift the knee, the hamstring muscles flex the knee and the calf muscles flex and extend the ankle, all these muscles are important when walking or running. The ligaments support the knee joint and keep every part intact to function optimally. These actions of the muscles and ligaments ensure correct alignment of the leg that allows man to walk and run, the stronger the muscles the better our performance in walking and running. However, not only the strength of these muscles are important to running, the degrees of flexion and extension, the reaction times of these muscles (voluntary or spinal) play an important role in running speed.

Thus any interference the brace has upon these ligaments and muscles will probably have some affect on the speed performance, therefore it is important to investigate all possible effects of the brace on these structures and actions. The main reason for wearing a prophylactic brace is to increase stability and to protect the ligaments against lateral and medial forces, therefore the effect of the brace on the muscles and ligaments must be important to speed performance. Thus if strength, reaction time of the muscles (hamstrings, quadriceps and calf), flexion and extension or even ground action reaction forces are influenced by bracing then the speed of the movement should also be presumably influenced with prophylactic bracing.

The kinematics of the knee with prophylactic bracing was derived through testing with electrogoniometers and video cameras. Measurements by means of an electrogoniometer taken during straight ahead running, while wearing a prophylactic knee brace, revealed that knee flexion was decreased by 11% to 22%, external rotation by 22%, internal rotation by 33%, and varus-valgus by 24% (Knutzen et al., 1983). Flexion was further influenced by bracing as Wojtys et al.

(1996) found that most prophylactic braces appear to consistently slow hamstring muscle reaction times at voluntary level. Voluntary activity is controlled by the brain, for example, assume the right leg is in the anatomical position and the desired movement is to lift the right knee as high as possible, the brain has to send the message for the action to occur. The voluntary reaction time is the time between the player's decision to lift the knee or run and the actual lifting of the knee, or run itself, or the decision to accelerate to the actual acceleration (de Vries, 1974). The slowed muscle reaction time produced with bracing is a cause for concern, especially in competitive athletes, because if flexion is reduced and slowed down the lifting of the leg is slowed down and thus speed would be slowed down. Quadriceps muscles' voluntary reaction times in general were also slowed with prophylactic knee bracing, and significant differences in times of the medial and lateral quadriceps muscles were found (Wojtys et al., 1996). Voluntary reaction time is the time between the decision to move and the initial movement, for example in running the time between the thought and that initial lift of the leg is voluntary reaction time. Thus the pushing of the leg forward in the running stride is also slowed down, and will decrease speed even more.

But bracing appears to improve spinal reflex time in response to anterior tibial translation to some extent and prophylactic bracing produced improvement in the quadriceps muscles' spinal reaction time (Wojtys et al., 1996). Spinal reaction or reflex is mostly defined as an involuntary motor response to a given stimulus. An illustration is the automatic, unthinking response to touching a hot surface. For example, this factor partly determines how successful a basketball player can be on defense when the offensive player makes his move. The difference between a slow and a fast reaction (possibly 0.1 second) can result in the offensive players getting a lead of several feet simply because the defense player must react to the offensive move. The medial quadriceps spinal reflex responses were significantly faster with prophylactic bracing and the lateral quadriceps muscle also performed significantly better with prophylactic brace application. The spinal reflex in the lateral hamstring muscle was improved with the application of prophylactic bracing resulting in significantly faster response times. The medial hamstring muscle response time showed no significant difference (Wojtys et al., 1996). The

voluntary and the intermediate response times are important for speed in rugby players where spinal reflex is more important for the prevention of injuries. Thus, if the voluntary and intermediate responses are slowed down then presumably speed would be slowed or decreased with prophylactic bracing.

Another interesting study was done by Knutzen et al. (1987) on force platform parameters and the results obtained from the study contribute unique information to the body of knowledge concerning the effects of prophylactic knee bracing on ground reaction force parameters. Selected force parameters were shown to vary significantly as a result of wearing a prophylactic knee brace. Most of the changes in the ground reaction forces occurred during the impact phase of the support period where the brace conditions were shown to produce greater impact forces, coupled with a time delay in the achievement of the maximum impact force. This alteration in force generation has previously been shown to be associated with changes in running speed. Normally the running speed was effected negatively due to an unnatural running style developed because of the unbalanced reaction forces. The change in these forces with brace application strongly suggests that the brace is creating an alteration in the lower extremity function. The conclusion is that application of knee orthosis significantly alters the kinematic characteristics of the ground reaction force data and therefore would hamper running speed performance (Knutzen et al., 1987).

It would appear, therefore, that the altered kinematic characteristics of the ground reaction force had the effect of decreased voluntary and intermediate reaction times in the hamstring, quadriceps and gastrocnemius muscles with prophylactic brace application. With this in mind together with the fact that these muscles are the prime movers, one can conclude in saying that running speed in general would decrease significantly with the application of a prophylactic brace (Wojtys et al., 1996).

The above conclusion was not supported in a previous study done by Stephens (1995) who performed a dynamic test of the effects of prophylactic knee bracing on speed in basketball players. No significant differences in the running test times

were found. Speed as such was not significantly affected with the prophylactic knee bracing for non-injured basketball players. It was suggested that leg dominance could play an important role/part in the possible negative/positive effects of the prophylactic knee brace on people. But it was also found that in injured athletes, where the injured quadriceps torque did not reach 80% of that of the uninjured quadriceps, the brace caused an increase in straight line running speed (Stephens, 1995).

But in injured athletes where the injured quadriceps torque reached 90% of the uninjured quadriceps torque, wearing a brace did not influence performance on the test (Stephens, 1995).

From a perusal of the literature one could make the conclusion that prophylactic bracing affects many important factors involved in running speed, but researchers do not all agree and results are controversial. More research is needed to resolve the controversy around the effects of prophylactic bracing on running speed.

## **STRENGTH**

### **Introduction**

Strength is defined generally as the muscular force exerted against movable and immovable objects, and is best measured by tests that require one maximum effort for a given movement or position (Davies, 1987). The two types of muscular contractions most frequently measured are dynamic (isotonic) and static (isometric) contractions. In isotonic contraction, muscular force moves an object of resistance and the contraction takes place over a range of movement. In isometric contraction, muscular force is exerted over a period (usually 6 to 10 seconds) without movement of the resisting object or the body joints involved (Davies, 1987). Isotonic contractions include isokinetic exercise and testing. Isokinetic training and testing is attractive because it has a fixed speed with a variable resistance that is totally accommodating to the individual throughout the range of motion (Davies,

1987). Therefore the velocity is constant at a pre-selected dynamic rate where the resistance varies to exactly match the force applied at every point in the range of movement.

Thus the muscles can be overloaded through a full range of movement and at a variety of muscle shortening velocities (Davies, 1987). The question is, does bracing have any affect on these muscle contractions, and more specifically on isokinetic leg strength performance. Van Heerden (1996) elaborates upon the essential goals of isokinetic dynamometer usage and identifies the importance of assessment of muscular function to identify asymmetry (bilateral or ipsilateral) or weakness. Such data, according to the same author, has relevance for three distinct reasons;

- a) the prevention of injuries due to muscle imbalance;
- b) ascertaining specific goals for resistance training programs; and
- c) providing guidelines for orthopedic rehabilitation and for resuming sports participation after injury.

Therefore one might tentatively suggest that the use of isokinetic testing is the most appealing method in determining the influence of a prophylactic bracing on strength performance.

The most important stabilizers of the knee are the quadriceps, hamstrings, and the gastrocnemius muscles, which cross the joint. Studies by Goldfuss et al. (1973); Markolf et al. (1984); and Walker et al. (1988) have demonstrated the powerful dynamic effect of these muscles, which can decrease tibial translations and rotations while stiffening the knee joint. This dynamic joint compression system, which protects the knee ligaments, should be preserved or enhanced whenever possible (Markolf et al., 1984; Goldfuss et al., 1973; Walker et al., 1974). In fact, this protective joint compression effect should be one of the training and conditioning goals for athletes in rigorous contact sports. Unfortunately, because this internal protection system is frequently deficient or altered by injury to the knee joint, external support has become quite popular (Wojtys et al., 1996).

## **Bracing and Strength**

Studies suggest that increased performance does occur with brace usage, especially in the patient who has instability of the knee and quadriceps weakness (Johnston & Paulos, 1991). Contrary to those studies are a few which note some negative effects on performance, especially during use of the more rigid and heavy types of braces. This was particularly noted in metabolic parameters such as oxygen consumption and in muscle performance like endurance strength and velocity of contraction (Johnston & Paulos, 1991).

The isokinetic dynamometer has been shown to be a reliable device for studying contractile characteristics of intact human muscles over a range of controlled velocities (Houston & Goemans, 1982). Peak torque values during dynamic contractions in the Cybex apparatus were significantly lower when subjects used prophylactic bracing. It also revealed that with an increase of velocity the differences in torque between brace and no brace conditions were larger. Marked strength performance reductions with bracing during knee extension and stair run tests, involving both knee extension and flexion, suggest that braces had a damping or breaking effect, absorbing force output by muscles about the knee joint (Houston & Goemans, 1982). Thus the force output of the muscles is interfered with, with prophylactic bracing, and the force is decreased.

Stephens (1995) stated some negative effects bracing could have on injured athletes, for example the brace causes negative psychological effects on the injured subjects, constantly reminding them of the injury, thus decreasing performance. In support of this latter finding, Sforzo et al. (1989) illustrated an inhibitory effect on strength performance of prophylactic knee brace wearing upon asymptomatic female lacrosse players during selected laboratory tests. Vailas & Pink. (1993) who studied prophylactic bracing and noted marginal reduction of strength supported these results. They also showed that prophylactic bracing could reduce the range of movement of hip abduction adduction. This was not supported by Lysholm et al. (1984) who reported on isokinetic strength tests done with a Cybex II dynamometer.

The patients injured leg was tested with and without a brace, and the normal leg was tested as control on the same occasion. The mean isokinetic peak torque in the injured leg without bracing was 138 Newton meters (Nm) compared to 167 Nm in the control leg (Lysholm et al., 1984). With the brace, the peak strength value of the injured leg increased to 156.7 Nm. Twenty-one patients (88%) improved their performance in the strength test with bracing of the injured leg by a mean of 13.7 Nm (9.1%) of their result without the brace. Fourteen of the patients (58%) performed at 95% or more of their control leg with the brace on compared to six (25%) without the brace (Lysholm et al., 1984). No statistical differences were found comparing patients only with pain to those with pain in combination with a feeling of patella instability (Lysholm et al., 1984).

However, no such affect was evident in healthy male football players (Sforzo et al., 1989). In support of this latter finding, Highgenboten et al. (1991) also reported no significant effect of bracing the knee upon isokinetic dynamometry in football players. This taken in conjunction with previous research leads us to suggest that wearing a prophylactic knee brace does not significantly affect strength performance in male subjects with stable knee function.

A recent study concerning the prophylactic use of knee braces give rise to serious doubts regarding their injury prevention effect. In addition, in sports practice it is generally assumed that when a brace is worn for preventive purposes, the joint stability relies less on muscular function. This will lead to muscular atrophy and consequently decreased performance (Veldhuizen et al., 1991). Supportive of this view are the findings of Houston & Goemans. (1996) and Zetterlund et al. (1986) who concluded that knee bracing affects muscle strength and aerobic capacity negatively. Thus, decreased muscular strength, and lower leg stability may counterbalance the gain in passive stability. However, it is not known to what extent preventive bracing does induce muscular atrophy and decrease performance.

One notable trend seen in isokinetic testing was that prophylactic brace application decreases hamstring muscle performance. With the application each of the four

hamstring muscle test variables showed decreased performance: peak torque/body weight; average work/body weight; average power, and work fatigue (Wojtys et al., 1996). In addition, the torque produced by the hamstring muscle was inhibited by prophylactic bracing by an average of 5.8% (range, 0.2% to 10.7%) (Wojtys et al., 1996). Important to know is that muscle contraction pressure is a measure of the force output from the muscle (Styf et al., 1995), and is increased in braced legs. However, the increased pressure is not a measure of increased force generation but rather a result of external compression.

The mean maximal force generation during isokinetic knee extension in the braced leg was found to be decreased (Houston & Goemans, 1982). Supportive of this view are findings of Wojtys et al. (1996) who concluded that prophylactic knee bracing significantly reduced the amount of force generated by an average of 2.4% in the quadriceps muscle (range, 0.0% to 5.7%). Houston and Goemans (1982) who showed that in their study the mean maximal force output during isokinetic knee extensions with prophylactic bracing decreased by 12 to 30% supported this latter finding. They also found that the difference between the braced and unbraced conditions increased contraction velocity. The maximal velocity of knee extension was 20% higher when the subjects did not wear the brace (Houston & Goemans, 1982).

In terms of average work/body weight, there was no significant change in the quadriceps muscle performance with brace application, but bracing produced significant reduction in hamstring muscle performance. Average power measurements showed no significant change in quadriceps muscle function with bracing, but a significant decrease in the hamstring muscle power with bracing was found (Wojtys et al., 1996).

It would appear from the above-mentioned studies by different researchers, that they all have different opinions on the effect of knee braces on muscle strength performance. This illustrates that views on the effect of prophylactic knee bracing on strength performance are controversial.

# **PROPRIOCEPTION**

## **Introduction**

Proprioception is defined as an awareness of joint position in space as sensed by the central nervous system (Swash, 1986). It incorporates joint sensation and spatial orientation (Lephart et al., 1997; Borsa et al., 1997). The central nervous system receives information from specialized nerve endings, or mechanoreceptors, that are located in the skin, muscle, tendon, joint capsule, and ligaments. Together with vestibular and visual input, mechanoreceptors provide the central nervous system with information about limb position (Baker et al., 1989).

Muscle contraction is important to prevent injury. It has been shown that individuals who are injured were unable to activate their leg muscles fast enough to provide a significant protective effect (Paulos et al., 1987). Furthermore, the voluntary reaction time of muscle contraction of a braced leg was too slow to protect the knee from injury (Horsch, 1975; Pope et al., 1979; Clark, 1985). For protection the muscles and brace should work together to eliminate or to absorb the medial and lateral forces thrown at them in contact sports, but if the reaction time of the muscles are decreased with bracing, they could react too slowly to protect the leg against these forces.

## **Bracing and Proprioception**

Literature allows one to speculate as to the mechanism of the improved knee proprioception seen with bandage and brace application. Certainly, afferent receptors in the skin, muscle, ACL, and joint capsule exist, and these contribute to proprioceptive input (Guyton, 1986; Beynnon, 1999). Major position sense receptors in the joint capsule and ligaments, such as free nerve endings and golgi tendon organ stretch receptors, would likely be too deep to be affected significantly with bracing and elastic bandaging. The bandage and the brace certainly stimulate the skin during joint motion and also increase the pressure on the underlying

musculature and joint capsule (Guyton, 1986; Corrigan, 1992). Therefore, the most plausible receptors to be involved are the rapidly adapting superficial receptors in the skin and layers beneath muscle such as free nerve endings, hair organs, and Merkels discs. These receptors react strongly to new stimuli, such as movement of the brace on the skin, and adapt quickly once the motion becomes monotonous (Guyton, 1986). Receptors in deeper skin layers and joint capsule, like flowerspray organ of Ruffini, could also receive input from the pressure of the brace (Guyton, 1986). These receptors are tonic, slowly adapting receptors and can provide dynamic and static phase proprioceptive input that would be enhanced with bracing and bandaging, but to a lesser degree than the more superficial receptors (Guyton, 1986).

Ferrell. (1985) observed gait abnormalities induced in cats after the injection of local anaesthetic into the knee joint, and more recently, Marshall et al. (1993) have shown that gait changes are evident as a result of excessive fluid in otherwise healthy knee joints. Interesting, Ferrell et al. (1987) also showed that excessive fluid in normal knee joints can lead to improved position sense. These findings were related to increase in capsular tension, which was thought to enhance the mechanoreceptors in the joint capsule. This supports the concept that bracing may improve the proprioceptive ability. Given the reported deficiencies of braces when subjected to mechanical impact tests, it may be that alterations in proprioception may be responsible for the improvement in knee injury statistics reported in some epidemiological studies (McNair et al., 1996).

Perlau et al. (1995) showed that before the application of the elastic bandage the range of inaccuracy, which is the range of the mistake in joint sensation, and orientation for a group of participants was from zero degrees to thirteen degrees with 50% of the values between two degrees and five degrees. These values represented the inherent proprioceptive ability of the participants for the tested knee. After application of the elastic bandage the inaccuracy range was from 0 degrees to eleven degrees with 50% of the values between one degree and four degrees. This change represented a mean decrease in inaccuracy of one degree,

equivalent to a 25% improvement. The researchers also stated that better improvements were expected with the more rigid prophylactic brace. Perla et al. (1995) also found that a definite trend was evident, the change in inaccuracy readings depended on the degree of inaccuracy present before application of the elastic bandage. Namely, if the mean inaccuracy was five degrees or more, the elastic bandage resulted in a marked improvement in proprioception (mean decrease in inaccuracy of four degrees or a 66% improvement), which was lost after removal of the bandage. However, if the mean inaccuracy demonstrated before bandage application was less than five degrees, the bandage had no demonstrable positive effect. In the case of bracing normal knees the sleeve type brace also acts as a prophylactic brace to protect the knee against injury but the normal prophylactic brace improves tracking ability even more. These results were not supported by Barrett et al. (1991) who found that elastic bandages and bracing do not show any benefit to the unaffected population of knees used in their study. But researchers do believe that the normal population may show a proprioceptive benefit from elastic bandages and bracing if they are tested under different circumstances and examined critically (Perla et al., 1995).

Helfet et al. (1983) performed a study on basketball players in a search of the effects of prophylactic knee bracing on their proprioception performance. The "braking effect" theory was developed. Tests used were very similar to movements that take place in a match, thus simulating/mimicking the physiological demands placed on the players during a match. This braking effect theory suggests that the touching of the brace on the knee may increase proprioception and gait biomechanics. It is important though to look at the work by Cawley et al. (1991), which suggests that this effect could be different for various types of movements and, very importantly, different designs and materials of braces. McNair et al. (1996), have compared braced and unbraced conditions and observed differences in electromyographic activity and joint kinematics during functional tasks. Based on these findings, it has been suggested that proprioception may be affected with prophylactic knee bracing.

As stated previously proprioception has been defined as the awareness of joint position in space. This awareness is important in the theory of action reaction forces and thus protection against injuries on the sport field. For the muscles to protect the body against these forces they must know what is happening to the body at that point in time. Reaction times are very important because they are the mechanism that reacts to that initial force that could harm the body (Grisogono, 1985). Thus the effect of the prophylactic brace on the reaction times is important for proprioception, which is the awareness mechanism of the body. A study done by Wojtys et al. (1996) stated that prophylactic bracing appear to consistently slow hamstring, quadriceps and gastrocnemius muscle reaction times at voluntary level with significant difference in time for the medial and lateral quadriceps and hamstring muscles.

Similar results were found with the intermediate reaction responses for the quadriceps, hamstring and gastrocnemius muscles. The slowed muscle reaction time produced with prophylactic bracing is a cause for concern, especially in competitive, contact sport athletes because if an abnormal force is applied to the body the reaction of the muscles might be too slow to react and serious injury might occur to the knee.

Biomechanical studies examining impacts on cadavers/surrogates have shown that prophylactic bracing is effective only during impacts in which the associated forces are much lower than those experienced in the sporting environment. McNair et al. (1996), however, examining joint kinematics and muscle activity, have compared braced and unbraced conditions and observed differences in electromyographic activity and joint kinematics during functional tasks.

To conclude, for the uninjured population tested, prophylactic bracing significantly improved knee joint proprioception during the duration of its use. The positive effect was maintained for 60 to 90 minutes of bandage wear and was immediately lost after removal of the bandage with no learning curve demonstrated. The question of whether this same positive effect would be seen after strenuous activity, where other variables are introduced, requires further study.

## **Bracing Affected Knees**

There is little information examining proprioception and prophylactic bracing in injured athletes. But Barrett et al. (1991) observed a group of subjects with knee arthritis and found that a person's ability to match knee joint position in flexion could be enhanced with an elastic bandage or a prophylactic brace placed firmly about the joint. These results are similar to those of Perla et al. (1995) who showed that elastic bandaging and prophylactic bracing can improve position sense in subjects with arthritic knees.

Many patients and physicians believe that elastic bandages, wrapped around a previously injured or weak joint, give the bandage wearer an increased sense of security during physical activity (Perla et al., 1995). Since these bandages are mechanically weak, the prophylactic braces came to the foreground to improve sense of security but also the sense of stability and thus protect the knee from injury. Perla et al. (1995) hypothesized that the main beneficial effect of elastic bandages and bracing is related to their enhancement of joint proprioception for the wearer. This was supported in Barrett et al. (1991) whose study found that bracing and bandages do improve proprioception in osteoarthritic and replaced knees.

## **AGILITY**

### **Introduction**

Agility is defined as the physical ability that enables rapid and precise change of body position and direction. Agility is important in many sports activities, as exemplified by rugby players in today's professional era (Johnson & Nelson, 1986). Agility tests can be used in several ways: 1) As an element for predicting potential in different sport activities 2) As a measure for determining achievement, progress, and grades when agility is a specific objective in the training unit 3) As a

factor in motor ability tests 4) As a means to evaluate the effectiveness of a specific unit of instruction on improvement in agility. For example, if agility is measured before and after a specific training session or technique, the results can then be compared to determine if the session was efficient in improving their agility performance.

If agility is compared with speed activity it is obvious that to be agile a certain amount of speed, especially speed as it relates to movements of body parts, are essential. Running speed and agility do not necessarily correlate, but leg speed is important for sprinting, and would also be important for agility (Johnson & Nelson, 1986). Therefore the effect of the brace on speed and this leg speed is as important as the effect of bracing on agility to evaluate performance of agility.

### **Bracing and Agility**

Perry (1989) focused on the functional demands imposed by running and cutting, the consequences of cruciate ligament tears, and the therapeutic effectiveness of prophylactic knee bracing. This research article presents useful information regarding running and cutting movements found during speed and agility tests. Both functional and prophylactic braces on normal and injured (ACL) athletes were used. Fifteen athletes were tested for their ability to perform straight and cross cuts both with and without a prophylactic brace. Results on the cutting tests showed improved function with the brace. Total force for the straight cut, cross cut and cutting index were greater with the brace than with the knee unprotected.

Muscle activation data indicates that specific knee and ankle flexors and extensor muscles, such as vastus lateralis, vastus medialis, bicep femoris, semimembranosus, gastrocnemius, and tibialis anterior muscles were highly sensitive to prophylactic knee bracing. Osternig & Robertson. (1993) reported that 67% to 83% of all, braced to non-braced comparisons for these muscles produced significant differences in EMG activity during side cutting activities. Of these, 73% resulted in significant reduction in activity. Branch et al. (1989) studied

prophylactic bracing on ACL-deficient and normal subjects, and reported 12% to 15% decrease in quadriceps and medial and lateral hamstring activity when compared with nonbraced conditions during the side cutting maneuver. If the activity in the hamstring, quadriceps, gastrocnemius and the tibialis anterior muscles decrease in cutting activities surely the performance in agility would also decrease. In support of this latter finding, Teitz et al. (1987) also reported an increase in knee injuries among the football players who wore prophylactic braces compared with players used as controls. They suggested that decreased agility and potential decrease in mobility, resulting from brace wear, may have predisposed the brace-wearing athletes to higher injury rates. But if one compares school-boy rugby with Super 12 rugby, Mannings (1998) stated that at Super 12 level there are more injuries than at school boy level. And according to common belief the less agile and less mobile players show lower injury rates especially to the knee. This is explained by the fact that less mobile and agile (ability) players are not exposed to high injury situations such as the more agile players.

Because the lower extremity muscles are the most important stabilizers of the knee, it is also important to consider the effects of bracing on the lower extremity muscle performance, if one considers evaluating agility performance. Branch et al. (1989) used a surface electrode technique to investigate muscle function in ten patients with isolated ACL tears, and five uninjured subjects. They evaluated the effect of prophylactic bracing during a side-step cut maneuver. They were interested in determining whether muscle firing, amplitude, timing, or duration changed with prophylactic brace application. Branch et al. (1989) demonstrated that ACL-deficient patients without braces showed a significant increase in hamstring muscle activity but decreased activity in their quadriceps muscles during side cutting testing. When wearing a brace, the patient with an ACL-deficient knee showed a further reduction in the degree of quadriceps muscle activity, along with a decrease in hamstring muscle activity. But he also found that muscle timing (pattern of muscle use) during cutting maneuvers did not change between braced and unbraced tests, during swing or stance phases of running. Because the pattern of muscle activation did not change with brace application, the investigators

concluded that prophylactic bracing did not augment agility performance. The decrease in muscle activity reported by Branch et al. (1989) can be explained in two ways. The brace may have stabilized the knee and subsequently lessened the need for muscle control, or the brace may have directly inhibited the performance of the muscles crossing the knee joint.

As stated previously, if activity in the quadriceps, hamstrings, gastrocnemius and tibialis anterior decrease in side cutting activities as well as the activity in the lower leg muscles, the performance in agility surely would also decrease. More research is needed to resolve the controversy around the effects of prophylactic bracing on agility performance.

## **ECONOMY OF RUNNING**

### **Introduction**

A minimum level of energy is required to sustain the body's vital functions in the waking state. This energy requirement is called the basal metabolic rate, or BMR. In most instances, the so called basal values measured under controlled laboratory conditions are only slightly lower than values for resting metabolic rate (RMR) measured under less strict conditions. For our purposes, RMR refers to the sum of the metabolic processes of the active cell mass, related to the maintenance of the normal body functions and regulatory balance during rest. But physical activity has a profound effect on human energy cost or expenditure. World-class athletes, for example, nearly double their daily caloric outputs as a result of three to four hours of hard training. Under normal circumstances, physical activity accounts for between 15% and 30% of a person's total daily energy expenditure. Thus, the more active the person gets the more energy is used to sustain the body's needs (McArdle et al., 1996).

Economy of running or the efficiency of human movement is a relation of the amount of energy required to perform a particular task to the actual work accomplished. In a sense, this evaluation occurs when assessing the ease of movement of elite athletes (Corbin, 1991; McArdle et al., 1996; Wilson, 1997). One does not need a trained eye to notice the ease that swimmers, skiers, cyclists, and dancers perform to their less skilled counterparts who seemingly expend considerable "wasted energy" performing the same task (McArdle et al., 1996). The best endurance athletes are usually the most efficient athletes (Noakes, 1988).

Economy of running takes on considerable importance during longer duration exercise, where success largely depends on the aerobic capability of the individual and the oxygen requirements of the task (McArdle et al., 1996). All factors being equal, any adjustment in training that improves the economy of effort translates directly into improved performance. Morgan & Graib. (1992) related running economy to endurance performance in elite athletes of comparable aerobic fitness. This clearly showed that athletes with greater running economy achieved better performance. In a statistical sense, approximately 64% of the total variation in 10-km running performance among athletes can be explained by the variation in running economy.

There is no single biomechanical factor that accounts for individual differences in running economy. Significant variation in economy observed at a particular running speed occurs even among trained runners (McArdle et al., 1996). In general, improvements in running economy can result from long term programs of run-training. Short term training that emphasizes only the "proper techniques" of running (that is, arm movements and body alignment) probably does not improve running economy. Research indicates, however, that distance runners lacking an economical stride length pattern benefit from a short term program of audio visual feedback that focuses on optimizing stride length (McArdle et al., 1996).

Evidence from studies of cycling indicates that muscle fiber-type distribution may effect the economy of effort. During submaximal cycling, the exercise economies of well trained cyclists varied as much as 15% (McArdle et al., 1996). An important component of this variation was differences in muscle fiber types in the working muscles. Those cyclists exhibiting greater economy also possessed the greater percentage of slow twitch, type I, muscle fibers in their legs. This suggests that type I fibers act with greater mechanical efficiency than type II fibers in submaximal exercise (McArdle et al., 1996).

The question that remains unresolved is why some individuals demonstrate markedly better economy when compared with counterparts exhibiting similar fitness and performance backgrounds. An alternative hypothesis is that successful long distance runners may have a structural or anatomical makeup, which genetically predisposes them towards better economy. Previous research has indicated that the between subject variation in running economy can be as much as 20-30% among trained male and female runners of similar ability (Williams et al., 1991).

### **Bracing and Economy of Running**

Osternig et al. (1993) who has examined the influence of prophylactic knee bracing on dynamic activity, demonstrated significant alterations in knee joint range of movement and force distribution characteristics with custom braces, compared with not braced conditions. It was also found that prophylactic knee bracing increases the metabolic cost of treadmill running compared with nonbraced trails and thus the energy expenditure of runners significantly. In support of the latter finding Zetterland et al. (1986) found that oxygen consumption and heart rate increased by 5% in braced athletes and Highgenboten et al. (1991) showed that prophylactic knee bracing caused a consistent increase in metabolic cost, which was related to the weight of the brace. Other interesting results from Houston and Goemans. (1991) showed that the brace increased the end trail blood lactate concentration by 40%. The time period to elicit muscle fatigue in the braced leg

decreased by 35% (Styf et al., 1994). This was supported by Sforzo et al. (1989) who found a quicker accumulation of lactate, shorter time to fatigue, and increased lactate concentration in individuals with a braced leg. With the above-mentioned in mind, one would expect prophylactic bracing to decrease the economy of running.

Because data from these studies were derived from tests performed with prescription braces, they cannot be extended directly to the more commonly used over-the-counter prophylactic braces. However, the present data, in combination with those of others, suggest the possibility that lower extremity neuromuscular control is altered when external devices are used and that economy of running will definitely be influenced negatively.

### **Assessment of Economy of Running**

A common method for assessing differences between individuals in their economy of running requires evaluating the oxygen consumed while the subject performs a particular exercise at a set power output or speed (Ramsbottom, 1988; McArdle et al., 1996). This approach applies to steady rate exercise, during which the oxygen uptake closely mirrors the energy expended. For example, at a given submaximal speed of running, cycling, or swimming, an individual with greater economy consumes less oxygen. Heart rate on the other hand is seen as a good indication of oxygen consumed, thus if a subject's heart rate increases it implies that there is an increase in oxygen used to perform that specific level or task.

New ideas and methods continue to be developed to better satisfy the demands and needs of research. The recent emergence of the Multi Stage Fitness Test (MST) (Leger et al., 1988; Paliczka, 1993) as a method for predicting maximum aerobic uptake holds considerable promise, because it is less susceptible to variation and inconsistency as compared with other field tests of predicted  $\text{VO}_2$  max (Boreham et al., 1990; Davies and Scott, 1997; Devita, 1998). The principle of the MST is straight forward: the person being assessed runs to and along a measured track (20 meters) keeping up with a series of timed bleeps on an

audio/music cassette player. The timing of the bleeps start off relatively slowly, but becomes progressively faster so that it becomes more difficult to maintain the required pace. The runner stops when he/she can no longer keep going at the pace set by the cassette. In assessing economy of running the protocol of the MST was used, simply because it is an easy way to do a standardised incremental running test. The heart rates were measured at each increment of the MST protocol, and the difference in the heart rate between braced and non-braced was used to predict loss of economy of running.

## **FACTORS THAT AFFECT ECONOMY OF RUNNING**

There are many factors that affect running economy i.e. age, sex, training, stride length and frequency, shoe weight, air resistance, including lower air density found at altitude (Daniels & Daniels., 1991). Furthermore, clothing, surface and terrain, and possibly fatigue are additional factors that can change the cost of running. Brisswalter et al. (1994) indicated that elite runners display a wide range of daily variation in the energy cost of running that is independent of variation in stride rate or respiratory parameters.

### **Children versus Adults**

Children are less economical than adults. Running at submaximal speeds elicits a greater relative demand for oxygen in children (Krahenbuhl & Williams., 1991). They also concluded that running economy improves steadily with age in normally active children. This improvement occurs with or without participation in formal running training programs (Sharkey, 1990). Some of the reasons why children are less economical than adults are that when compared with adults they exhibit higher resting metabolic rates, greater ventilatory equivalents for oxygen at a given running pace, and disadvantageous stride lengths (Sharkey, 1990).

## **Male versus Female**

Daniels & Daniels (1991) concluded that at absolute running velocities, men are more economical than women, but when expressed in  $\text{ml} \cdot \text{Kg} \cdot \text{min}^{-1}$  there is no gender difference at similar relative intensities of running. Also, when men and women of equal  $\text{VO}_2$  max or equal economy are matched, the men showed a better aerobic performance (Sharkey, 1990). Some studies however showed that there are no differences in running economy (Pyne, 1994). Daniels & Daniels (1991) recommended that economy data must be collected up to speeds equal to or faster than 90% of their  $\text{VO}_2$  max. Much of the variance in physiological parameters can be accounted for by differences in body composition and proportions of fat free mass. Pyne (1994) proposed that smaller individuals possess a relatively greater amount of his or her body mass in the extremities, and would therefore perform a relatively greater amount of work moving body segments during running than larger individuals. Given that female runners are, on average, smaller than their male counterparts, it is possible that this might be one explanation for the relatively poorer economy in female runners (Sharkey, 1990).

Morgan et al., (1990) speculated that the higher stride frequency and greater oxygen debt exhibited by females might have contributed to their higher overall energy cost of running. Morgan & Graib (1992) also suggested that females may exhibit greater vertical displacement of the body during running, which would theoretically require a higher aerobic demand because of the added muscular effort needed to lift the body a greater vertical distance.

## **Training**

The major objective in training is to facilitate biological adaptations that improve performance in specific tasks. These adaptations require adherence to carefully planned workout programs, with attention focused on factors such as frequency and length of workouts, type of training, speed, intensity, duration, and repetition of the activity, rest intervals, and appropriate competition (McArdle et al., 1996).

Noakes et al. (1990) noted a relation between peak treadmill running velocity and running economy; those athletes who reached the highest treadmill running velocities were also the most economical in aerobic events. This suggests that with appropriate training for longer distance events, the fastest 10-km runners will also be the fastest marathon and ultramarathon runners. The positive correlation found between running economy and running times further substantiates that faster runners were also more metabolically economical (House et al., 1988). Morgan & Graib (1992) stated that athletes who are specialists in shorter distance events have been shown to exhibit better economy at faster speeds, whereas long-distance specialists tend to be more economical at slower running speeds.

Krahenbuhl & Williams (1991) found that instruction on techniques of running, at least over a short term (2-3 months) is ineffective in bringing about improvements in running economy. Running training results in little or no improvement in running economy during childhood and adolescence. Over a longer term (years), improvements in running economy may be augmented through participation in running training programs (Krahenbuhl & Williams, 1991). Morgan et al. (1990) concluded that growth related factors and training were likely causes for the enhancement in running economy.

Ideally, runners are most concerned with being optimally economical at race pace. The longer the race and the smaller the anaerobic racing component, the greater will be the influence of running economy on performance quality (Sharkey, 1990). Thus marathoners can probably benefit most, either from above average running economy through genetic factors, or from specific training to improve it. This has been offered as an explanation for the rather low  $VO_2$  max values recorded among some top-level marathon runners (Martin & Coe, 1997). Better running economy was associated with lower heart rate and ventilation (Bailey & Pate, 1991).

## Stride Length and Frequency

Running speed can be increased in one of three ways: (a) by increasing the number of steps each minute (stride frequency), (b) by increasing the distance between steps (stride length), or (c) by increasing both the length and frequency of strides. Although the third option may seem the obvious way to increase running speed, several experiments have provided objective data concerning this question. In 1944, the stride pattern was evaluated for the Danish champion in the 5-km and 10-km running events. At a running speed of 9.3 km per hour, this athlete's stride frequency was 160 per minute with a corresponding stride length of 97 cm. When running speed was increased 91% to 17.8 km per hour, the stride frequency increased only 10% to 176 strides per minute, whereas an 83% increase to 168 cm was observed in stride length (McArdle et al., 1996).

Elite runners also appear to choose an optimal stride length at which they are most efficient, and when forced to take either longer or shorter strides for the same running velocity, they require an increased oxygen uptake, thus becoming less efficient (Hawley, 1995). Morgan et al. (1990) concluded that there is little need for a coach to dictate a particular stride length profile in most athletes, since they tend to display nearly optimal stride lengths. They suggest that this phenomenon might be due to two mechanisms. The first states that runners may gravitate naturally toward an optimal stride length/stride rate. And a second possibility is that runners may adapt physiologically through repeated training at a particular combination of stride length and stride frequency for a given running speed (Sharkey, 1990).

Rowland et al. (1987) stated that both adults and children elected to increase stride length rather than frequency as treadmill speed increased. This further supports the idea that greater running economy is achieved by increasing stride length rather than frequency. Bailey & Pate (1991) showed that stride length and running economy differ between experienced and novice runners, with experienced runners possessing longer stride lengths and greater running economy.

The results indicated that the most economical runners possessed a significantly lower force peak at heel strike, greater shank angle at heel strike, smaller maximal plantar flexion angle following toe off and greater forward trunk lean (Sharkey, 1990).

## **Fatigue**

Fatigue is defined as the decline in muscle tension capacity with repeated stimulation. Motor unit fatigue is the result of many factors, each of which is related to the specific demands of the exercise that produces it. These factors can interact in a manner that ultimately affects either contraction or excitation or both (McArdle et al., 1996).

Zavorsky et al. (1998) stated that fatigue induced by submaximal long duration exercise significantly increases the aerobic demand of running. For exercises lasting more than two hours, it has been shown that the running economy decreased at the end of a long distance run (Hauswirth et al., 1996). Thus fatigue affects economy in a negative way, increasing aerobic demand through the use of increasingly tired prime movers plus others brought into action to help maintain pace. With prolonged exercise heart rate and core temperature increases and an increase in core temperature induces an increase in  $V_E$  with accompanying oxygen cost for the respiratory muscles. Increased ventilation, enhanced oxygen extraction, or a combination of these mechanisms should account for the increase in  $VO_2$  (Zavorsky et al., 1998).

Data obtained on elite and trained endurance runners performing long distance runs have produced conflicting results, one study reported higher aerobic demands following a competitive distance race (Cavanagh et al., 1985), and others demonstrated no change in economy 1 day after a hard training workout (Martin & Coe, 1987). Morgan et al. (1990) replicated the Martin & Coe. (1987) study by expanding the experimental design. These findings suggest that an intense 30-minute training run or a competitive 10 km race would not raise the aerobic

demand of running by increasing dependence on fat metabolism, or disrupting the gait pattern in subsequent submaximal runs over the short term. Viewed from a theoretical perspective, these results demonstrate the imperturbability of the metabolic and biomechanical profiles of trained runners following a prolonged maximal run (Sharkey, 1990). In a more recent study Zavorsky et al. (1998) conclude that running economy is worsened after repeated hard efforts.

### **Body Mass**

Morgan et al. (1990) observed a modest inverse relationship between body mass or weight and economy in elite female runners. However, greater body mass in the trunk area appears to be advantageous in terms of running economy. Conversely, those individuals who possess greater percentages of their body weight in the arms and legs may be able to obtain higher  $\text{VO}_2$  max values because a greater proportion of their lean muscle mass is active during running (Bailey & Pate, 1991).

It is also considerably more costly to carry weights on the feet or ankles than to carry a similar weight attached to the torso. For example, with a weight equal to 1.4% of body mass placed on the ankles, the energy cost of walking increases an average of 8%, or nearly 6 times more than if the same weight were carried on the torso. In a practical sense, the energy cost of walking and running is significantly increased by wearing boots compared to running shoes. Simply adding an additional 100g to each shoe causes a 1% increase in oxygen uptake during moderate running. Thus small changes in shoe design and weight produce meaningful changes in the economy of locomotion (McArdle et al., 1996). From the above-mentioned it seems that the knee brace should have some effect on the economy of running due to the fact that it would be additional weight to the lower extremity.

## **CHAPTER 3**

### **METHODOLOGY**

#### **SUBJECT CHARACTERISTICS**

Thirty subjects, all males with a mean age of  $24,33 \pm 4,98$ , playing first league rugby in the Natal club championships (2000) were selected from a group of volunteers to participate in the present study. Subject selection was based on the team's level of participation and the individual level of participation. They represented four different teams, and their ages ranged from 21- 30 years. Seventy percent of the players represented either the U/21, or seniors of the Zululand provincial sides (2000) and the remaining thirty-percent represented Zululand in previous seasons. The players were selected without taking their playing positions into consideration. All the subjects were non-smokers and were free from any disease or injury. The day before each test, no intensive training was allowed.

#### **INFORMED CONSENT**

Prior to participation, the testing procedures were explained verbally, in English and Afrikaans to the subjects, to ensure every subject fully understood the requirements of the study. All subjects were given the opportunity to ask questions or withdraw from the tests, if they so wished.

All subjects were obliged to sign an informed consent form before participating, approved by the University of Zululand's Ethics Committee (Appendix A). This consent form consisted of an explanation of exactly what was expected of each player. The benefits and risks associated with the research were explained to the subjects.

## **INSTRUMENTS**

### **Anthropometrical measurements**

An anthropometric tape of flexible steel calibrated in centimeters with millimeter gradations was used to measure the girths of subjects. Each subject's weight was measured using a Deco medical balance scale, calibrated to the nearest 100 g. For height measurement the Deco anthropometer with footplate, calibrated in centimeters with millimeter gradations was used. And for determining body composition, the Lange spring-loaded 10 kPa caliper was used to measure skinfold thickness and thus body fat %.

### **Speed Test**

Cones were used to mark the 0-meter mark (start), 30 meters mark and the 35 meters mark. The 30-meter sprint test was used, because Johnson & Nelson (1986) stated that most sprinters or sportsmen reach their optimal speed between 25 and 35 meters. Further research showed that in only a few occasions would a rugby player need to sprint more than 30 meters.

Three timekeepers were used in each sprint test and to ensure the timekeeping was reliable, the same three timekeepers and stopwatches were used throughout the entire testing procedures.

### **Agility Test**

The SEMO agility test of Johnson et al. (1986) was used to develop the modified agility test used in the present study. Johnson & Nelson (1986) reported reliability scores ( $r = 0.88$ ) and validity scores ( $r = 0.63$ ) when the SEMO agility test was correlated with the AAHPERD shuttle run test. Cones were used to mark the modified SEMO agility course. Three timekeepers were used to time

the agility tests, and to ensure that the timekeeping was reliable, the same three timekeepers and stopwatches were used through-out the entire testing procedures. Modifications to the SEMO agility test included more specific rugby related activities such as picking up balls, side cutting movements, running in different directions and tackling of tackle bags. All these activities took place within the original SEMO agility test and therefore would not have affected the test reliability and validity.

### **Proprioception Test**

The Wilknox Quad Time Logging instrument for use with balancing discs, utilizes embedded micro controller technology and was developed by the Human Movement Science department of the University of Zululand. It is a measuring device for the use of research in proprioception. The Wilknox control unit and the separate balancing discs are interconnected via a multi core cable. The control unit can be set for any given period of balancing; for example, if the unit is set at 120 seconds the subject will balance for 120 seconds, and the control unit will measure time unbalanced for this period.

### **Strength Test**

In the late 1960s, the concept of isokinetic exercise and testing was developed by James Perrine, which proved to be a revolution in exercise training, testing and rehabilitation. Instead of the traditional exercises, which involve a constant weight or resistance, performed at variable speed. Perrine developed the concept of isokinetics, which involves dynamic pre-set fixed speed, with resistance that is totally accommodating throughout the range of motion. Since the inception of isokinetics, this form of testing and exercise has become increasingly popular in clinical, athletic, and research settings (Davies, 1987).

The Akron isokinetic unit consists of a fully adjustable chair, on which the subject is positioned for specific exercise tests. The motion is transferred directly to a

hydraulic pump-head by an appropriate attachment, thereby eliminating any losses or inaccuracy due to the use of linkages. This pump-head is mounted on a trolley, which can be moved along the length of a rail fixed on both sides of the couch or positioned across the end of the couch by the use of a rail. The electronic control box can be mounted as part of this trolley, thereby making it an integral exercise machine, or it may be on a separate console connected to the pump head by a single umbilical, which is particularly convenient when using the machine in conjunction with a computer.

Rechargeable batteries power the unit, so there need be no trailing mains leads. When charging becomes necessary simply plug the unit into a suitable mains supply and switch on at the rear panel, the machine is in continuous use whilst on mains supply, regardless of battery condition.

To enable joint testing of the upper and lower limbs the pump-head is also adjustable in height. Most of the height is supported by a sealed gas spring so that height adjustment may be effected without undue effort.

Speed of rotation can be controlled separately in each direction and the force displayed on vertical bar graphs for each direction. A target force may be set on each bar graph or they can be set to record the maximum force applied over a number of repetitions. The force applied is displayed over one of the three cable ranges and indicated by the calibrated scales alongside the bar graphs. The computer can calculate from the test performed, the peak flexion/extension and the average flexion/extension of the limb tested. But to prevent a computer error the results were also calculated by hand, to correlate results obtained from the computer. This will decrease the possibility of incorrect results.

### **Economy of running Test**

New ideas and methods continue to be developed to better satisfy the demands and needs of research. The recent emergence of the Multi-Stage Fitness Test

(MST) (Leger et al., 1988) as a method for predicting maximum aerobic uptake holds considerable promise, because it is less susceptible to variation and inconsistency as compared with other field tests of predicted  $VO_2$  max (Boreham et al., 1990; Davies and Scott 1997). In the case of assessing economy of running the protocol of the MST was used simply because it is an effective way to do a standardised incremental running test.

The maximal aerobic power (endurance fitness) of team sports players can be assessed by a progressive multistage shuttle run according to the protocol of Leger et al. (1988). This test has both excellent test retest reliability ( $r = 0.97$ ) and validity ( $r = 0.84$ ) (Leger et al., 1982). The heart rates were measured at each increment of the MST protocol, by means of a Polar Heart Rate Monitor, that is, a portable heart rate monitor. It has three components: the watch receiver, an electrode strap which was placed around the subject's chest at the level of the inferior border of the pectorals muscle, and the watch which was attached to the subjects arm prior to the MST.

It is common knowledge that oxygen consumed is an indication of economy of running but it is also recognized that heart rate is an indication of oxygen consumed and thus an indication of energy used to perform a task. In the present study heart rate is used to evaluate the difference between economy of running for braced versus not braced conditions.

## **PROCEDURES**

At a meeting held with coaches and managers of Empangeni and Richards Bay rugby clubs, all interested parties agreed to participate in the study. It was also agreed that testing would take place at Mick Kelly Park, which is the home ground of the North Coast Rhinos. Laboratory testing occurred in the Biokinetics Laboratory at the Human Movement Science Department, University of Zululand.

Four weeks prior to testing three rugby teams were visited and all players were briefed about the study in Afrikaans and English. Thirty players volunteered, where after the procedures of the study were explained to them once more. One week before subjects were tested, they were contacted to remind them of the research testing and for confirmation of the time. On the day of testing, each subject completed an informed consent form prior to preparations for testing.

All testing sessions were carried out using the same protocol and procedures. Each subject was required to perform five motor tasks: 1) Straight sprint, 2) Agility run, 3) Proprioception balancing test, 4) Knee extension/flexion strength test, 5) Multi Stage Fitness Test, while participating in each of the treatment conditions (Brace vs. Non-Brace). Fifteen subjects wore the brace on the right leg and the other fifteen wore it on the left leg. The test order, which leg is used, and the sequence of brace or no brace was completely randomised. Subjects were required to wear full rugby kit and boots throughout all treatment sessions but when subjects performed the Multi Stage Fitness run they were required to use running shoes for both variables. Subjects were given a five minute recovery between trails of each test and two days between different tests.

### **Pilot study**

A pilot study was performed on three subjects to identify any limitations to the testing procedures. From the pilot study where only one timekeeper was used, it was decided to use three timekeepers to increase the accuracy of the final score, for the speed as well as the agility tests. The two closest times of the two tests were recorded and the other one was ignored. For the final score the fastest time of the remaining four scores of the two tests was recorded as the sprint time. In the pilot study the sprint distance of thirty meters was used, but some subjects relaxed earlier than others influencing the performance. It was decided that the thirty meters should be increased to thirty-five meters, but the time was still taken over the distance of 30 meters.

From the pilot study it was also clear that one has to make sure that in each of the tests, the subjects must know exactly what to do and when to do it. This is very important especially for the agility course.

Originally the strength test was based on the Akron computer print outs, but it was decided to incorporate hand calculations as well. The reason for this is that the computer might use a one-off spike performance to calculate the strength. This way you can ensure that the computer print-outs are a true representation of the subject's strength performance. No improvements were made to the proprioception test.

All scorers and timekeepers received scoring sheets (Appendix C-G), which provided them with all the subjects' names in alphabetical order. Scorers and timekeepers worked separately to prevent them from comparing scores.

## **DESIGN AND ANALYSIS**

### **Anthropometric Measures**

In this study anthropometric measurements, which centered on body composition, were utilized. Body composition refers to the relative percentage of muscle, fat, bone and other tissue of which the body is comprised. Morphological measures included stature, body mass and percentage of body fat. Percentage body fat was calculated from skinfold measures of four sites: biceps, triceps, supra-iliac and subscapular according to Durnin and Womersley (1974). An example of scoring sheets can be seen in Appendix B.

### **Stature**

Stature was recorded in centimeters to the nearest millimeter with a required accuracy of < 2mm, using a stadiometer. The subject stood erect and barefoot,

with the weight evenly distributed on both feet, and the head in the Frankfurt Horizontal Plane. The arms hung freely at the sides of the trunk with the palms facing the thighs. The heels were placed together, gluteus, scapulae and posterior cranium were in contact with the stadiometer. Before taking the measurement the subject was instructed to inhale deeply and stretch upwards to the fullest extent. The vertical distance from the vertex in the mid-sagittal plane to the floor was measured (see Figure 7 A).

### **Leg length**

Leg length was recorded in centimeters to the nearest millimeter with a required accuracy of < 2mm, using a stadiometer. The subject stood erect and barefoot, with the weight evenly distributed on both feet. The heels were placed together, the lateral side of the ankle and hip was in contact with the stadiometer. Measurement was taken from the floor to the trochanter of the leg.

### **Body mass**

The subjects were asked to remove all clothing except for shorts and T-shirt before being measured on the Deco scale. Body mass was measured in kilograms on a calibrated scale and recorded to the nearest 100 grams, with a required accuracy of < 0.5 kg (see Figure 7 B).

### **Body composition: skinfold measurements**

Measuring the skinfold thickness at various sites (see Figure 8A & 9A) offers an effective method of estimating body fat, which is a central factor in body composition. The following measurement technique was applied for all sites using a Lange spring-loaded 10 kPa skinfold caliper. Recordings were taken on the subject's right hand side. All measurements are recorded in millimeters, with a required accuracy of <1.5mm.

The thumb and index finger of the left hand were used to elevate the double fold of the skin and subcutaneous adipose tissue one-centimeter proximal to the site at which the skinfold is measured. The jaws of the caliper were applied at right angles to the site, and the spring-loaded handles are fully released. Once full pressure is applied and a maximum of three seconds has passed, the measurement was taken. Durnin and Womersley (1974) found using the four sites of triceps, biceps, subscapular and supra-iliac enabled the tester to assess total body fat with relative ease and reasonable accuracy. Two measures were taken and recorded to the nearest 0.5 mm. If the difference was greater than 1mm, then a third measurement was taken and the mean of the best two was recorded (see Figure 8 A).

### **Triceps skinfold**

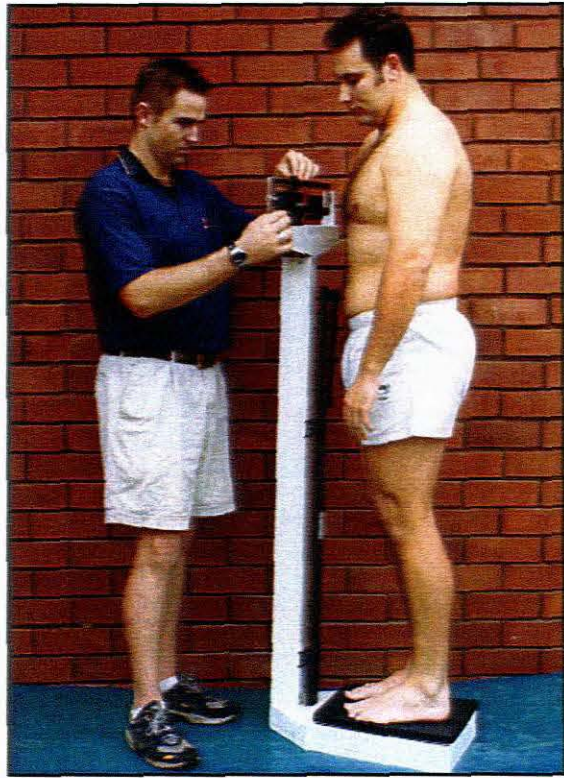
This was measured on the posterior surface of the unclothed pendant arm at a level midway between the acromion and the olecranon processes with the arm held freely to the side of the body. The midpoint was established with the elbow fixed at 90 degrees. The skinfold was lifted parallel to the long axis of the arm, after which the subject lowered the forearm and the caliper jaws were applied.

### **Subscapular skinfold**

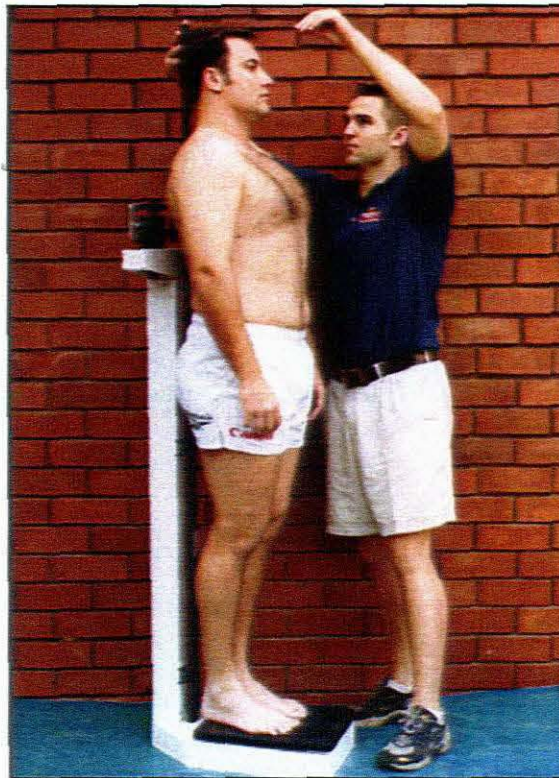
This is a diagonal fold (at 45° angle), measured 1 to 2 cm below the inferior angle of the scapula, along a line running laterally and obliquely downwards from the subscapular landmark with the subject standing erect and upper limbs pendant.

### **Biceps skinfold**

This is a vertical fold on the anterior aspect of the pendant upper arm, midway between the acromion and the olecranon process of the elbow joint. It is measured 1 cm above the level used to mark the triceps site.



A.



B.

Figure 17. Anthropometric Measurements: (A.) Weight and (B.) Height.

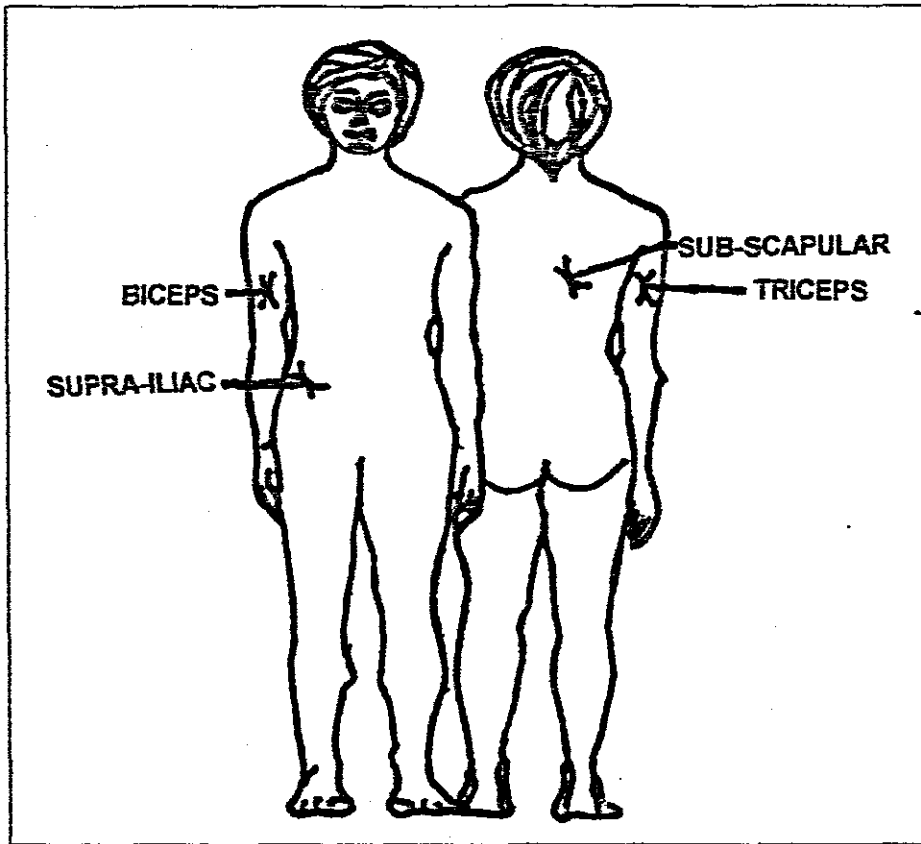


A.

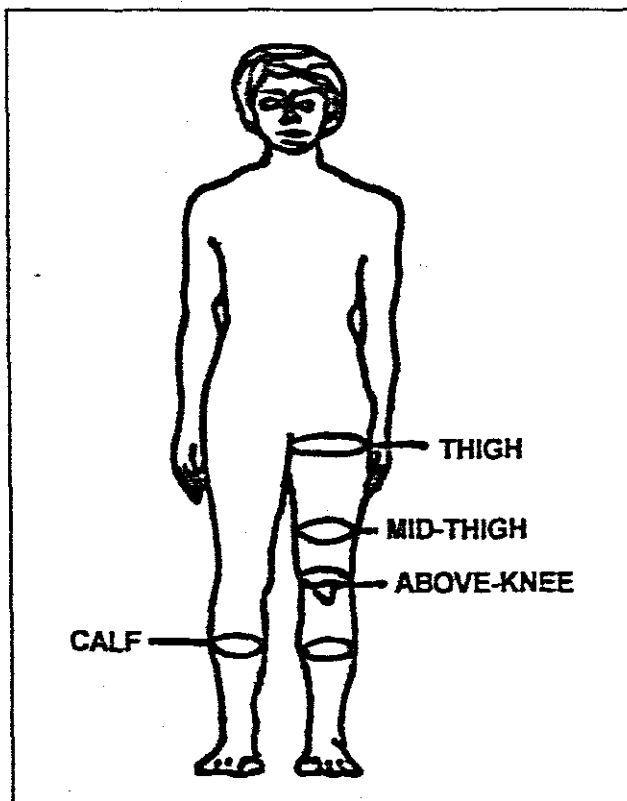


B.

**Figure 8. Anthropometric Measurements: (A.) Tricep Skinfold; (B.) Mid Thigh Girth.**



A.



B.

Figure 9. Anthropometric Measurements: (A.) Sites of Skinfolds and (B.) Girths.

## **Supra-iliac skinfold**

This is a diagonal fold in line with the natural angle of the iliac crest, taken in the anterior axillary line, 3-cm superior to the iliac crest.

## **Percentage body fat**

Calculating the body density. The four skinfolds were added: triceps, biceps, subscapular and supra-iliac. Using the equation derived from Durnin and Womersley (1974) the density was calculated from linear regression, which estimated density from the logarithm of skinfold thickness:

Density =  $c - m \cdot \log \text{skinfold}$

Where "c" and "m" vary in regression equations depending on age and gender.

The formula for estimating percentage of body fat is the Siri equation:

$$\% \text{ fat} = (495/\text{body density}) - 450$$

The anthropological measurements included stature, body mass and percentage body fat and were calculated from skinfold measures of the four sites, namely triceps, subscapular, biceps and supra-iliac according to Durnin and Womersley (1974). A comprehensive description of the morphological measures and procedures was presented on pages 58 to 60. Measures were taken beforehand at the Human Movement Science laboratory at the University of Zululand.

## **Girth Measurements**

A flexible anthropometric steel tape was used for all the girth measurements, which were recorded in centimeters to the nearest millimeter. Care was taken to ensure that while the tape makes firm and continuous contact it did not deform the contours of the skin. In all the girth measurements the tape was positioned in

a plane, which was at right angles to the long axis of the particular segment or body (see Figure 9 B).

### **Thigh girth**

The upper thigh was measured at the skin-marked site one centimeter below the gluteal fold while the subject was standing erect, upper limbs pendent with the body mass equally distributed on both feet, which were hip width apart. The measurement was taken from the side. Middle thigh was measured at the middle point between the upper thigh and the supra patella measurement (see Figure 8 B). The Supra patella was measured at the skin-marked site, one centimeter above the patella.

### **Calf girth**

The subject assumed the same position as during the thigh girth measurement. The maximum calf girths on both legs were measured from behind.

## **Fitness and Skill Measurements**

### **Speed**

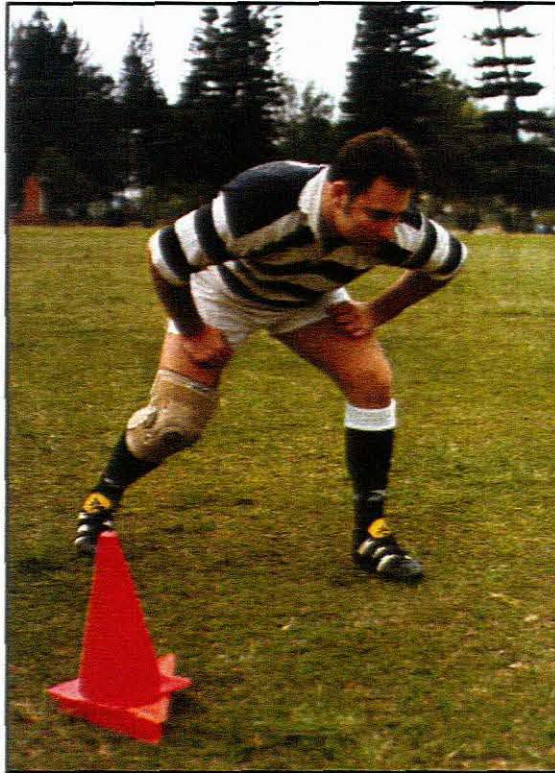
Speed testing involved a 35-meter sprint but the time was taken for 0-30 meters. This method was used to ensure a true representation of their sprint performance. The distances were clearly marked with orange cones and before testing started the subjects had a comprehensive warm-up for 15-20 minutes. The same person that warms them up before normal rugby training and matches did the warm-up before testing. Sprint tests were explained again just before the test was initiated. Each subject was allowed three sprints with the brace and three without the brace but the first sprint was seen as an additional warm-up.

The test order, which leg is used, and the sequence of brace or non-brace, was completely randomized. Each subject completed both variables (braced vs. non-braced) on the same day of testing, but different subjects not necessarily on the same day. Subjects started the sprint in the standing position with their knees slightly bent and were allowed to use their most comfortable leg to push off from the starting line (see Figure 10). After each sprint there was a recovery period of five minutes allowed before the second and third tests followed. The first sprint of each variable was used as an additional warm-up and these times were not recorded. During testing, subjects were wearing full rugby kit and boots. Three timekeepers were used to record the last two sprint test times; this resulted in six times for each variable. The closest two times of each sprint was recorded, and the other one ignored (see Appendix C). The fastest time of the recorded four times was then recorded as the final time for the thirty-meter sprint test.

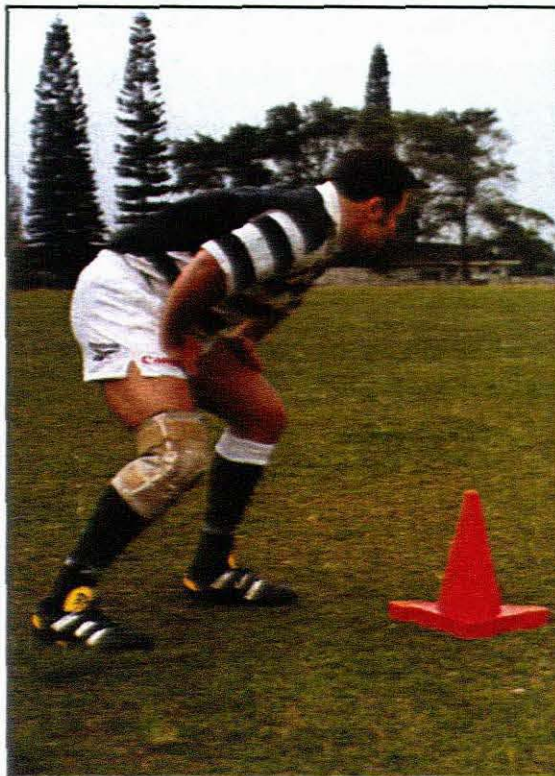
To ensure that the timekeeping was reliable, the same three timekeepers and stopwatches were used through-out the entire testing procedures.

## **Agility**

Agility was measured by means of the time it required to perform the modified SEMO agility test. Agility testing took place on the same surface area as the sprint tests and the course was marked out with orange cones (see Figure 10). The course was explained to the subjects while they were walking through the course. They repeated the walk just before the test to ensure full understanding and knowledge to complete the course. The same person that warms them up before normal rugby training and matches did a comprehensive warm-up for 15-20 minutes. Each subject was allowed three agility sprints with the brace and three without the brace. The test order, which leg is used, and the sequence of brace or no brace was completely randomized. Subjects started the agility sprint in the standing position with their knees slightly bent and were allowed to use their most comfortable leg to push off from the starting line.



A.



B.

Figure 10. Starting position for the 30-meter Speed and SEMO Agility tests.

The first agility sprint of each variable was used as an additional warm-up and these times were not recorded.

After each agility sprint a recovery period of five minutes was allowed before the second and third trial followed. During testing, subjects were wearing full rugby kit and boots. Three timekeepers were used to record the two agility sprint test times; this resulted in six times for each variable. The closest two times of each agility sprint was recorded, and the other one ignored (see Appendix D). The fastest time of the recorded four times was then recorded as the final time for the modified SEMO agility run. To ensure that the timekeeping was reliable, the same three timekeepers and stopwatches were used through-out the entire testing procedures.

The modified SEMO agility course incorporated the following activities (see Figure 11). Subjects started with the jumping run over the tackle bags, sprinting forward to tackle the tackle bag and then they picked up the rugby ball lying on the grass. With the ball in hand they started the side cutting movements through the cones where the ball was put down on the corner of the course as they started to sprint side-ways to the right side.

Subjects changed direction at the cone and sprinted side-ways to the left side where they turned again at the corner of the course and sprinted backwards to the next cone. At this cone the subjects turned around and sprinted forward to tackle the next tackle bag, again they had to pick up the ball on the grass followed by swerving movements through the cones. Directly after the swerving movements the ball was put down on the grass as the subject sprinted forward to tackle the third and last tackle bag, followed by the last forward sprint to finish the course.

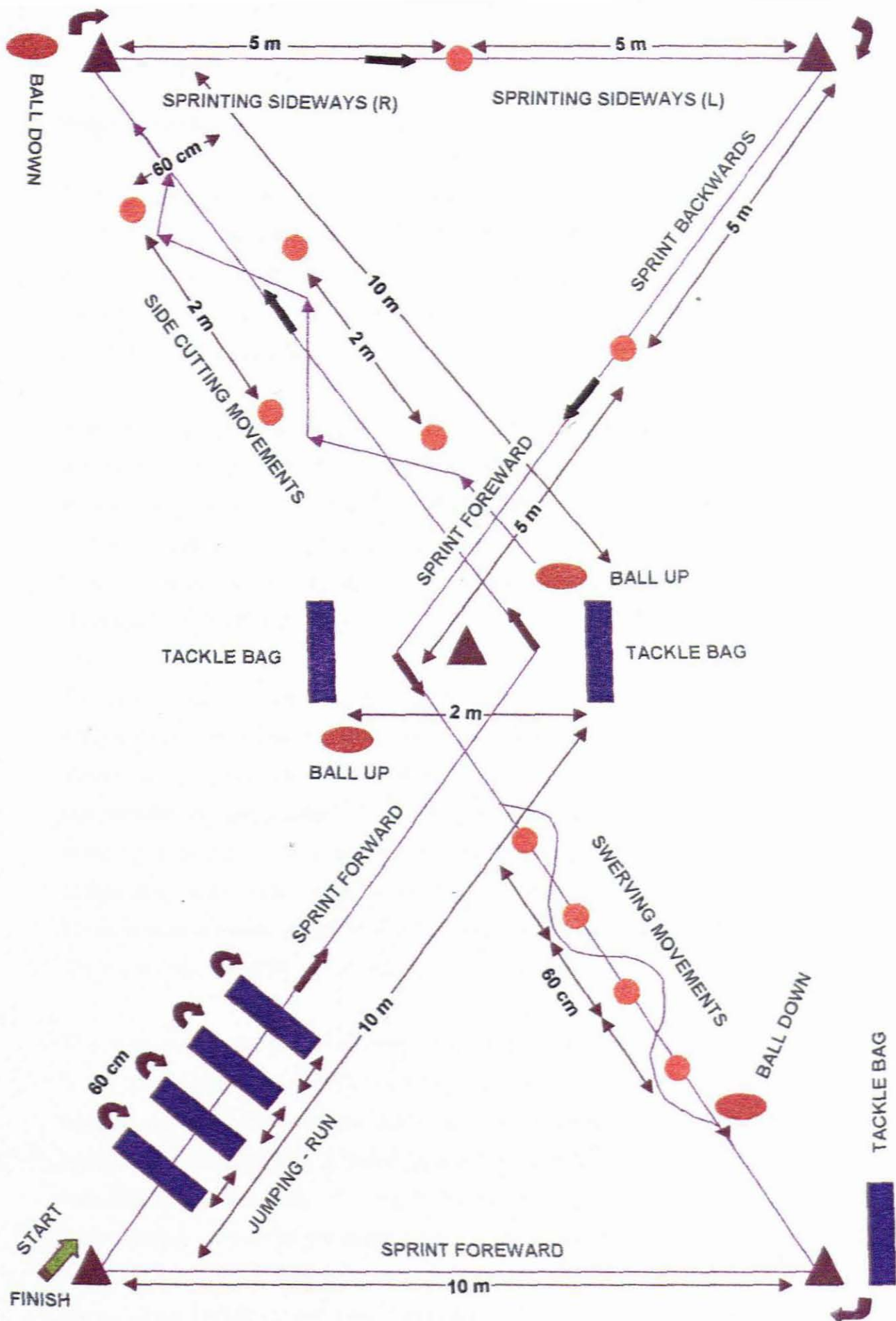


Figure 11. Agility Course for the modified SEMO Agility test.

## **Proprioception**

Proprioception testing was administered in the air-conditioned Biokinetics Laboratory of the University of Zululand, where the temperature was kept at 26°C, and a relative humidity of 45%-55%. The test was explained and demonstrated to the subjects to ensure full understanding and knowledge to complete the test successfully.

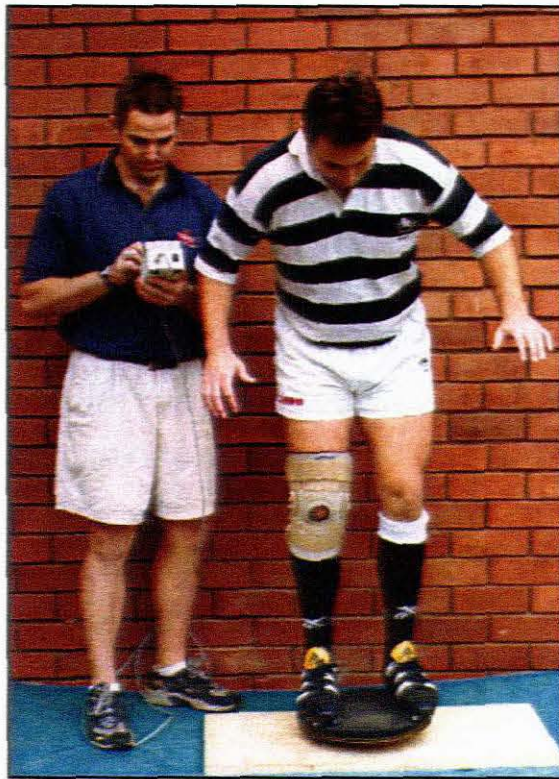
The same person that is responsible for warm up before normal rugby training and matches did a comprehensive warm-up for 15-20 minutes. Each subject was allowed four proprioception tests (Balance tests) of two minutes each on the Wilknox Quad Time Logger (see Figure 12) with the brace and four without the brace. The test order, leg tested, and the sequence of brace or no brace was completely randomized.

The Wilknox Quad Time Logger was placed on a hard wooden plank on the floor and subjects were instructed to place their feet parallel on the Wilknox Quad Time Logger (25 cm apart) with knees slightly bent and to balance themselves for two minutes without using their arms and hands to assist them with the task. After each proprioception test a recovery period of five minutes was allowed before the other three tests followed. The first proprioception test of each variable was used as an additional warm-up and these times were not recorded. During testing, subjects were wearing full rugby kit and boots.

The remaining three proprioception tests were used to collect data. The Wilknox Quad Time Logger calculates the time unbalanced, the less time the subject is unbalanced the better his performance. For example if subject A scores 30 seconds unbalanced, this 30 seconds is then subtracted from a 120 seconds (two minutes) to give the tester a score of 90 seconds that the subject was balanced. Each subject performed the proprioception test three times, the best time of the recorded three times was then recorded as the final time for the Wilknox Quad Time Logger balancing test (see Appendix E).



A.



B.

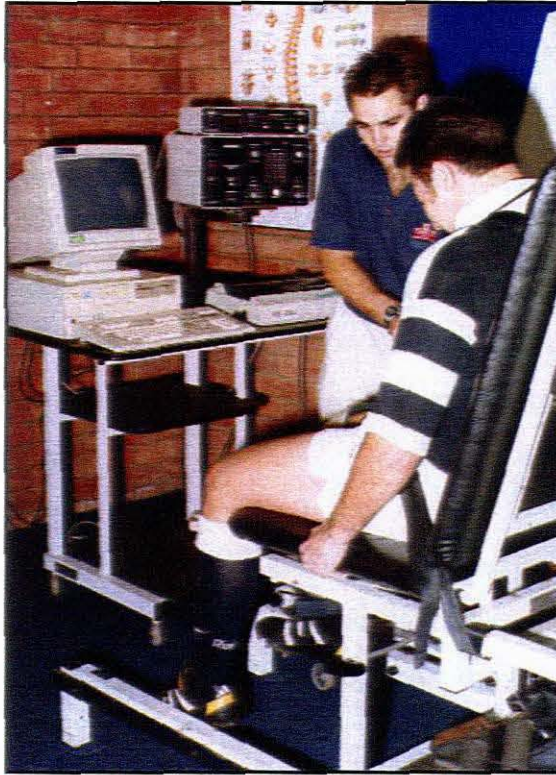
Figure 12. Proprioception Test on the Wilknox Quad Time Logger.

## Strength

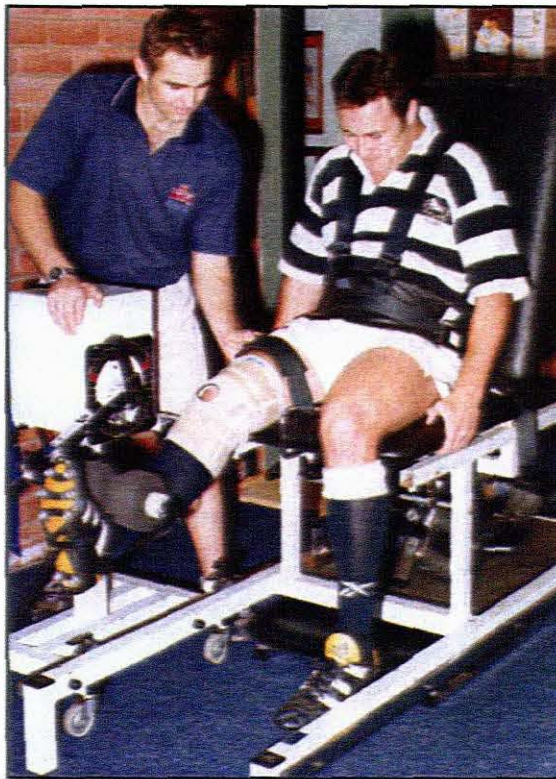
Strength testing was administered in the air-conditioned Biokinetics Laboratory of the University of Zululand, where the temperature were kept at 26°C, and a relative humidity of 45%-55%. The test was explained and demonstrated to the subjects to ensure full understanding and knowledge to complete the test successfully.

The same person that warms the subjects up before normal rugby training and matches did a comprehensive warm-up for 15-20 minutes. The last five minutes of the warm-up was done on the Akron isokinetic unit, this unit allows the flexion/extension action of the knees (see Figure 13A & B). Subjects were seated and strapped in on the akron isokinetic chair to ensure as little as possible movement of the body except knee extension and flexion. The warm-up on the unit consisted of ten flexion/extensions of the knee at a slow speed, followed by ten faster flexion/extensions and then by three flexion/extensions as fast as possible. After the warm-up subjects were asked to complete two tests for data collection, each test consists of full flexion/extensions of the knee for a period of ten seconds each at 60 degrees per second. After each strength test a recovery period of five minutes was allowed before the next test followed.

The Akron records the data and calculates the peak flexion/extension torque very accurately (see Appendix F). The Akron takes the highest peak as the peak torque, and it might be possible that this is an artificial spike therefore calculations were also done manually to eliminate such errors. This decreased the possibility of incorrect results. The strength (flexion/extension) of each test was calculated and scored, this resulted in two peak scores for flexion and extension from the two tests. The highest torque scored as the final score for peak flexion and extension.



A.



B.

Figure 13. The Akron Isokinetic Testing for Flexion/Extension strength.

## **Economy of Running**

The MST test protocol was used in the present study in assessing economy of running. The protocol was used to measure the heart rate of subjects at a known speed of running (each level), the change in heart rate at a known speed is commonly believed to indicate a change in economy of running. The principle of the assessment is straight-forward: the person being assessed runs to and along a measured track (20 meters) keeping up with a series of timed bleeps on an audio/music cassette player.

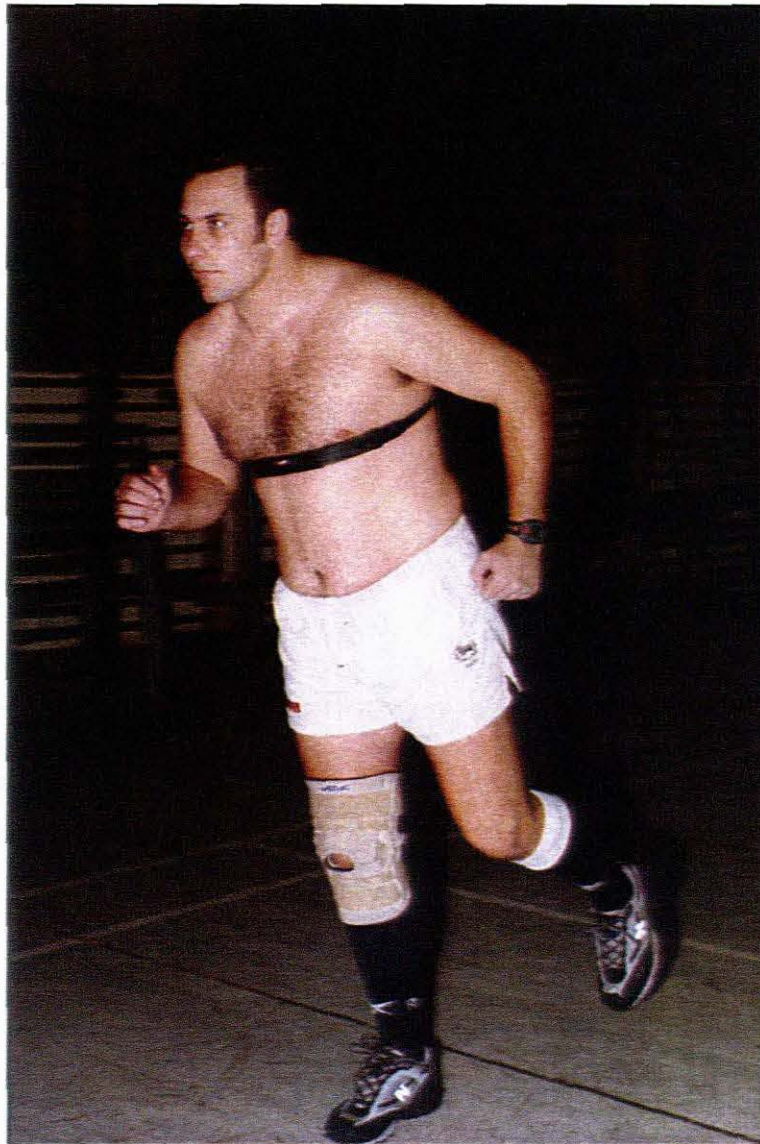
The timing of the bleeps starts off relatively slowly, but becomes progressively faster so that it becomes more difficult to maintain the required pace. Testing was done in the physical education hall of the University of Zululand (see Figure 14).

Heart rate measurements were taken because it is commonly recognized that they are indicative of the physiological strain of the cardio-vascular system during exercise (Armstrong and Bray, 1991). It is also recognized that heart rate is an indication of oxygen consumed and this again an indication of energy used to perform the task (McArdle et al., 1996). Heart rate was measured by means of a Polar Heart Rate Monitor that is a portable heart rate monitor. It has three components: the watch receiver, an electrode strap which was placed around the subject's chest at the level of the inferior border of the pectoral muscle, and the watch which was attached to the subjects arm prior to the MST.

A pre-exercise heart rate was established prior to participation in the MST. This was given by the subject 15 seconds before he started to run in the test, and was determined by the 15-second countdown heard on the cassette. The subject thereafter, was instructed to call out the heart rate reading from the watch on the recorder towards the completion of each level/minute (see Appendix G). This entailed the subject reading the heart watch at a distance 3-5 meters from the end of each shuttle. The recorder duly recorded the heart rate on the data sheet. This procedure continued until the subject was no longer able to keep up with the

set rhythm of the MST and a final reading was taken at the point when the subject withdrew from the test.

The stage in the assessment when the subject stops provides a good indication of that person's individual aerobic capacity, and the change in heart rates between bracing and not bracing a good indication of economy of running.



**Figure 14. Heart Rate monitoring in the 20 meter MST protocol test run.**

## **STATISTICAL ANALYSIS AND TREATMENT OF DATA**

Results are expressed as means and standard deviations, along with one way ANOVA and independent t-tests to determine whether significant ( $p < 0.05$ ) or ( $p < 0.01$ ) differences occur between test-retest measured parameters. This will determine whether the test procedures adopted is reliable and to bring modifications to protocols where necessary.

## **CHAPTER 4**

### **RESULTS AND DISCUSSION**

The major objective of this study was to examine the influence of prophylactic knee bracing on performance of first league rugby players. Performance was broken down into more specific fitness and skill components found in rugby, such as speed, agility, proprioception, strength and economy of running. The performance of forwards and backline players were evaluated.

The data are organized and presented in three subsections: Subject Characteristics, Anthropometric Results, and Results for Fitness and Skill Components.

#### **SUBJECT CHARACTERISTICS**

Thirty subjects participated in the study, of which all were male rugby players playing in the Natal club championships (2000). Twenty subjects were backline players and the remaining ten were forwards. The subjects were recruited from three teams in the Zululand area. Subject selection was based on the team's level of participation and the individual level of participation; therefore all thirty subjects represented either the U/21, or seniors of the Zululand provincial sides. The subjects were injury free and fit to take part in the study. The mean age of the sample was  $24.33 \pm 4.98$  years, the youngest being 20 years and the oldest being 32 years.

**TABLE I:** Anthropometric results: means and standard deviations for stature, leg length, mass and body fat for all groups.

Groups	Stature (cm)	Leg Length (cm)	Mass (kg)	Body Fat (%)
Combined (n=30)	182.2 (7.6)	93.5 (4.5)	87.5 (12.5)	16.4 (4.0)
Backs (n=20)	179.2 (6.1)	91.0 (2.8)	80.4 (7.3)	14.9 (2.4)
Forwards (n=10)	188.1 (6.9)	96.0 (3.6)	101.8 (7.3)	18.4 (5.6)
% difference	+ 5.0	+ 5.5	+ 21.0	+ 19.0
Significant difference	p<0.05 *	p<0.05 *	p<0.01 **	p<0.01 **

\* Indicates a significant difference at level p<0.05

\*\* Indicates a significant difference at level p<0.01

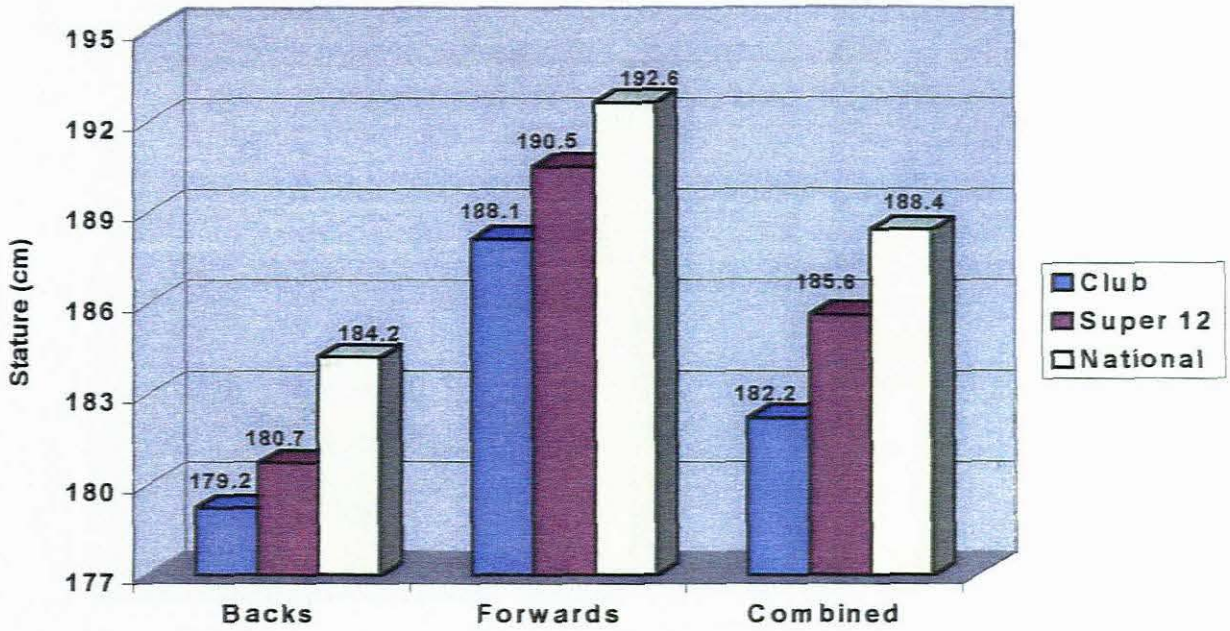
## ANTHROPOMETRIC RESULTS

Noakes (1990) indicated that sports in South Africa are organized in highly competitive structures and inferred that as a consequence this system caters for the needs of the genetically gifted. If this contention holds true then one would envisage forwards and backline players to be characterised by discernable anthropometric attributes.

### Stature

Forwards in the present study were on average significantly (p<0.05) taller at  $188.10 \pm 6.9$  cm than backline players who measured  $179.20 \pm 6.1$  cm (See Table I). This was expected if the different physical demands of forwards and backline players are taken into consideration. Forwards need to be taller because they compete for the ball in lineouts, and only in very unusual circumstances is it necessary for backline players to compete for the ball in such a manner. Results of the present study were supported by research done by Van Heerden (1996) on youth sport, where the difference in height between forwards

A.



B.

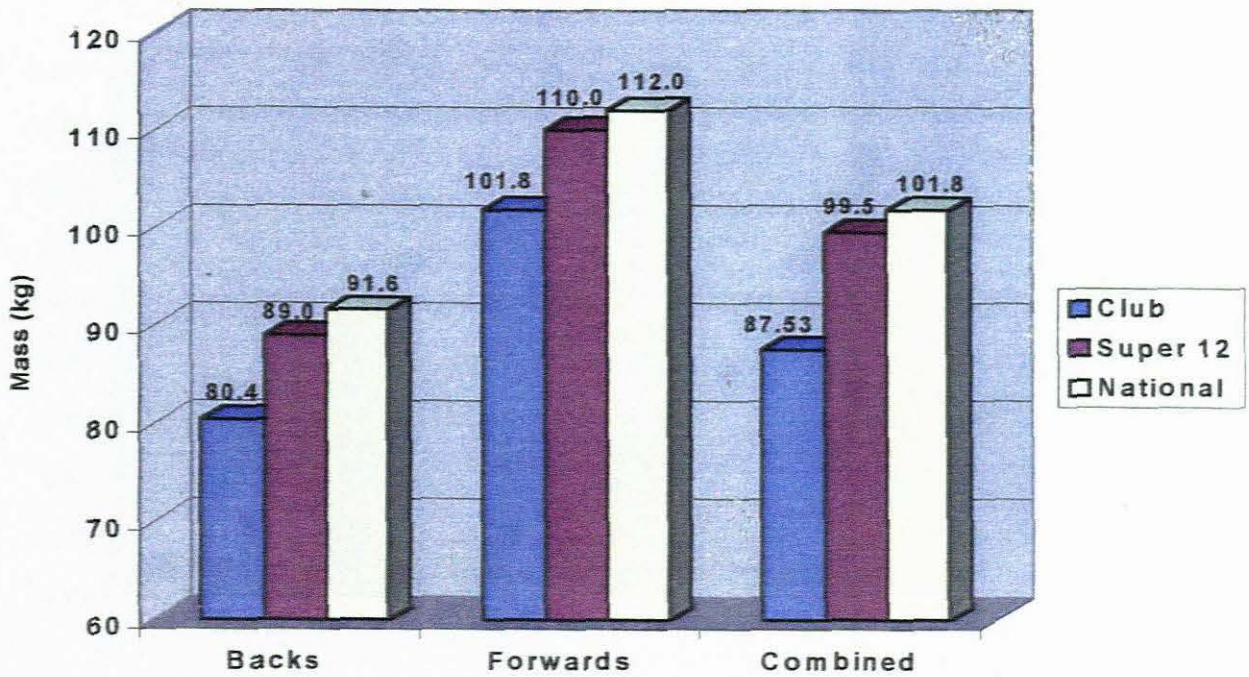
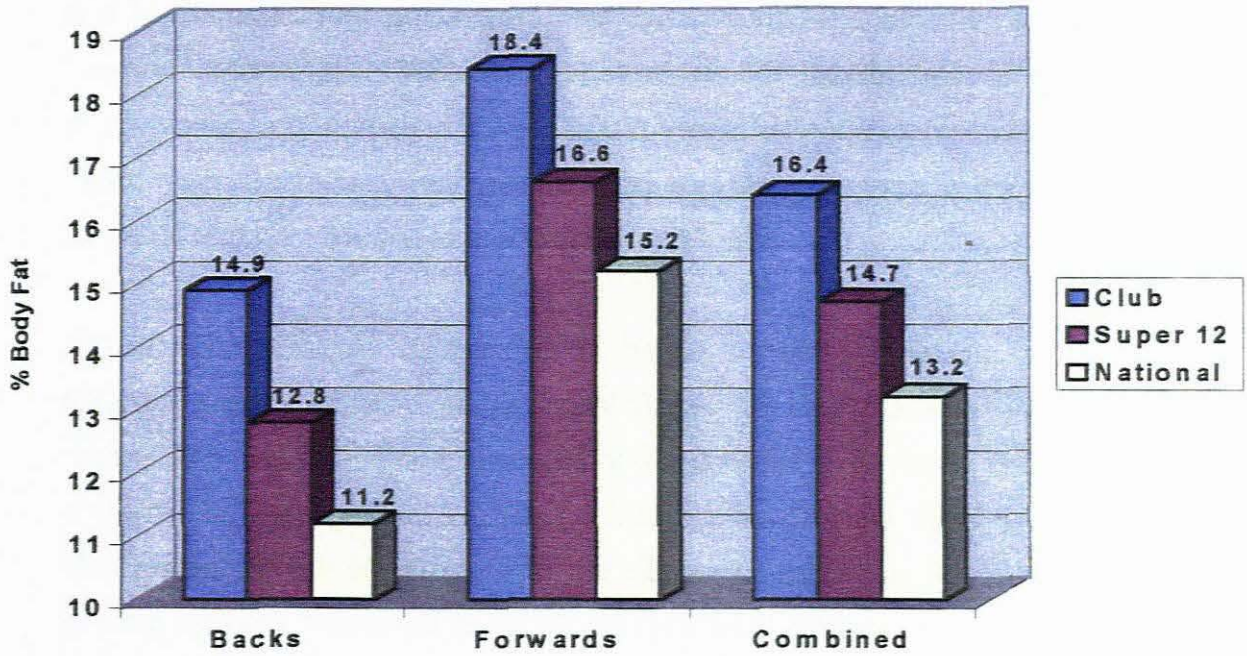


Figure 15. Anthropometric Mean Results of (A.) Stature and (B.) Mass for the subjects of the present study (club), NSW Super 12 team and the Australian national side (Mannings, 1998)

A.



B.

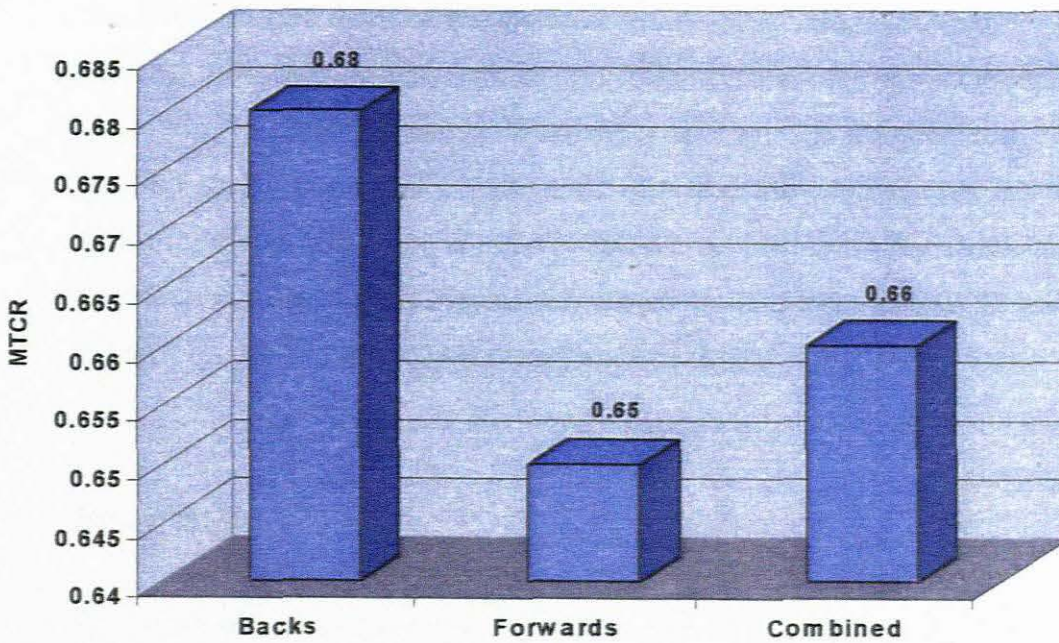


Figure 16. Anthropometric Mean Results of (A.) Body Fat for subjects in the present study (club), NSW Super 12 team and the Australian national side (Mannings, 1998) and (B.) Middle Thigh Calf Ratio (MTCR) for the present study.

and backline players occurred in all age groups and even in senior rugby players. Mannings (1998) also reported similar results from a study on a professional side, namely the New South Wales (NSW) Rugby Union Super 12 Team from Australia. There was a considerable difference in height between forwards and backline players of the Super 12 side.

Figure 15A illustrates differences in height between forwards in the three different groups (present study, NSW Super 12 and the Australian national team). The first league club forwards of the present study measured 188.10 cm and were on average 2.40 cm shorter than forwards of the NSW Super 12 side who measured at 190.50 cm. In the same research the Australian national forward statures measured at 192.6 cm and were 4.50 cm taller than the club side forwards of the present study. This was expected because in the professional game today, to compete successfully as a forward, it is advantageous to be taller. Differences between the backline players' statures of the three groups (club of the present study, NSW Super 12 and the Australian national side) were much smaller, but Figure 15A illustrates constant difference between the three groups. The backs of the first league club sides of the present study measured  $179.20 \pm 6.1$  cm and the professional NSW Super 12 side measured 180.7 cm, a difference of only 1.50 cm. The Australian national backline players' stature measured 184.20 cm and they were 5.00 cm taller than their club counterparts of the present study (Mannings, 1998).

## **Body Mass**

Forwards were on average significantly ( $p < 0.01$ ) heavier at  $101.80 \pm 7.3$  kg compared to backline players with a mean mass  $80.40 \pm 7.3$  kg (see Table I). This is consistent with the physical demands of the different playing positions. Three reasons why the forwards are heavier and taller than backline players are: a) In contact sport and especially for forwards in rugby, momentum plays a very important role in crossing the advantage line and mass is an important

component of momentum. Furthermore, muscle mass and strength correlates. Thus the heavier the player the stronger he would be. Forwards also play in more confined situations where speed and agility are less important and momentum and strength more important. b) Therefore forwards are bigger and stronger than the average backline player because backline players rely more on speed and agility for more open play, while forwards depend more on strength and momentum for their confined playing situations. c) Van Heerden (1996) also said that it is the typical selection policy of coaches to select those players with superior morphological size to be forwards. This was well illustrated in recent research done on a professional NSW side in the Super 12, where the forwards were on average heavier at 110.60 kg, compared to the backline players of 89.00 kg. In the same study the weight of the forwards of the Australian national side was 112.00 kg compared to their back line weight of 91.60 kg (Mannings, 1998). Again it was expected that backline players would weigh considerably less than forwards because they do not have to compete for the ball in the same circumstances as the forwards. In some cases it does happen that a backline player will find himself in a similar situation, but the backline players' first priority is to carry the ball at pace in the backline (Mannings, 1998). This, however, does not rule out the fact that a very heavy player with exceptional speed and agility may become a very good backline player. Jonah Lomu of New Zealand is a good example, his height is 1.92 meters, body mass of 120 kg, however, he sprints the hundred meters in only 11 seconds.

It is noticeable that the players are on average taller and heavier at a more professional competition level. It would appear that the more professional the sport the more competitive the sport and the more advanced the training techniques, and this would presumably result in bigger, heavier and stronger players (Mannings, 1998). Figure 15A (stature) illustrates a linear increase in height for players in the present study to Super 12 to the Australian national level but Figure 15B (mass) illustrated that the increase in mass was not linear. The mass of the NSW Super 12 side and the Australian national side was very similar, but the club sides of the present study weighed on average nine

kilograms less than the NSW Super 12 and the Australian national sides. Thus there was a linear difference in height between the Super 12 and the Australian national side but not in mass between the same sides. This could be explained by the differences in body fat between these sides. The taller national players had a lower fat percentage than the shorter Super 12 players and that resulted in similar body weight between the two sides.

## **Body composition**

Consistent with previous morphological assessments of body composition, a significant difference ( $p < 0.01$ ) in terms of percentage body fat was observed between backline players (14.9%) and forwards (18.4%) (see Table I). Van Heerden (1996) illustrated that among all levels of rugby players 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. Mannings (1998) supported Van Heerden when he illustrated that all rugby players exhibited a high level of bone mass and muscularity, but forwards that have the greatest requirement for strength, power and capacity to absorb impact exhibited the highest muscularity and skinfold measures.

Taking into consideration the aspects of the game forwards are involved in, they need bigger and stronger bodies than the normal backline player. A forward with a bigger body tends to have more body fat due to lesser mobility and therefore lesser aerobic activity than the normal backline player. However, this is not necessarily true in the modern game, because of what is expected of the forwards. Forwards are expected to be as mobile and aerobically active as their backline counter parts. The increasing necessity for greater mobility of the forwards is reflected in lower body fat levels than in the past, but levels are still significantly ( $p < 0.05$ ) greater than the backline players, who have a greater need for speed and agility (Manning, 1998). Figure 16A show that an increase in the level of achievement has an apparent relationship with a decrease in body fat.

## Girths

Girth measurements (Table II) were taken to evaluate the differences between the leg size of the forwards and backline players. It was expected that the forwards would have bigger and stronger legs than backline players due to the more confined situations that they are involved in, for example scrumming, mauling and rucking.

**TABLE II:** Anthropometric Girth results: means and standard deviations for upper thigh, middle thigh, above knee, calf girth and the middle thigh calf ratio for all groups.

Groups	Upper Thigh (cm)	Mid-Thigh (cm)	Above Knee (cm)	CALF (cm)	Mid-Thigh Calf Ratio (cm)
<b>Combined (n=30)</b>	<b>58.6 (5.6)</b>	<b>54.6 (5.1)</b>	<b>40.7 (5.2)</b>	<b>36.5 (2.9)</b>	<b>0.67 (0.07)</b>
<b>Backs (n=20)</b>	<b>55.9 (3.9)</b>	<b>52.5 (4.2)</b>	<b>39.6 (5.0)</b>	<b>35.7 (2.9)</b>	<b>0.68 (0.08)</b>
<b>Forwards (n=10)</b>	<b>64.2 (3.9)</b>	<b>58.9 (3.9)</b>	<b>43.2 (5.0)</b>	<b>38.3 (2.1)</b>	<b>0.65 (0.05)</b>
<b>% difference</b>	<b>+ 14.9</b>	<b>+ 12.2</b>	<b>+ 9.0</b>	<b>+ 7.3</b>	<b>- 3.3</b>
<b>Sig difference</b>	<b>p&lt;0.01 **</b>	<b>p&lt;0.01 **</b>	<b>p&lt;0.05 *</b>	<b>p&lt;0.05 *</b>	<b>p&lt;0.05 *</b>

\* Indicates a significant difference at level  $p<0.05$

\*\* Indicates a significant difference at level  $p<0.01$

Girth measurements for the forwards were on average significantly ( $p<0.01$ ) bigger than the girths of the backline players. The mean upper thigh (UT) girth of the forwards was  $64.2 \pm 3.9$  cm compared to the backline player's UT girth of  $55.9 \pm 3.9$  cm. The forwards' mean middle thigh (MT) girth measured  $58.9 \pm 3.9$  cm and was 6.4 cm bigger than the  $52.5 \pm 4.2$  cm of the backline players girth. The forwards' mean above knee (AK) girth of  $43.2 \pm 5.0$  cm was on average significant ( $p<0.05$ ) bigger at 3.6 cm than the backline players' AK measurement of  $39.6 \pm 5.0$  cm. The mean calf girths of the forwards was at  $38.3 \pm 2.1$  cm, on average 2.6 cm significantly ( $p<0.05$ ) bigger than the  $35.7 \pm 2.9$  cm girth of the backline players. The non-linearity of variations for the different girths of

forwards and backline players should be noted. The difference for UT was 14.9%, for MT it was 12.2%, for AK it was 9.0% and for the Calf it was only 7.3%. This might be interesting and of relevance to this study, where the brace fit could affect external compression, which in turn could play a role in performances of players.

It is apparent that the taller and heavier players are dependent on stronger legs to propel their bodies or limbs around the rugby field. It is also important to remember that girth measurement does not distinguish between muscle and fat (Manning, 1998), and therefore one would expect forwards to have bigger girths because of the significant difference ( $p < 0.01$ ) in body fat percentage observed in the present study between forwards and backline players. Mannings (1998) supported this significant difference between forward and backline players' body fat percentage.

The Middle Thigh Calf Ratio (MTCR) was calculated to compare the correlation between the mean girth of the middle thigh and the calf, between forwards and backline players (see Figure 16B). This revealed that the backline player's ratio was slightly bigger at  $0.68 \pm 0.08$  compared to the forwards' ratio of  $0.65 \pm 0.05$  (see Table II). If the MTCR is calculated from the braces used in the present study, the large brace used for forward had a ratio of 0.83 compared to the ratio of the medium brace used for the backline players of 0.81. Thus forwards with the smaller leg MTCR used the brace with the bigger MTCR, and the backline players with the bigger leg MTCR had to use the brace with the smaller MTCR. This could result in an increased external compression exerted by the brace and a decreased blood flow and reduced performance. It is a very important consideration for the manufacturers of these braces to note, because if the ratios of these braces are not compatible with the legs of their users, then the brace is inadequate and not performing its' intended optimal function. A possible reason for the incorrect or incompatible ratios of these braces could be that the ratios and sizes of the braces were calculated and determined at a time when rugby was not as professional and the players were much smaller. If this is the case, the manufacturers should re-evaluate their MTCR of the braces to

make them more compatible with their target market. It is clear from Tables I and II that forwards and backline players have different morphological characteristics. Forwards need strength and size to compete for the ball in scrums, rucks and mauls and backline players need speed and agility to propel their bodies and limbs at a high speed around the rugby field (Mannings, 1998).

In summing up the basic morphological characteristics of the subjects in the present study, one could conclude that the demands of rugby union at first league level, requires certain desirable physical traits, or as Noakes (1990) suggest, genetic qualities. These traits are quite clear in the diagrammatic representation of the anthropometric data in Figures 15 and 16. Therefore one could forecast the position a player could possibly play before you even see his skills, just looking at his morphological characteristics and traits (Noakes, 1990).

## **RESULTS OF FITNESS AND SKILL COMPONENTS**

### **EFFECT OF BRACING ON SPEED**

Speed is an indication of how quickly motion takes place, i.e. how far an object moves in a specific time. The speedometer of a car, for example, measures how fast its motion is taking place. Speed is therefore the rate at which a distance is traversed or the rate that the body is propelled between two points (Johnson & Nelson, 1986). The word "rate" implies that something occurs per unit time, i.e. per hour or per second. The speedometer, however, gives no indication of the direction in which the motion takes place. Speed is therefore a scalar, which can be calculated as distance traversed over elapsed time (Johnson & Nelson, 1986).

The total time in seconds that it took to complete the 30-meter sprint by each subject provides an accurate prediction of speed. Table III represents the means and standard deviations of the 30-meter sprints completed by subjects.

**TABLE III.** Means and standard deviations (SD) for time in seconds to complete the 30-meter sprints (Braced vs. Non-Braced) for all groups.

Groups	Non-Braced	Braced	% difference	Significant difference
Combined (n=30)	4.509 (0.24)	4.629 (0.25)	+ 2.7	
Backs (n=20)	4.394 (0.16)	4.526 (0.20)	+ 3.0	*
Forwards (n=10)	4.738 (0.19)	4.835 (0.24)	+ 2.0	

\* Indicates a significant difference at level  $p < 0.05$

### Combined Speed

The combined mean 30-meter sprint times for the total group of subjects illustrated an insignificant difference ( $p > 0.05$ ) between the braced and non-braced knee. The sprint time for bracing was  $4.629 \pm 0.25$  seconds or  $6.48 \text{ m} \cdot \text{s}^{-1}$  compared to the  $4.509 \pm 0.24$  seconds or  $6.65 \text{ m} \cdot \text{s}^{-1}$  of the non-braced knee. The difference of 0.12 seconds or  $0.17 \text{ m} \cdot \text{s}^{-1}$  illustrated to be insignificant for a sprint of 30 meters, it means a difference in distance of 0.79 meters. If one takes into consideration that games can be won or lost by one try because a tackle was not made, then this loss of speed could be the difference between winning or losing.

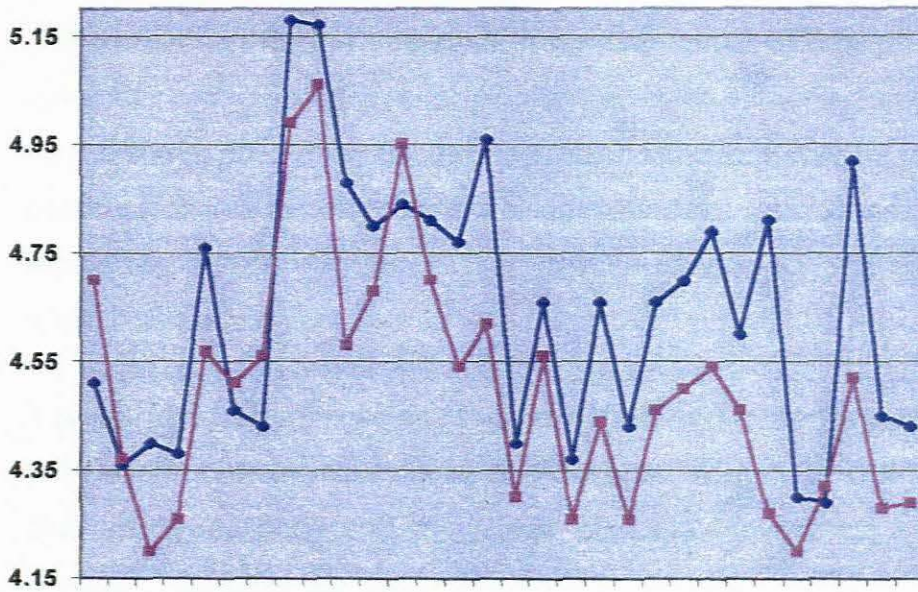
The reasons for the inhibitory effect that prophylactic bracing had on sprint ability and performance (see Figure 17A) was not researched in this study and therefore no definite conclusions can be made as to why bracing decreased sprint performance of these subjects. However, decrease in running speed and performance (see Figure 17A & B) is well documented in literature. Verbrugge (1996) studied the influence of bracing and taping on sprint times. He found that sprint times over 35 meters for subjects with taped knees were 0.10 seconds slower compared to when no support device was worn; and sprint times for subjects with knee braces was 0.15 seconds slower than times when no device was worn (Verbrugge, 1996). Knutzen et al. (1987) also found that bracing

influences sprint times and performance negatively. The differences in the sprint times between bracing and non-bracing might be small, but according to Noakes (1990) on such slim margins hang the fruits of victory in closely fought contests.

It is well known that during walking and running the athletes' legs are very important because they are the support system that move or propel the body from one point to the other. The quadriceps muscles extend the knees and the hamstring muscles are responsible for flexion of the knees. The calf muscles and anterior lower leg muscles stabilize the knee and allow flexion and extension of the ankles (Dorsi and Plantar flexion). Flexion and extension of the knees and ankles complete the walking and running motion of picking the legs up and pushing them forward. With the importance of the legs for walking and running in mind the following factors were identified as factors that could affect speed performance. a) The speed and degrees of flexion and extension of the knees and ankles, reaction forces generated from the ground with flexion and extension of the ankles, b) voluntary and spinal reaction times (response reaction time) of the muscles in the legs and c) the strength of the muscles in the legs. If bracing affects one of these factors, one might expect bracing also to affect sprinting performance. This could have contributed to the decrease in sprinting performance in the present study as depicted in Table III.

If one considers the discomfort and additional weight of the brace (medium 425 grams and large 480 grams), one would think that flexion and extension of the knee could be hampered. This fact was supported by Knutzen et al. (1987) who found that prophylactic knee bracing during straight ahead running decreased knee flexion by 11 to 22%, internal rotation by 33%, external rotation by 22% and varus-valgus by 24%. If bracing influenced dorsi and plantar flexion of the ankles it could affect the ground reaction forces. Knutzen et al. (1988) studied force platform parameters and found that application of knee bracing significantly ( $p < 0.05$ ) changed the ground reaction forces. This alteration in

A.



B.

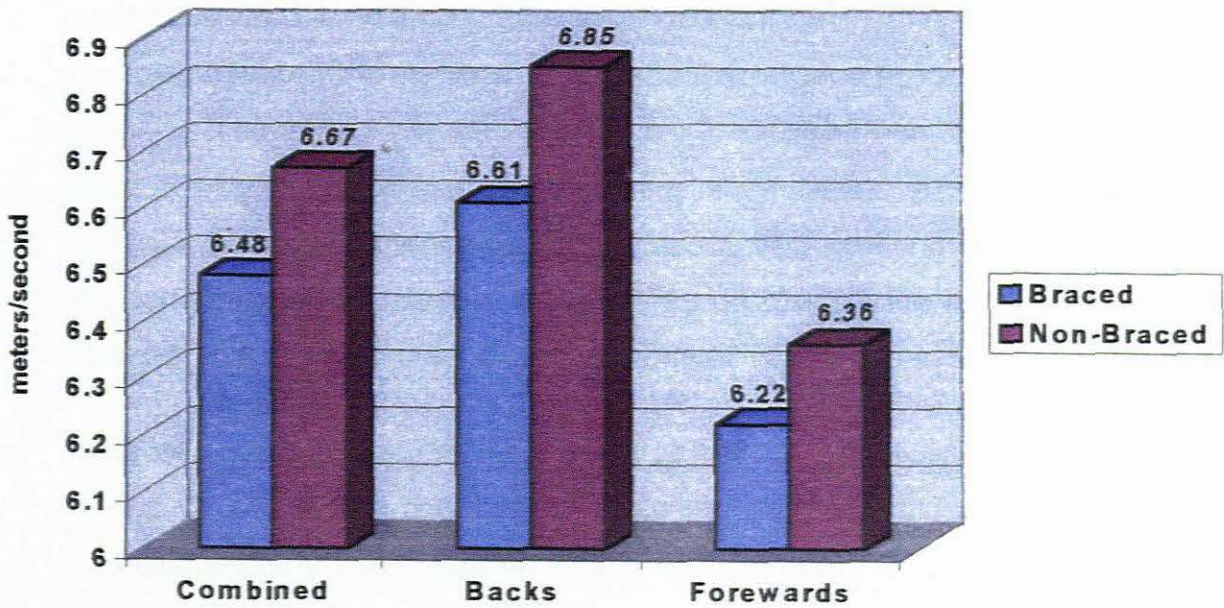


Figure 17. Speed for (A.) Braced and Non-Braced individual subjects in seconds per 30 meters and (B.) Braced and Non-Braced for different groups in seconds per 30 meters.

force generation has shown to be associated with changes in running speed, and the reason for the decrease in running speed is due to alterations in the lower extremity function. Alteration to the lower extremity, which normally acts as the shock absorption for the body, also interferes with the running style and balance. If this is correct and flexion/extension, rotation and ground reaction forces are hampered with bracing, one could suspect that sprint performance might also be hampered.

It is well known that muscles react to stimuli, and depending on the stimuli they will perform certain movements and actions. Stimuli control all movements of muscles in the body and the speed of these movements. As discussed in Chapter Two there are two reactions that are important to muscle movements, voluntary reaction and spinal reaction (response reaction), and they are the reactions to stimuli. Therefore, if these reactions were slowed, it could result in slowed movements of the limbs and the body. This is exactly what Woijtys et al. (1996) found, that at voluntary level the response reaction times in the quadriceps and the hamstring muscles were significantly ( $p < 0.05$ ) slowed, thus the times between the decision to run and the actual run are increased. The spinal reaction times were also significantly ( $p < 0.05$ ) slowed in the medial and lateral quadriceps muscles and lateral hamstring muscles. If the movements of the limbs are slowed then surely one would expect sprinting time to increase and performance to decrease. It is also recognized that leg strength plays an important role in sprinting, for example, if one considers sprinters.

The above-mentioned are all mechanical alterations that could occur during the bracing of knees, but one has to evaluate other possible reasons for the subjects' decreased performance in the sprinting test. One might agree that mechanical alterations seem like the most logical reason for the poor performance but surely mechanical alterations cannot be the only reason.

This is where psychological alterations may come into the equation. After the knee brace was fitted, but prior to the warm-up and testing, all subjects were asked to comment on the feeling of the brace. Interestingly enough the majority

of the subjects had something to say about the brace even before they were asked the question. The results of the pre-test questionnaire revealed that the most common comment was that the brace feels uncomfortable (40%). Another complaint was that the brace felt heavy on the leg (26%). Subjects then took part in a 15-minute warm up with the brace fitted to habituate themselves with the brace. They were not allowed to habituate themselves for a longer period than 15-minutes with the brace due to previous studies that found that wearing of prophylactic braces for long periods could induce muscular atrophy (Zetterlund et al., 1986; Veldhuizen et al., 1991). After the sprint tests had been completed the subjects were again asked to comment on the feeling of the brace. In spite of the habituation of 15-minutes, additional complaints were that it felt like running with a stiff leg (33%), felt heavy and it affected the lifting of the leg (40%). Because the subjects felt uncomfortable and unsure with the brace prior to testing, it was likely to influence their performance. The fact that these attitudes were still apparent after tests were completed could have meant that they were thinking of these factors while they were sprinting. There is a possibility that subconsciously they could have felt that they were going to perform worse.

The major conclusion made is that prophylactic knee bracing does hamper sprint times significantly ( $p < 0.01$ ) and thus performance of the rugby players.

### **Speed for Backline Players**

When one evaluates sprinting times of rugby players it is also necessary to look at the performance of backline players and forwards separately. The brace might have different effects on forwards than on backline players. Table III indicates that there was an insignificant ( $p > 0.05$ ) difference found for 30-meter sprinting times between bracing and non-bracing of backline players. However backline players performed better without the brace, with their braced time  $4.526 \pm 0.2$  seconds or  $6.63 \text{ m} \cdot \text{s}^{-1}$  and non-braced time  $4.394 \pm 0.16$  seconds or  $6.83 \text{ m} \cdot \text{s}^{-1}$ . The difference in times between braced and non-braced knees was

0.132 seconds, which seems like a small difference but in a sprint of 30 meters the difference in distance will be 0.91 meters. In backline play this is a relatively big difference, the difference between tackling the opponent and missing the tackle. Figure 17B illustrates these differences between bracing and non-bracing.

### **Speed for Forwards**

When one evaluates the 30-meter sprint times of forwards one might also expect their sprint performance to be decreased with knee bracing. But one found that the difference between bracing and non-bracing was insignificant ( $p>0.05$ ). From table III the forwards' sprint time with bracing was  $4.835 \pm 0.24$  seconds or  $6.20 \text{ m} \cdot \text{s}^{-1}$  and with non-bracing  $4.738 \pm 0.19$  seconds or  $6.33 \text{ m} \cdot \text{s}^{-1}$ . The difference between bracing and non-bracing the knees was 0.097 seconds and in distance 0.63 meters in a 30-meter sprint; it was insignificant ( $p>0.05$ ), but the difference could still play a role in game situations. Figure 17B illustrates the difference between braced and non-braced knees for the forwards. It seems overall that the forwards adapted to the additional weight and discomfort of the brace somewhat better than the backline players. The reason for this is not that obvious, but one could say that the forwards are conditioned to carry their heavier bodies around the rugby field, and that the additional weight of the brace in relation to their body weight did not interfere with their sprinting ability and style. But for the lighter backline players the additional weight could have interfered with their sprinting ability and style and thus decreased their sprinting times.

### **SPEED OF FORWARDS VERSUS BACKLINE PLAYERS**

If one compares the sprinting ability of backline players with forwards', one would expect the backs to perform better. But since the professional era has arrived that is not necessarily a fact. But when one compares a group of

forwards to a group of backline players it seems more likely that the backline players would be faster.

**TABLE IV.** Means and standard deviations (SD) for time in seconds to complete the 30-meter sprint test for forward and backline players in both variables (Braced vs. Non-Braced).

Test	Variable	Backs (n=20)	Forwards (n=10)	% difference	Significant difference
30-meter Sprint	Braced	4.526 (0.20)	4.835 (0.24)	+ 6.8	
	Non-Braced	4.394 (0.16)	4.738 (0.19)	+ 7.8	

\* Indicates a significant difference at level  $p < 0.05$

\*\* Indicates a significant difference at level  $p < 0.01$

Results in table IV from the present study supports the statement that the backline players' sprinting times over the 30 meters with no brace application would be faster than that of the forwards. The 30 meters sprinting time for the backs was  $4.394 \pm 0.16$  seconds or  $6.83 \text{ m} \cdot \text{s}^{-1}$  compared to the forwards' of  $4.738 \pm 0.19$  seconds or  $6.33 \text{ m} \cdot \text{s}^{-1}$ . In a sprint of 30 meters the non-braced difference in distance between forwards and backline players was 2.37 meters. This difference of 2.37 meters was insignificant ( $p > 0.05$ ). This insignificant difference could be explained due to subject numbers (forwards  $n=10$ , backs  $n=20$ ).

When one compares the braced 30-meter sprint times, similar results were found with an insignificant ( $p > 0.05$ ) difference between forwards and backs, however, forwards were slower. The braced 30-meter sprint time for the backline players was  $4.526 \pm 0.2$  seconds or  $6.63 \text{ m} \cdot \text{s}^{-1}$  compared to the forwards' braced time of  $4.835 \pm 0.24$  seconds or  $6.20 \text{ m} \cdot \text{s}^{-1}$ . In a 30-meter sprint the difference in distance would only be 1.49 meters between the two groups. The results were unexpected because of the significant difference in size of forwards compared to backline players, therefore one would assume that the heavier forwards would be comparatively slower sprinters. Normally

backline players are selected on skill and their ability to accelerate and to maintain their speed over short to relatively longer distances (Mannings, 1998) and forwards on size and strength. However, in the professional era that rugby is finding itself in, forwards are faster and more mobile than in the past.

If one compares the difference in meters between forwards and backs for the non-braced condition, it was 2.37 meters and when braced 1.49 meters. It seems that backs were more affected by the brace than the forwards were. Forwards illustrated an improvement in the difference in meters between forwards and backs when braced, but the improvement was insignificant ( $p > 0.05$ ). The reasons for bracing affecting the performance of the backline players slightly more are not known but one of the possible reasons could be as follows. The prophylactic braces used in this study were all the same length irrespective of the size of the brace and the fact that the leg length of forwards and backline players differ. If one compares the surface area covered by the knee brace it is obvious that a relatively larger area was covered in the backline player's with respect to their leg length. For example the braces no matter what size, were all 30 centimeters (cm) long and the backline players mean leg length were 91 cm and the forwards mean leg length were 96 cm, a 5 cm difference. Therefore less of the forward's leg is covered by the brace in relation to leg length. In comparison, the backline players have a larger surface area covered by the brace than in the case of the forward players. Therefore the larger the area covered by the brace the bigger the influence of the brace on performance.

## **EFFECT OF BRACING ON AGILITY**

Agility is defined as the physical ability that enables rapid and precise change of body position and direction. Agility is important in many sports activities, as exemplified by rugby players in today's professional era (Johnson & Nelson, 1986).

The modified SEMO agility test (Johnston & Nelson, 1986), was used to evaluate the agility of rugby players while performing rugby skills. Table V represents the means and standard deviations of the modified SEMO agility tests completed.

**TABLE V.** Means and standard deviations (SD) for time in seconds to complete the modified SEMO Agility test for all groups.

Groups	Non-Braced	Braced	% difference	Significant difference
<b>Combined</b> (n=30)	<b>24.444 (2.1)</b>	<b>25.708 (2.5)</b>	<b>+ 5.1</b>	
<b>Backs</b> (n=20)	<b>23.453 (1.2)</b>	<b>24.510 (1.1)</b>	<b>+ 4.5</b>	
<b>Forwards</b> (n=10)	<b>26.031 (2.2)</b>	<b>27.630 (3.1)</b>	<b>+ 6.1</b>	

\* Indicates a significant difference at level  $p < 0.05$

### Combined Agility

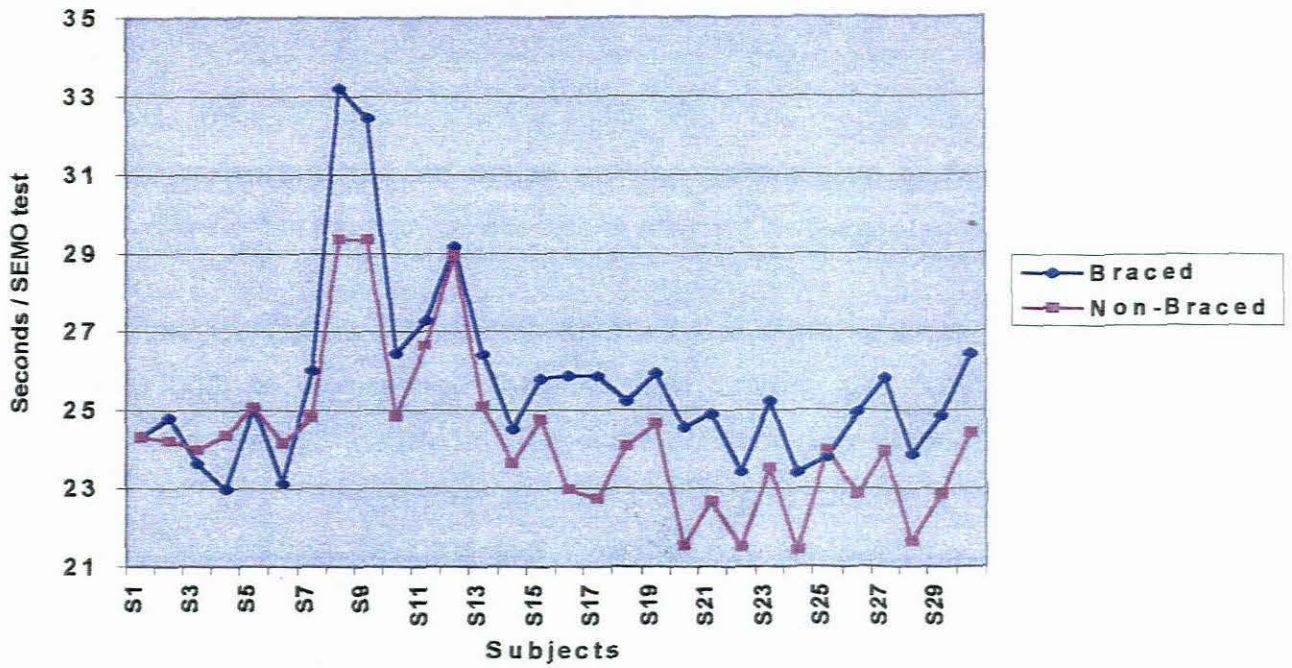
The combined agility performance of the forwards and backline players illustrated an insignificant ( $p > 0.01$ ) difference between braced and non-braced knees. The modified SEMO agility test time for bracing was  $25.708 \pm 2.5$  seconds or  $2.334 \text{ m} \cdot \text{s}^{-1}$  compared to the  $24.444 \pm 2.1$  seconds or  $2.455 \text{ m} \cdot \text{s}^{-1}$  of non-braced knees. The difference of 1.264 seconds ( $0.121 \text{ m} \cdot \text{s}^{-1}$ ) results in a difference in distance of 3.11 meters for the agility test. Figure 18A illustrates the individual agility times of all 30 subjects. Subjects 3, 4 and 6 performed worse without the brace. When these three subjects were asked to explain why they thought they performed better with bracing they replied that they felt more stable and mobile with bracing in the agility test, especially around the corners and during the side-ways movements. Perry (1988) supports the finding of more stability and mobility felt by subjects when braced, when he illustrated an improvement in cutting tests with knees being braced. The explanation by the three subjects that they felt more stable and mobile while taking part in the SEMO agility test with the brace seems like a reasonable explanation for their

improved performance with bracing. When the subjects were asked after completion of the agility test how they felt during the test, 70% said that they felt more in control and stable with bracing especially around the corners, side-ways movements and even backwards movements. If 70% reported better control and stability it indicates that these prophylactic braces supply a perception of knee stability, but from the results it seemed that bracing also interfered with their overall agility performance as measured by the modified SEMO agility test.

An important question is why do these subjects feel more in control and stable but their performance does not reflect the same improvement. One could assume that the feeling of more stability and control could be true on the turns and corners of the test, but that bracing actually interfered with the short sprints in between the turns and corners. Therefore the SEMO agility test might not be specific enough to isolate agility. However, it does closely simulate the activity of rugby and therefore the results obtained are of value for this study.

A further factor to consider is the discomfort and additional weight of the brace. It is expected that flexion and extension of the knee could be hampered, and this would then compromise overall ability to perform motor tasks such as running and jumping. In the previous section on speed performance we saw that both flexion and extension of the knee were significantly ( $p < 0.05$ ) affected with bracing (Knutzen et al., 1987). Furthermore if flexion and extension (Dorsi and Plantar flexion) of the ankles were to be influenced with bracing it could hamper the ground reaction forces generated, this was also seen in the previous section to be significantly ( $p < 0.05$ ) influenced with brace application (Knutzen et al., 1987). This was supported by Osternig et al. (1993) who found that bracing effects specific knee and ankle flexors and extensor muscles by a 73% reduction in EMG activity. Teitz et al. (1987) reported increase in knee injuries in braced football players due to the decrease in agility and potential mobility resulting from brace wear.

A.



B.

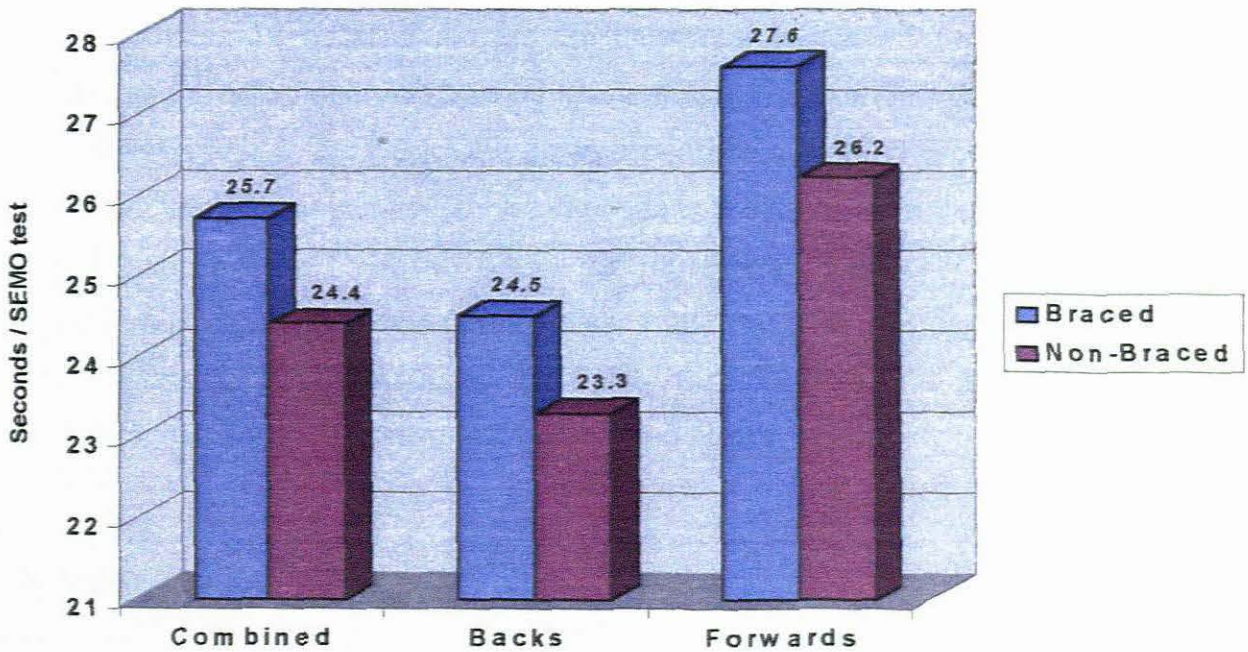


Figure 18. Agility for (A.) Braced and Non-Braced for individual subjects and (B.) Braced and Non-Braced for different groups in seconds to complete the modified SEMO agility test.

The above-mentioned are all mechanical alterations that could occur during the bracing of knees, but one has to evaluate other possible reasons for the subjects' poor performance in the agility test. The mechanical alterations that appear to have influenced speed are the most logical explanation for poor performance, but mechanical alterations may not be the only reason.

Psychological factors can play an important role in performance. Subjects were asked prior to testing how they felt with bracing and 60% said they felt uncomfortable with the brace. The same question was asked after completion of the test and 70% said they felt more stable and in control around the corners and during the side-ways running. One may assume that if they felt better after completion of the test, that the brace had no negative psychological effect on their agility performance during the test.

### **Agility for Backline Players**

Agility times for backline players are illustrated in Table V, where the times between bracing and non-bracing are compared and an insignificant ( $p>0.05$ ) difference was found. Backline players performed better without bracing, with bracing agility time of  $24.510 \pm 1.1$  seconds or  $2.448 \text{ m} \cdot \text{s}^{-1}$  and a time of  $23.453 \pm 1.2$  seconds or  $2.558 \text{ m} \cdot \text{s}^{-1}$  for the non-braced condition. The difference between bracing and non-bracing was 1.057 seconds ( $0.110 \text{ m} \cdot \text{s}^{-1}$ ), which translates to 2.70 meters for the agility test. Figure 18B illustrates these differences between braced and non-braced knees for backline players.

### **Agility for Forwards**

Agility times for forwards were similar to agility times for backs. Table V illustrates braced agility time for the forwards of  $27.630 \pm 3.1$  seconds or  $2.172 \text{ m} \cdot \text{s}^{-1}$  and an agility time of  $26.031 \pm 2.2$  seconds or  $2.305 \text{ m} \cdot \text{s}^{-1}$  for the non-braced condition. The difference between braced and non-braced knees for

agility was insignificant ( $p>0.05$ ) at 1.599 seconds ( $0.133 \text{ m} \cdot \text{s}^{-1}$ ) and translates to 3.67 meters for the agility test. Figure 18B illustrates the difference between braced and non-braced conditions for the forwards.

## AGILITY OF FORWARDS VERSUS BACKLINE PLAYERS

When evaluating the difference between forwards and backline players, one might anticipate that the bigger and heavier forwards would be slower in changing position and direction.

**TABLE VI.** Means and standard deviations (SD) for time in seconds to complete the modified SEMO agility test for forward and backline players for both variables (Braced vs. Non-Braced).

Test	Variable	Backs (n=20)	Forwards (n=10)	% difference	Significant difference
SEMO Agility	Braced	24.510 (1.1)	27.630 (3.1)	+ 12.7	$p<0.05$ *
	Non-Braced	23.453 (1.2)	26.031 (2.2)	+ 11.0	$p<0.05$ *

\* Indicates a significant difference at level  $p<0.05$

\*\* Indicates a significant difference at level  $p<0.01$

From the results in table VI the modified SEMO agility test, the non-braced time for the backline players was  $23.453 \pm 1.2$  seconds or  $2.558 \text{ m} \cdot \text{s}^{-1}$ , significantly ( $p<0.05$ ) faster than the forwards' time of  $26.031 \pm 2.2$  seconds or  $2.305 \text{ m} \cdot \text{s}^{-1}$ . The difference in the non-braced agility time between forwards and backline players was 2.578 seconds ( $0.253 \text{ m} \cdot \text{s}^{-1}$ ) and translates to 6.59 meters for the agility test. The braced agility time for backs was  $24.51 \pm 1.1$  seconds or  $2.448 \text{ m} \cdot \text{s}^{-1}$  and for the forwards  $27.63 \pm 3.1$  seconds or  $2.172 \text{ m} \cdot \text{s}^{-1}$ . The difference for the braced agility performance between backs and forwards was 3.12

seconds ( $0.276 \text{ m} \cdot \text{s}^{-1}$ ) and translates to 7.63 meters. If one compared the difference in meters between forwards and backs when not braced, the difference was 6.59 meters and when braced 7.63 meters. This illustrated that the brace affected the forwards slightly more than the backs but the difference was insignificant ( $p < 0.05$ ). If one considers the big difference in body size, for example in weight and height between forwards and backs, one would have expected a big difference in their agility performance. Newton's first law states that "an object or body will remain at rest or will continue to move uniformly in a straight line or previous direction at a constant velocity unless acted on by a greater force." Considering this law one would expect the bigger heavier bodies to resist any change of momentum and direction even more than the smaller bodies, and thus one anticipates a bigger difference in the time to complete the agility test braced or non-braced.

The reason that comes to mind for the small difference in time between the forwards and backline players is the fact that the game is different for forwards and backline players. In forward play, the distances that they need to accelerate are shorter, for example, from scrums to mauls to rucks are shorter distances (between 2-5 meters). It means that their game incorporates more situations where they need to use agility over short distances, where the backline players need agility over longer distances, for example from backline to backline allows about 20 meters. If this was the reason then one could say that rugby demands this kind of agility from forwards.

## **EFFECT OF BRACING ON PROPRIOCEPTION**

Proprioception is defined as an awareness of joint position in space as sensed by the central nervous system (Swash, 1986). It incorporates joint sensation and spatial orientation (Lephart et al., 1997; Borsa et al., 1997). The central nervous system receives information from specialized nerve endings, or mechanoreceptors, that are located in the skin, muscle, tendon, joint capsule,

and ligaments. Together with vestibular and visual input, mechanoreceptors provide the central nervous system with information about limb position (Baker et al., 1989).

Proprioception is the action-reaction mechanism in the body protecting it against harmful forces, this is an important factor in maintaining joint stability. Therefore voluntary and spinal reflexes are important in sending the messages to the muscles to react and protect the body (Wojtys et al., 1996). Thus if the muscles are fatigued, voluntary and spinal reflex times increase and proprioception performance decreases, this results in a decreased joint stability and probably injury (Perlau et al. 1995; Wojtys et al., 1996). Table VII illustrates proprioception results from the present study.

**TABLE VII.** Means and standard deviations for the time in seconds unbalanced during the two-minute Wilknox Quad Time Logger proprioception test for all groups in both variables (Braced vs. Non-Braced).

Groups	Non-Braced	Braced	% difference	Significant difference
Combined (n=30)	17.850 (9.5)	14.449 (9.2)	- 19.0	p<0.01 **
Backs (n=20)	15.070 (9.5)	11.700 (9.2)	- 22.4	p<0.01 **
Forwards (n=10)	21.160 (9.2)	17.060 (9.3)	- 19.4	p<0.05 *

\* Indicates a significant difference at level p<0.05

\*\* Indicates a significant difference at level p<0.01

### Combined Proprioception

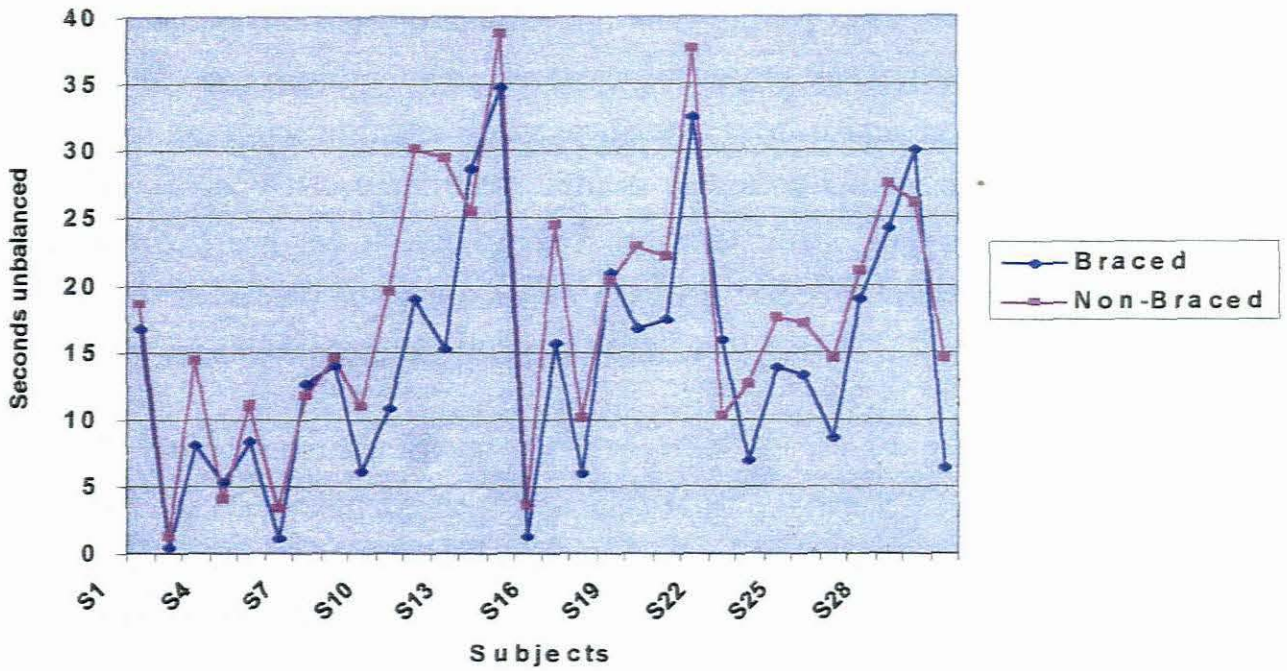
The combined two-minute Wilknox Quad proprioception times for the total group of subjects illustrated a significant (p<0.01) difference between braced and non-braced knees. The mean proprioception time for bracing the knees was 14.449 ± 9.2 seconds, while the non-braced mean time was 17.85 ± 9.5 seconds. This

difference of 3.401 seconds is important in rugby where an injury could occur in a split second, and where the muscles are the only action-reaction mechanism in the body to protect the knee against injury forces. Therefore, the difference of 3.401 seconds could be the difference between tearing or preventing a tear of the knee ligaments.

Figure 19A illustrates the individual proprioception times of all 30 subjects. After completion of the tests subjects were requested to comment on any differences experienced during the tests. Subjects stated that they felt more in control and stable with bracing, and their proprioceptive results have supported their feelings of more control. Improvement in proprioception with brace application is well documented in a study done by McNair et al. (1996), where he examined the effects of bracing on proprioceptive ability of subjects with normal knee joints. The poor mechanical performance of braces in resisting impact forces, together with altered kinematics when wearing a brace during sports activities, has led some researchers to suggest that proprioception is the factor that may be responsible for findings of decreased injury when wearing a brace (McNair et al., 1996).

Literature allows us to speculate on the mechanism of the improved knee proprioception which was achieved with the application of prophylactic knee braces and bandaging. Certainly, afferent receptors in the skin, muscle, ACL, and joint capsule exist, and these contribute to proprioceptive input (Guyton, 1986). Major position sense receptors in the joint capsule and ligaments, such as free nerve endings and golgi tendon organ stretch receptors, could be affected by the elastic bandaging and prophylactic bracing. The bandage and brace certainly stimulates the skin during joint motion and also increases the pressure on the underlying musculature and joint capsule (Guyton, 1986). Therefore, the most plausible receptors to be involved are the rapidly adapting superficial receptors in the skin and layers such as free nerve endings, hair end organs, and Merkels discs.

A.



B.

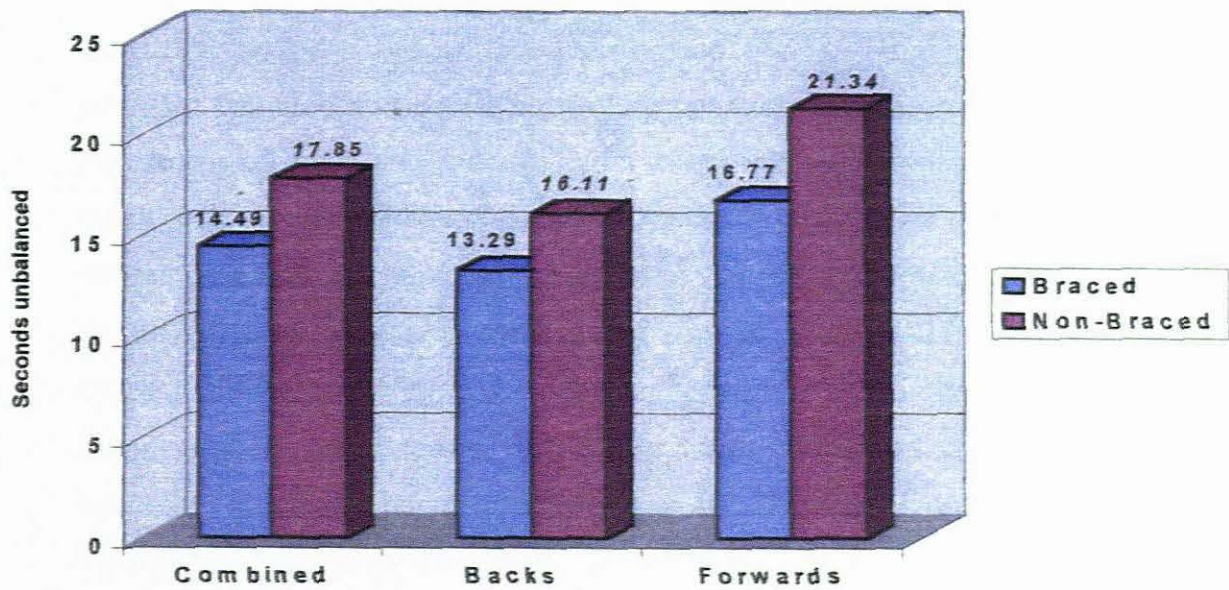


Figure 19. Proprioception for (A.) Braced and Non-Braced knees of individual subjects and (B.) Braced and Non-Braced knees for different groups in seconds unbalanced on the Wilknox Quad Time Logger.

These receptors react strongly to new stimuli, such as movement of the bandage and brace on the skin, and adapt quickly once the motion becomes monotonous (Guyton, 1986). Receptors in deeper skin layers and joint capsule, like flowery organs of Ruffini, could also receive input from the pressure of the bandage (Guyton, 1986). These receptors are tonic, slowly adapting receptors and can provide dynamic and static phase proprioceptive input that would be enhanced by the elastic bandage, but to a lesser degree than the more superficial receptors (Guyton, 1986).

The major conclusion made is that prophylactic knee bracing does improve proprioception performance of injured or healthy subjects. Therefore improved proprioception of first league rugby players could mean the difference between injury and no injury.

### **Proprioception for Backline Players**

The combined mean proprioception time illustrated a significant ( $p < 0.01$ ) difference between braced and non-braced knees. But it is necessary to evaluate forwards and backs separately because they normally have different morphological build and bracing might affect them differently. Evaluating the mean proprioception times of backline players in table VII, a significant ( $p < 0.01$ ) difference between braced and non-braced knees was found, bracing time of  $11.70 \pm 9.2$  seconds and non-bracing time of  $15.07 \pm 9.5$  seconds. Thus bracing decreased the proprioception times and so increased backline proprioception performance. The significant difference ( $p < 0.01$ ) in times between braced and non-braced knees was 3.37 seconds and, as said before, injuries can occur in split seconds, therefore any increase in performance could prevent injury.

Figure 19B illustrates differences between bracing and non-bracing for the backline players. Proprioception is important for backline players because of the fact that backline players are involved in high speed running and tackling.

Proprioception is the action reaction mechanism against large forces on the body, and at the rate that tackling is occurring in the backline this mechanism is probably tested to its limit. Therefore the results from the present study appears to present positive news for backline players because bracing could help reduce serious injuries in backline play and sport.

### **Proprioception for Forwards**

In table VII one found that proprioception times for forwards were significantly ( $p < 0.05$ ) different between bracing and non-bracing. It was interesting that the difference between bracing and non-bracing was only significant at level ( $p < 0.05$ ) whereas for the backline players the difference was significant at level ( $p < 0.01$ ). Forwards' proprioception time for bracing was  $17.06 \pm 9.3$  seconds and for non-bracing of the knees was  $21.16 \pm 9.2$  seconds. The difference of 4.1 seconds was significant ( $p < 0.05$ ) and favored bracing of the knees.

Figure 19B illustrates differences between bracing and non-bracing for the forwards. The reason for the difference only being significant at level ( $p < 0.05$ ) between bracing and non-bracing compared to the backline significance at level ( $p < 0.01$ ), is due to the number of subjects tested. The t-critical value increases with a decrease in subjects, therefore the more subjects tested increases the power of the test. However, as said before, injuries occur in split seconds and if bracing can improve proprioception performance just a little it could result in the prevention or reduction of injuries on the sport field.

## **PROPRIOCEPTION OF FORWARDS VERSUS BACKLINE PLAYERS**

Evaluating the difference in proprioception between forwards and backline players one expects the taller and heavier forwards with a higher center of gravity to perform worse than the backline players in balancing tasks. However,

if one considers different sports such as pole vault and high jump where sportsmen need a high level of joint positioning in space, as sensed by the central nervous system, to perform well in their sport. These sportsmen are also tall and strong with high centers of gravity, but perform in their sports. The last example counters the statement that tall and heavy subjects might perform worse in balancing tasks. Therefore it is not a concluded fact that tall and heavy sportsmen would perform worse than their shorter and lighter counterparts. Results of proprioception performance of rugby players can be seen in Table VIII.

**TABLE VIII.** Means and standard deviations for the time in seconds unbalanced during the two-minute Wilknox Quad Time Logger proprioception test for forwards and backline players.

Test	Variable	Backs (n=20)	Forwards (n=10)	% difference	Significant difference
Time / 2 minutes	Braced	11.700 (9.2)	17.060 (9.3)	+ 45.81	p<0.01 **
	Non-Braced	15.070 (9.5)	21.160 (9.2)	+ 40.41	p<0.01 **

\* Indicates a significant difference at level  $p<0.05$

\*\* Indicates a significant difference at level  $p<0.01$

From Table VIII the non-braced proprioception time for the backline players was  $15.07 \pm 9.5$  seconds and for the forwards  $21.16 \pm 9.2$  seconds. The difference in the non-braced proprioception time between forwards and backline players illustrated an insignificant ( $p<0.01$ ) difference of 5.36 seconds. The braced proprioception time for the backline players was  $11.70 \pm 9.2$  seconds and for the forwards  $17.06 \pm 9.3$  seconds, also a significant ( $p<0.01$ ) difference, but this time the difference was 6.09 seconds. From the results in table VIII it was clear that forwards performed worse in proprioception in both variables, braced or non-braced, and that the backline players' proprioception performance improved more than the forwards' performance with bracing.

The difference in the proprioceptive improvement was significantly ( $p < 0.05$ ) in favor of the backline players.

Researchers imply that the pressure of the knee brace against the skin, receptors and ligaments creates the improved messaging of impulses and therefore better performance in proprioception. Thus the larger surface area that is in contact with these braces creates a larger contact area on these receptors, skin and ligaments and an even more improved messaging of impulses. If one consider the length of the forwards legs compared to those of the backline players' legs there is a difference. The prophylactic braces used in this study are all the same length irrespective of the size of the brace and the fact, that the leg length of forwards and backline players differs' creates the following assumption. If one compares the surface area covered by the knee brace it is obvious that a larger area is covered in backline players in relation to their leg length. For example the brace was 30 centimeters (cm) long no matter what size (S, M, L). The mean leg length of the backline players was 91 cm and the mean leg length of the forwards 96 cm, this resulted in a difference of 5 cm and thus less of the forward's leg is covered by the brace. Thus in comparison the backline players have a larger surface area covered by the brace than in the case of the forward players, which might increase the tactile sensation of the limbs and therefore increase their proprioceptive score.

In conclusion one can say that the forwards performed worse than the backline players in the proprioception test for both variables, and that the backline players' proprioception performance improved more than the forwards' proprioception performance with bracing.

## EFFECT OF BRACING ON STRENGTH

In the present study, isokinetic testing was used to determine the influence of bracing on strength performance. Isokinetic training and testing is attractive because it has a fixed speed with a variable resistance that is totally accommodating to the individual throughout the range of motion (Davies, 1987). Therefore, the velocity is constant at a pre-selected dynamic rate where the resistance varies to exactly match the force applied at every point in the range of motion. Thus the muscles can be overloaded through a full range of motion and at a variety of muscles' shortening velocities (Davies, 1987). Results are presented as extensions of the knee (quadriceps strength) in table IX and flexion of the knee (hamstring strength) in table X.

### Combined Isokinetic Knee Extension Performance

Extension of the knee represents the straightening action of the knee and is accomplished by the function of the quadriceps muscles. Extension results can be observed in Table IX.

**TABLE IX.** Means and standard deviations (SD) for Extension Torque in the Akron Isokinetic Strength test of Braced versus Non-Braced for all groups in Newton meters.

Groups	Extension (Nm)		% difference	Significant difference
	Non-Braced	Braced		
<b>Combined</b> (n=30)	<b>221.63 (39.0)</b>	<b>219.80 (47.5)</b>	- 0.8	
<b>Backs</b> (n=20)	<b>203.96 (35.0)</b>	<b>200.20 (50.6)</b>	- 1.8	
<b>Forwards</b> (n=10)	<b>248.13 (27.7)</b>	<b>249.30 (30.7)</b>	+ 0.5	

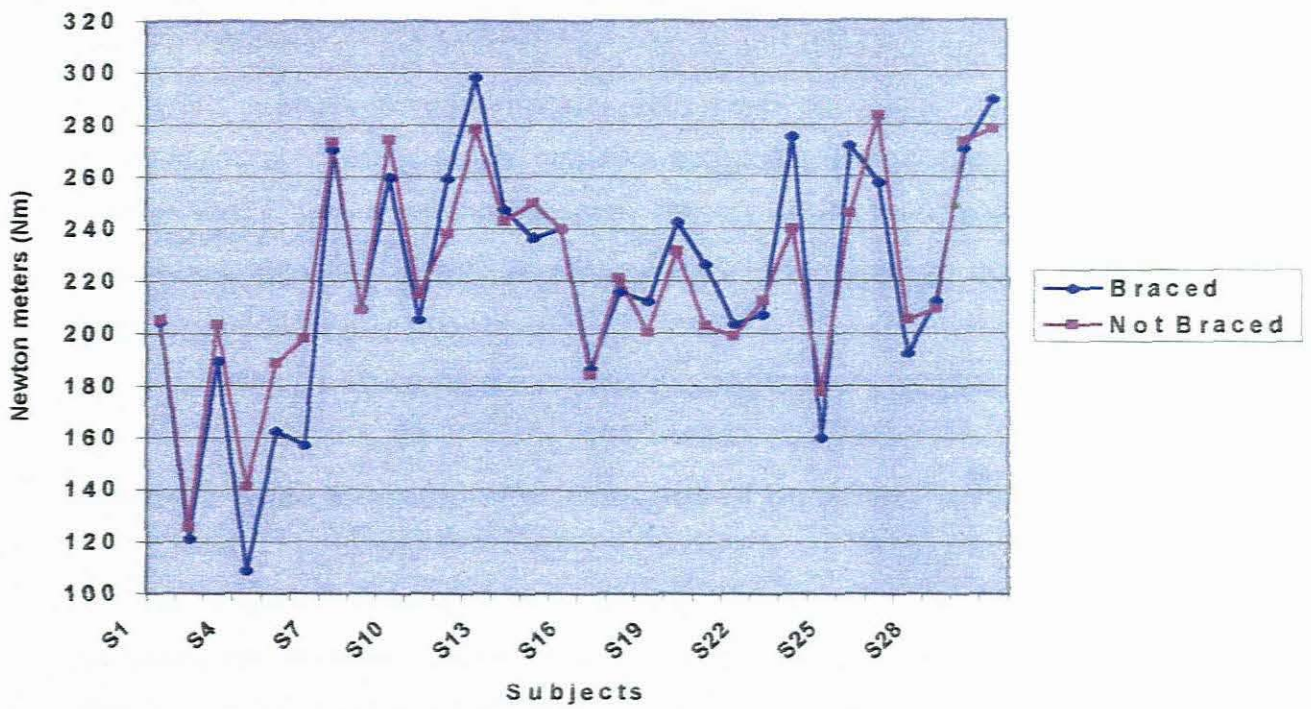
\* Indicates a significant difference at level  $p < 0.05$

\*\* indicates a significant difference at level  $p < 0.01$

The combined extension torque for the total group of subjects illustrated an insignificant ( $p>0.05$ ) difference between bracing and non-bracing. From table IX the extension torque for bracing the knees was  $219.8 \pm 47.5$  Nm and for non-bracing  $221.63 \pm 39.0$  Nm. This difference of 1.83 Nm, qualified as being insignificant ( $p>0.05$ ) and having little influence on the performance of the rugby players. This small difference in extension torque performance is well documented in Highenboten et al. (1991) and Wojtys et al's. (1996) research. They discovered that during isokinetic testing, the brace slightly inhibited performance of the quadriceps muscles but the differences were insignificant ( $p>0.05$ ).

Figure 20A, illustrates the individual extension torque of all 30 subjects. Subjects 11, 12, 13, 18, 19, 20, 23, 25 and 30 improved their performance with their knees being braced. This was supported by Lysholm et al. (1984) who found that extension performance increased slightly for injured players, however this was not the case for healthy subjects. The rest of the 30 subjects performed worse with bracing and this supports the fact that the effect of bracing on the leg extension and thus strength performance is probably very individualistic. Houston & Goemans. (1982) and Wojtys et al. (1996) supported the finding that bracing decreases performance in knee extension. Thus, the result from the present study illustrates that each subject and player may be affected differently with brace application. Therefore, the player's performance in knee extension when braced cannot be predicted and it is the player's choice whether to use bracing or not. The results from the strength tests in the present study resolved the question about the affect that prophylactic bracing would have on strength performance. In the case of extension (quadriceps muscles) the study found an insignificant ( $p>0.05$ ) decreased extension performance.

A.



B.

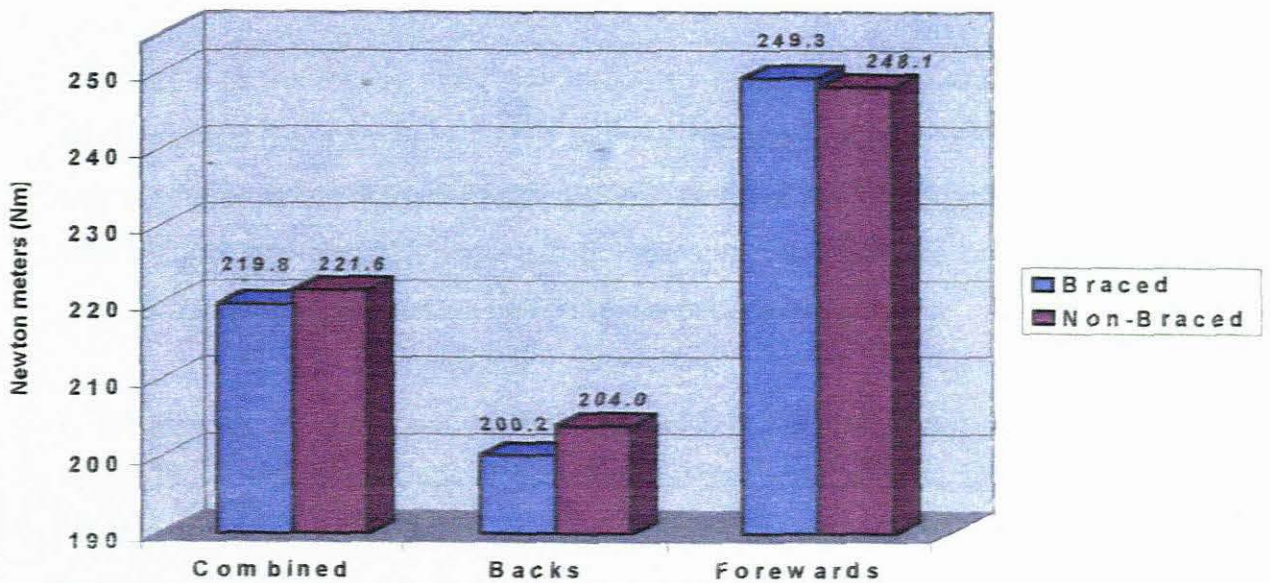


Figure 20. Extension Torque (Nm) for (A.) Braced and Non-Braced knees for the combined group and (B.) Braced and Non-Braced knees for different groups on the Akron isokinetic tester.

The major conclusion was that prophylactic knee bracing had no significant ( $p>0.05$ ) influence on leg strength (extension) and does not appear to hamper the player's strength and performance. This is well documented in the research of Valias et al. (1993), which noted a marginally insignificant reduction of strength with prophylactic knee bracing. Sforzo et al. (1989) also reported an insignificant ( $p>0.05$ ) affect of prophylactic knee bracing upon isokinetic dynamometry in football players.

### **Isokinetic Knee Extension Performance of Backline Players**

It is also important to look at forwards and backline players separately when evaluating the extension performance of rugby players. The brace covers the hamstring, quadriceps and calf muscles and might have different effects on the forwards and backs because of the differences in the morphological composition of their legs (see Table II). Is it possible that backline extension performance could be significantly influenced.

From table IX the braced extension torque for the backline players was  $200.20 \pm 50.6$  Nm and the extension torque without bracing  $203.96 \pm 35.0$  Nm. There was a difference of 3.76 Nm favoring non-bracing of the knees but the difference was insignificant ( $p>0.05$ ). Figure 20B illustrates the difference between bracing and non-bracing for extension performance of backline players.

It has already been mentioned that the backline players have well-trained and strong legs. The quadriceps (Extension muscles) needs to be strong to ensure rapid extension of the legs. Extension involves the lifting of the legs, and pushing them forward, ready for the next stride. One would have expected that the additional weight of the brace would have interfered with the ability to extend the knee powerfully. However, the present study's results illustrated that the effect of bracing on extension performance of backline players was insignificant ( $p>0.05$ ) and should be ignored.

## **Isokinetic Knee Extension Performance of Forward Players**

From table IX the braced extension torque for the forward players was  $249.30 \pm 30.7$  Nm and the extension torque without bracing  $248.13 \pm 27.7$  Nm. There was a small insignificant ( $P > 0.05$ ) difference of 1.17 Nm that favored bracing of the knees. Figure 20B, illustrates the small difference between bracing and non-bracing for extension performance of forwards. The backline player's extension performance supported non-bracing of the knees while the extension performance of the forwards favored bracing of the knees. These differences are very small and insignificant ( $p > 0.05$ ).

In examining the quadriceps muscle of forward players, the most prevalent physical quality observed, was that forwards had short mesomorphic-endomorphic or long mesomorphic legs. The reason for their strong legs was to transport their heavy bodies around the rugby field. It could be expected that their extension torque should respond well to bracing but only when there are no mechanical problems with the brace as that could hamper movement. In the present study, the results showed no significant ( $p > 0.05$ ) difference between bracing and non-bracing for extension strength performance in forwards.

In conclusion, one could say that prophylactic knee bracing have increased extension performance of forwards slightly but the increase was insignificant ( $p > 0.05$ ).

## **Combined Isokinetic Knee Flexion Performance**

Flexion of the knee represents the bending action of the knee and is accomplished by the function of the hamstring muscles. Flexion performance results can be observed in Table X.

**TABLE X.** Means and standard deviations (SD) for Flexion Torque in the Akron Isokinetic Strength test for Braced versus Non-Braced for all groups.

Groups	Flexion (Nm)		% difference	Significant difference
	Non-Braced	Braced		
Combined (n=30)	201.09 (46.8)	198.30 (50.1)	- 1.4	
Backs (n=20)	180.56 (38.8)	173.60 (48.8)	- 3.9	
Forwards (n=10)	231.88 (42.5)	235.40 (38.9)	+ 1.5	

\* Indicates a significant difference at level  $p < 0.05$

\*\* Indicates a significant difference at level  $p < 0.01$

The combined flexion torque for the total group of subjects illustrated no significant ( $p > 0.05$ ) difference between bracing and non-bracing. The flexion torque for bracing the knees in table X was  $198.30 \pm 50.1$  Nm and for non-bracing  $201.09 \pm 46.8$  Nm. The difference of 2.79 Nm was considered insignificant ( $p > 0.05$ ) and should have little influence on the performance of the rugby players. In the research of Carl et al. (1991) this insignificant difference in flexion torque performance was well documented, he found that with isokinetic testing brace application slightly decreased performance of all four hamstring muscles but that these differences were insignificant. These findings were supported by Wojtys et al. (1996).

Figure 21A, illustrates the individual torque of all 30 subjects. Subjects 1, 2, 3, 11, 12, 13, 23 and 30 of the present study improved their performance with bracing. Researchers have not supported these results for healthy subjects, although Lysholm et al. (1984) demonstrated an increase in flexion performance for slightly injured players. The other subjects performed worse with bracing and these results are well supported by researchers (Houston & Goemans., 1982; Wojtys et al., 1996).

The players' whose performance increased with bracing, did so tremendously, while those who struggled with the brace, performed slightly worse. Thus, these results show that the effect of prophylactic knee bracing on knee flexion is probably very individualistic. When one subject's performance increased another's performance decreased. This type of result calls for further data to try to find the reasons for this variability.

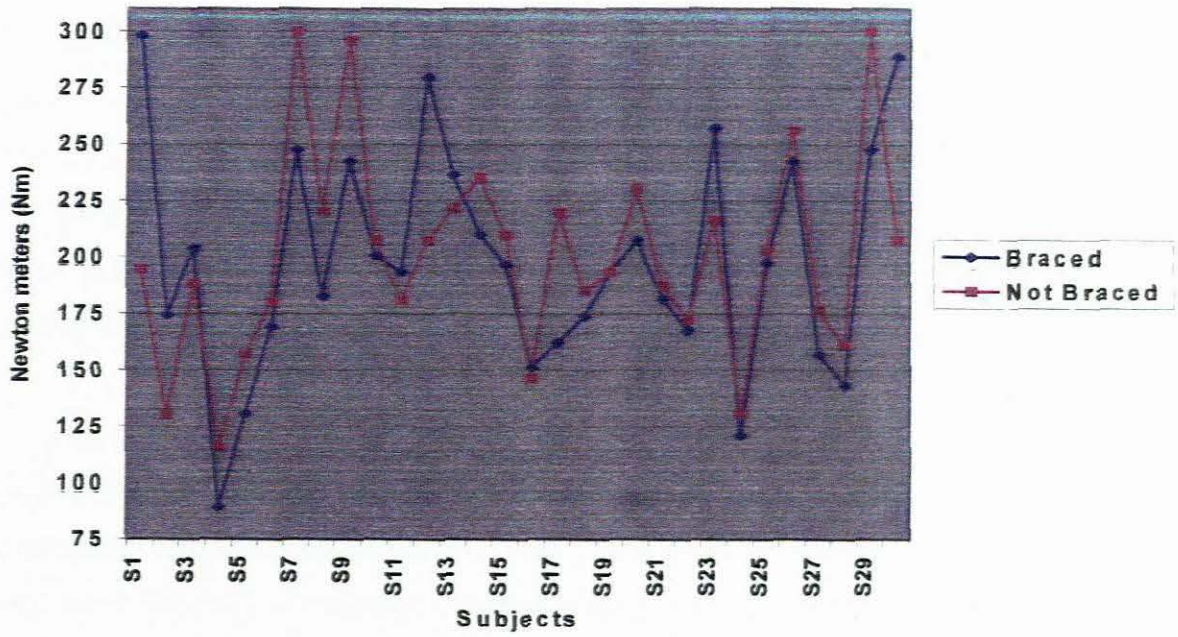
The conclusion drawn from the results of the present and other studies is that prophylactic knee bracing has an effect on the players' flexion performance but the effect varies from player to player and thus the difference is insignificant ( $p>0.05$ ). Therefore flexion torque response to knee bracing cannot be predicted and the player has to experiment with knee bracing to determine if he or she would benefit from the brace or not.

### **Isokinetic Knee Flexion Performance for Backline Players**

When flexion performance of rugby players is evaluated it is also necessary to look at the performance of backline players and forwards separately. The brace might have different effects on forwards and backline players. From table X the braced flexion torque for the backline players was  $173.60 \pm 48.8$  Nm and the non-braced flexion torque  $180.56 \pm 38.8$  Nm. There was a slight difference of 6.96 Nm favoring non-bracing of the knees but the difference was regarded as insignificant ( $p>0.05$ ). Figure 21B illustrates the effect of bracing on backline flexion performance.

Backline players' flexion (hamstrings muscles) are well trained and strong to ensure optimal ability to sprint across the rugby field. One would have expected that the additional weight of the brace would have decreased flexion torque performance tremendously, because subjects indicated the discomfort of the brace during flexion of the knee. However, the results of the present study illustrated that the effect of bracing on flexion performance for backline players was insignificant ( $p>0.05$ ).

A.



B.

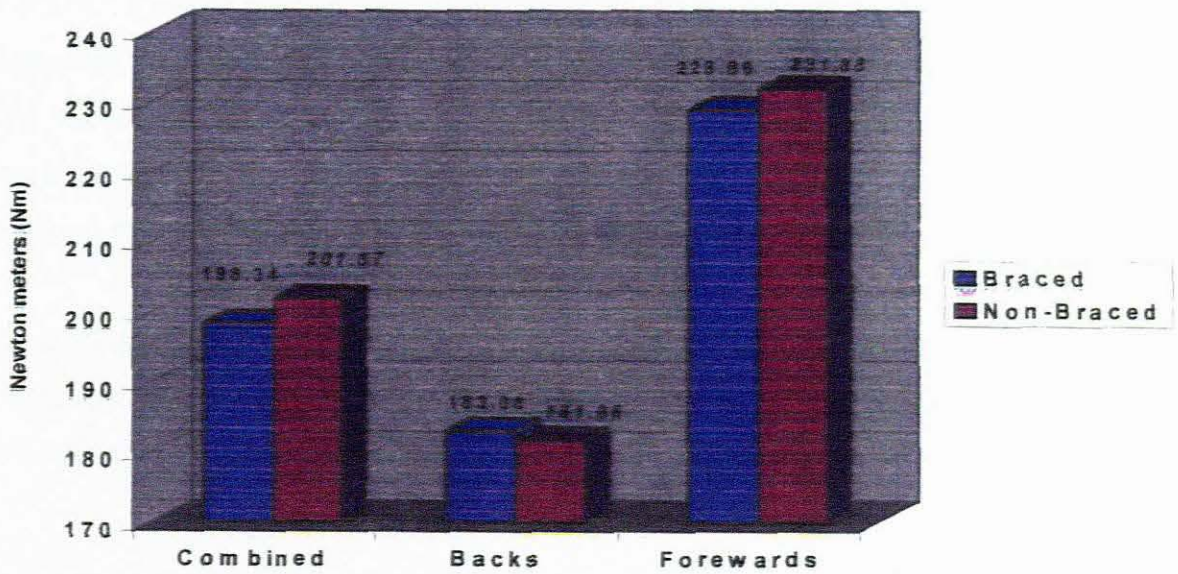


Figure 21. Flexion Torque (Nm) for (A.) Braced and Non-Braced knees for the combined group and (B.) Braced and Non-Braced knees for different groups on the Akron isokinetic tester.

## Isokinetic Knee Flexion Performance for Forward Players

The question that arises now is will prophylactic knee bracing affect knee flexion performance in forward players. Braced flexion torque for the forward players was  $235.40 \pm 38.9$  Nm and the flexion torque without bracing was  $231.88 \pm 42.5$  Nm (Table X). There was a slight difference of 3.52 Nm favoring bracing of the knee but the difference was insignificant ( $p > 0.05$ ). Figure 21B illustrates the difference with bracing and non-bracing for the forwards.

In examining the legs of forward players, there were two types of leg developments. The most prevalent types were short mesomorphic-endomorphic or long mesomorphic legs. The short mesomorphic-endomorphic legs were normally considered the very strong legs, which belonged to the three front rows. The long mesomorphic legs belonged to the locks and loose forwards. The forwards legs are very strong no matter if they were short or long, and the strength of their legs is very important because their legs are required to transport their heavy bodies around the rugby field. Therefore, one would have expected their flexion torque to respond to bracing without a problem because of the relation of brace weight to body weight. The results in the present study have illustrated that there was no significant ( $p > 0.05$ ) difference in flexion performance for the forwards between bracing and non-bracing.

In conclusion, one could say that prophylactic knee bracing does appear not to decrease flexion performance of forwards significantly ( $p > 0.05$ ) and that the use of knee bracing was not affected by body size.

## ISOKINETIC KNEE EXTENSION OF FORWARDS VERSUS KNEE EXTENSION OF BACKLINE PLAYERS

When evaluating forward and backline players, one could assume that the taller and heavier forwards would perform better in the extension strength test. Results of the forwards' and backline players' extension performance of both variables braced and non-braced can be seen in tables XI and XII.

**TABLE XI.** Mean and standard deviations (SD) for Peak Extension Torque in Newton meters of forwards and backline players in the Akron Isokinetic Strength test.

Test	Variable	Backs (n=20)	Forwards (n=10)	% difference	Significant difference
Torque (Nm)	Braced	200.20 (50.6)	249.30 (30.7)	+ 24.5	p<0.01 **
	Non-Braced	203.96 (35.0)	248.13 (27.7)	+ 21.7	p<0.01 **

\* Indicates a significant difference at level p<0.05

\*\* Indicates a significant difference at level p<0.01

**TABLE XII.** Mean and standard deviations (SD) for Relative Extension Torque in Newton meters per kilogram of forwards and backline players in the Akron Isokinetic Strength test.

Test	Variable	Backs (n=20)	Forwards (n=10)	% difference	Significant difference
Torque (Nm · kg <sup>-1</sup> )	Braced	2.49 (46.4)	2.49 (31.4)	0	
	Non-Braced	2.54 (34.6)	2.44 (26.4)	- 3.9	

\* Indicates a significant difference at level p<0.05

\*\* Indicates a significant difference at level p<0.01

The backline players' non-braced extension torque was  $203.96 \pm 35.0$  Newton meters (Nm) and the forwards' non-braced extension  $248.13 \pm 27.7$  Nm. Therefore, the forwards' extension torque performance was stronger than those of the backline players. The significant ( $p < 0.01$ ) difference of 44.17 Nm illustrates that backline players' non-braced extension performance was 17.80% worse than the forwards' non-braced extension performance. The braced extension torque of the backline players was  $200.20 \pm 33.0$  Nm and the forwards' braced extension torque was  $249.30 \pm 36.0$  Nm, with a significant ( $p < 0.01$ ) difference of 49.10 Nm or 21.7 % (see Table XI). Figure 22B clearly illustrates the differences in extension strength between forwards and backline players for both variables (Braced and Non-Braced).

When relative extension values i.e.  $\text{Nm} \cdot \text{kg}^{-1}$  were evaluated interesting results were found. The bracing values for the forwards was  $2.49 \text{ Nm} \cdot \text{kg}^{-1}$  compared to the backline value of  $2.49 \text{ Nm} \cdot \text{kg}^{-1}$ . The forward value for non-bracing was  $2.44 \text{ Nm} \cdot \text{kg}^{-1}$  compared to the backline value of  $2.54 \text{ Nm} \cdot \text{kg}^{-1}$ . From these results, one can conclude that the relative ( $\text{Nm} \cdot \text{kg}^{-1}$ ) extension performance of forwards and backs when braced was highly comparable. However, the backline players' non-braced condition illustrated better extension performance than the forwards did. The forwards' extension performance improved with bracing but backline players' decreased with bracing (see Table XII).

It is obvious that the taller, bigger and heavier bodies would need a larger and stronger support system (legs) to propel the body around the rugby field. Therefore, it would be expected that there was a significant difference in performance for flexion and extension between the forwards and backline players. It was concluded from the girth measurements that the leg size of the forwards was physically larger than those of the backline players. It is however, important to remember that girth measurements do not distinguish between muscle and fat layers. Therefore, one would also have expected forwards to have larger girths because of the significant difference in body fat percentage between forwards and backline players (Mannings, 1998).

Therefore, one would also have assumed that with larger and heavier legs they would need more leg muscles to carry the body around the rugby field. If the forwards have more leg muscle than the backline players one would have expected them to perform better in flexion and extension strength tests. When considering a forward's function in the game, which entails scrumming, rucks and mauls, it is almost essential that they develop strong legs. However, a backline player also requires strength for speed and agility, but short mesomorphic-endomorphic legs would restrict their ability to sprint. Therefore, it is imperative that forwards develop big strong legs, as speed is not their most important function.

### ISOKINETIC KNEE FLEXION FOR FORWARDS VERSUS KNEE FLEXION OF BACKLINE PLAYERS

When evaluating the difference between forward and backline players, it could be expected that the taller and heavier forwards would perform better in the flexion strength test than the shorter more slender backline players. Results for the forwards and backline players' flexion performance of both variables braced and non-braced can be seen in table XIII.

**TABLE XIII.** Means and standard deviations (SD) for Peak Flexion Torque in Newton meters of forwards and backline players in the Akron Isokinetic Strength test.

Test	Variable	Backs (n= 20)	Forwards (n= 10)	% difference	Significant difference
Torque (Nm)	Braced	173.60 (48.8)	235.40 (38.9)	+ 35.6	p<0.01 **
	Non-Braced	180.56 (38.8)	231.88 (42.5)	+ 28.4	p<0.01 **

\* Indicates a significant difference at level  $p<0.05$

\*\* Indicates a significant difference at level  $p<0.01$

**TABLE XIV.** Means and standard deviations (SD) for Relative Flexion Torque in Newton meters per kilogram of forwards and backline players in the Akron Isokinetic Strength test.

Test	Variable	Backs (n= 20)	Forwards (n= 10)	% difference	Significant difference
Torque (Nm · kg <sup>-1</sup> )	Braced	2.16 (57.8)	2.31 (38.4)	+ 6.9	
	Non-Braced	2.25 (35.6)	2.28 (40.5)	+ 1.4	

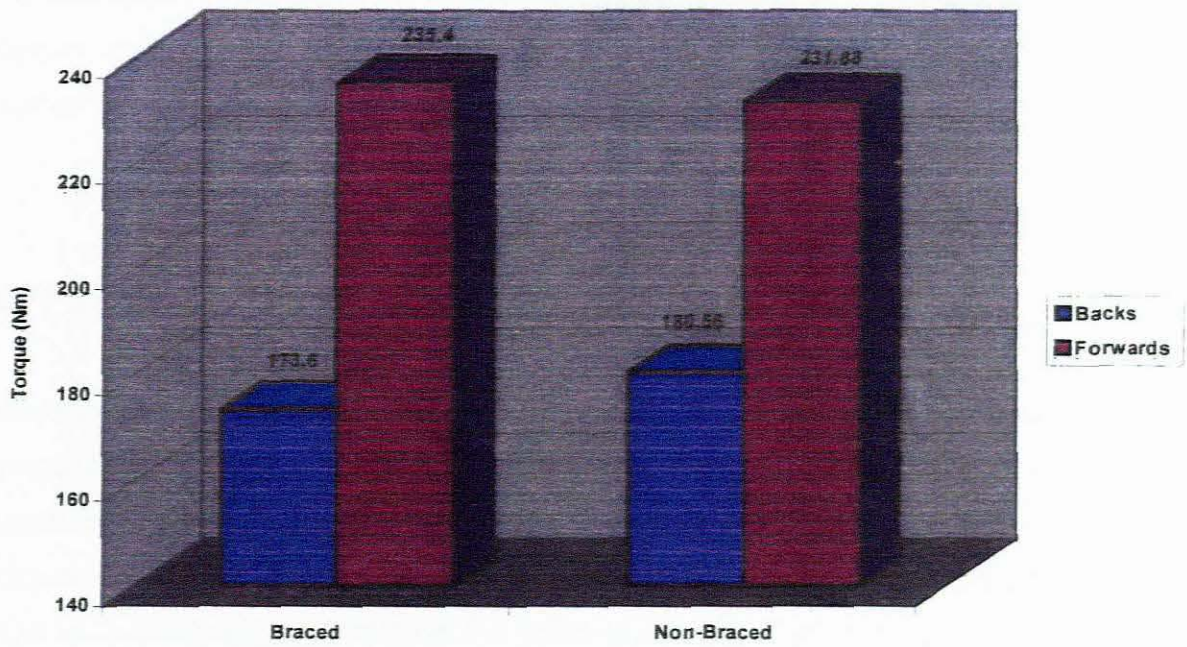
\* Indicates a significant difference at level  $p < 0.05$

\*\* Indicates a significant difference at level  $p < 0.01$

The backline players' non-braced flexion torque was  $180.56 \pm 38.8$  Newton meters (Nm) and the forwards' non-braced flexion torque was  $231.88 \pm 42.5$  Nm. As expected the forwards' flexion torque performance was considerably better than the backline players' performance with a significant ( $p < 0.01$ ) difference off 51.32 Nm. This illustrates that backline players' flexion performance was 22.13% worse than the forwards' non-braced flexion performance. When subjects were braced the backline flexion torque was at 173.60 Nm and the forwards' flexion when braced was 235.40 Nm. Therefore, the forwards performed better in flexion than the backline players with a significant ( $p < 0.01$ ) difference of 61.80 Nm and 35.6% when braced (see Table XIII). Figure 22A illustrates the differences between forwards and backline players' flexion. When considering the players' body size, the forwards generally are taller and heavier than the backline players and thus the support system (legs) were expected to be stronger than those of the backline players. Therefore, one could have expected and understood the large difference in non-braced flexion torque of 51.32 Nm and 61.80 Nm when braced between forwards and backline players.

Relative flexion values illustrated the same results, with forwards performing better in both variables, with the bracing values for the forwards at  $2.31 \text{ Nm} \cdot \text{kg}^{-1}$  compared to the backline value of  $2.16 \text{ Nm} \cdot \text{kg}^{-1}$ . The forward value for non-bracing was  $2.28 \text{ Nm} \cdot \text{kg}^{-1}$  compared to the backline value of  $2.25 \text{ Nm} \cdot \text{kg}^{-1}$ .

A.



B.

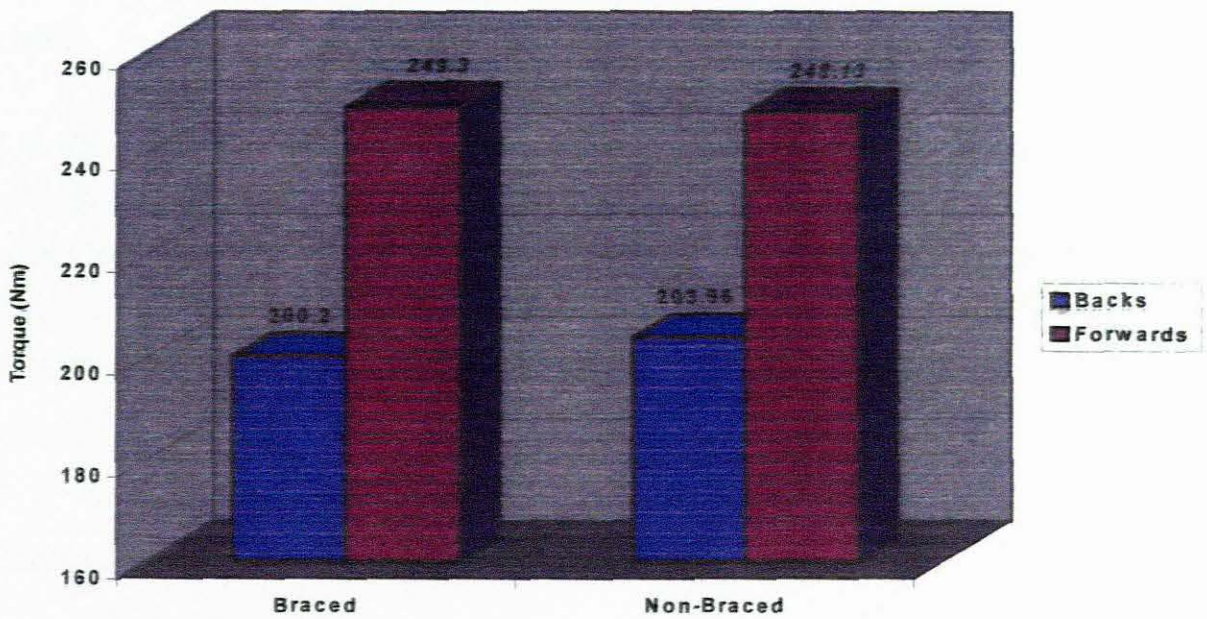


Figure 22. Torque recorded for (A.) Flexion and (B.) Extension in both variables for Forwards and Backs for the Akron isokinetic strength test in Newton meters.

From these results one can conclude that the relative ( $\text{Nm} \cdot \text{kg}^{-1}$ ) flexion performance of forwards and backs are relatively close and that the forwards' flexion performance improved with bracing but that backline players flexion performance decreased with bracing (see Table XIV).

## **EFFECT OF BRACING ON ECONOMY OF RUNNING**

Efficiency of human movement (running) is the relationship between the amounts of energy required to perform a particular task to the actual work accomplished. In a sense, this evaluation occurs when assessing the ease of movement of elite athletes (McArdle et al., 1996). One does not need a trained eye to qualitatively discriminate the ease that swimmers, skiers, cyclists, and dancers move with compared to their less skilled counterparts, who seemingly expend considerable "wasted energy" performing the same task (McArdle et al., 1996). The best endurance athletes are usually the most efficient (Noakes, 1988).

It is common knowledge that oxygen consumed is an indication of economy of running, but it is also recognized that heart rate is an indication of oxygen consumed, and thus can be used as a predictor of energy used to perform a task. In the present study heart rate was used to evaluate the difference between economy of running for braced versus non-braced conditions.

### **Economy of Running for Combined Subjects**

The combined heart rates of each level and variable for economy of running of the total group of subjects can be observed in table XV. From these results it is clear from level one to eight, that the heart rates were insignificantly ( $p > 0.05$ ) different, and at level nine the heart rates were significantly ( $p < 0.05$ ) different between bracing and non-bracing.

**TABLE XIII.** Means and standard deviations (SD) for exercise heart rates in beats per minute for each MST level in Braced versus Non-Braced of combined subjects (N=30).

MST Levels	Variables	Combined b/min	% difference	Significant difference
Rest	Braced	71.20 (16.0)	} 1.14	
	Non-Braced	70.40 (12.8)		
1	Braced	133.67 (16.4)	} 2.10	
	Non-Braced	130.67 (14.9)		
2	Braced	147.50 (17.2)	} 2.20	
	Non-Braced	144.50 (15.6)		
3	Braced	155.06 (16.2)	} 2.28	
	Non-Braced	151.61 (16.0)		
4	Braced	163.33 (14.9)	} 2.30	
	Non-Braced	160.17 (14.4)		
5	Braced	171.39 (14.0)	} 2.60	
	Non-Braced	167.06 (12.6)		
6	Braced	178.11 (13.1)	} 2.60	
	Non-Braced	173.61 (12.2)		
7	Braced	181.82 (9.8)	} 2.25	
	Non-Braced	177.82 (10.4)		
8	Braced	187.40 (9.3)	} 2.74	
	Non-Braced	182.41 (9.1)		
9	Braced	192.68 (8.4)	} 3.04	} *
	Non-Braced	187.00 (8.5)		

\* Indicates a significant difference at level  $p < 0.05$

\*\* Indicates a significant difference at level  $p < 0.01$

Figure 23A illustrates all the average heart rates between bracing and non-bracing for the nine levels of the total group. The heart rates at all nine levels increased with knee bracing, but the increase was only significant ( $p < 0.05$ ) at level nine. Possible reasons for this could be that subjects were still fresh and that the effort needed to run the first eight levels were so slow that the brace did not affect performance significantly. It was expected that bracing would have some effect on economy of running estimated by heart rate response. The following factors were identified as possible factors that could have an effect on economy of running. These included adding extra weight to the body, interference with the normal mechanics of motion and running style and the external compression of the brace.

The most obvious reason for the increased heart rates and thus a decreased economy of running could be the additional weight of the brace. McArdle et al. (1996) found that a weight equal to 1.4% of body mass placed on the ankles would increase the energy cost of walking by an average of 8%, or nearly six times more than if the same weight were carried on the torso. In a practical sense, the energy cost of walking and running is significantly ( $p < 0.05$ ) increased by wearing boots compared to running shoes. Simply adding an additional 100g to each shoe causes a one percent increase in oxygen uptake during moderate running. These small changes in shoe design and weight produce meaningful changes in the economy of locomotion (McArdle et al., 1996). These results support the increased heart rates found in the present study with the additional weight of a prophylactic knee brace.

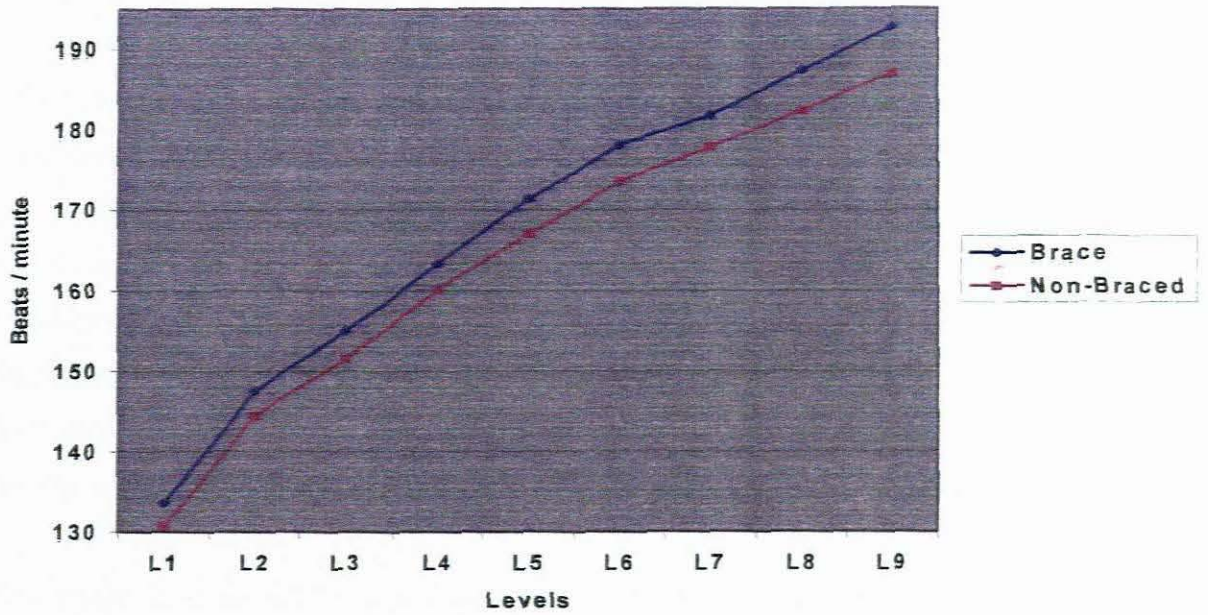
The second possible reason could be that the brace interfered with the subjects' normal mechanics of motion, for example the stride length or running style. In Chapter Two it was mentioned that knee flexion and extension was decreased by 11 to 22%, external rotation by 22%, internal rotation by 33%, and varus-valgus by 24% (Knutzen et al., 1983). Thus, it was expected that bracing of the knee would interfere with the subjects' mechanics of motion and running style. Therefore the heart rates and oxygen consumption of the subjects' would increase and thus would result in an increased energy cost. The third possible

reason for decreased economy with knee bracing could be the compression factor caused by the brace. Table II illustrates the relationship between the middle thigh and calf girth (called the mid-thigh calf ratio). The importance of this is that the prophylactic braces used in the present study were made in three sizes; namely small, medium and large. The ratio between upper-leg and lower leg girths were pre-determined by the manufacturers and could not be changed to suit individual subjects. The problem with the pre-determined ratio is that sportsmen are individualistic and the ratios between upper and lower leg can vary from player to player. For example one of the backline players' mid-thigh calf ratio was 0.73 and another 0.55. Yet, they both used the medium brace as it was perfect around the upper thigh, but the fit around the calf was too tight for the subject with the 0.73 mid-thigh calf ratios and comfortable for the subject with the 0.55 ratios.

About 90% of the backline players were tested with the medium brace. They all found that the large brace was too big and the medium brace fitted the thigh girth the best. About 60% of the 90%, complained of the poor fit of the brace around the calf. The real problem became most evident when the 20 MST test was in progress, between levels four and nine. Subjects complained about the feeling of pins and needles in the braced leg. These same subjects could not reached the same level with bracing than without bracing. The external compression created with the brace application is most probably responsible for this serious complication.

External compression increases hydrostatic pressure in the tissues beneath the brace, which could result in impaired muscle blood flow, which in turn could result in a decreased oxygen supply to the muscles. Under such conditions the heart would have to increase its work rate to supply enough oxygen to the working muscles and thus heart rate increases tremendously (Styf 1999).

A.



B.

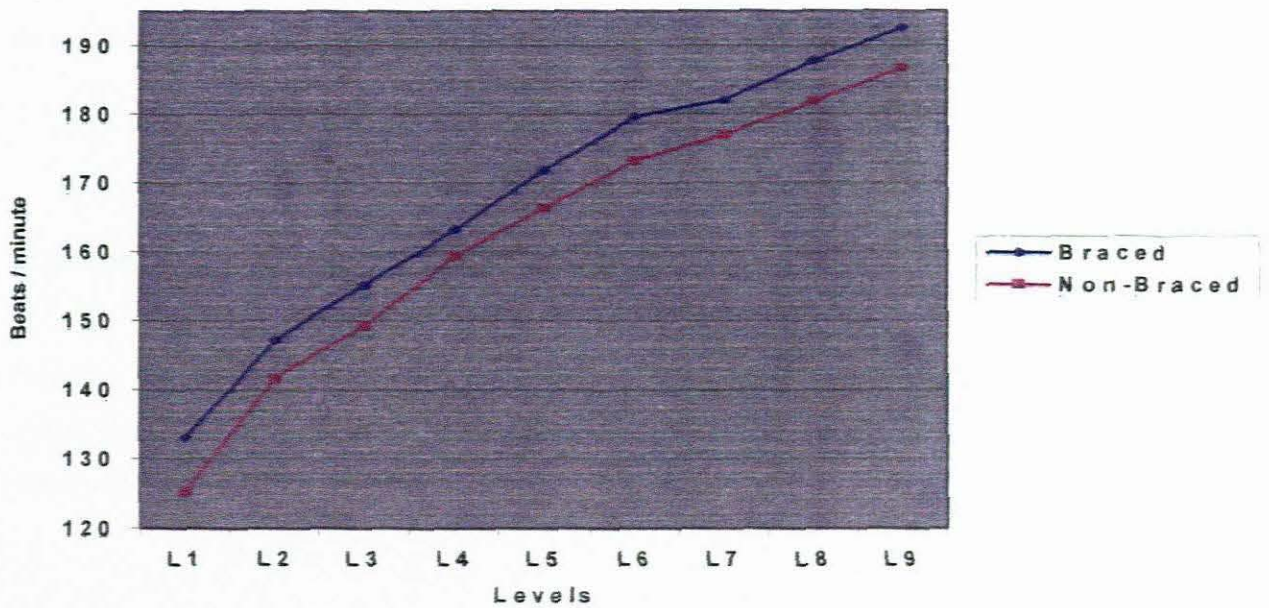


Figure 23. Mean heart rates (beats per minute) for (A.) Braced and Non-Braced knees of the combined group and (B.) Braced and Non-Braced knees for Backs during the 20 MST.

This increase in heart rate response and thus the increase in oxygen consumption, is an indication of a decreased economy of running. It is a well-known fact that a decrease in economy of running will lead to early fatigue, and thus a decrease in performance. Early fatigue is more important than just the tiredness players' feel, but fatigue plays an important rôle in all aspects of fitness and skill performance on the sports field. Fatigue is most likely to contribute to the fact that speed, agility and even proprioceptive performance decreased with brace application. Although strength performance did not decrease in the present study with brace application, strength might even decrease with the brace if players are fatigued. Therefore economy of running is very important to all aspects of performance and should not be ignored.

The major conclusion is that heart rate and therefore oxygen consumption increased, thus economy of running decreased, with brace application in first league rugby players. Decreased economy of running with brace application might then result in early fatigue, and early fatigue might result in decreased performance of rugby players in all aspects or components of the game.

### **Economy of Running for Backline Players**

Results in table XIV illustrates that the backline players' heart rates for the 20-meter MST for braced and non-braced conditions were significantly ( $p < 0.05$ ) different for levels five to nine.

**TABLE XIV.** Means and standard deviations (SD) for exercise heart rates in beats per minute of each MST level in Braced versus Non-Braced for Backline players (N=20).

MST Levels	Variables	Beats b/min	% difference	Significant difference
Rest	Braced	71.20 (16.0)	} 1.14	
	Non-Braced	70.40 (12.8)		
1	Braced	133.67 (16.4)	} 2.09	
	Non-Braced	130.67 (14.9)		
2	Braced	147.50 (17.2)	} 2.28	
	Non-Braced	144.50 (15.6)		
3	Braced	155.06 (16.2)	} 2.28	
	Non-Braced	151.61 (16.0)		
4	Braced	163.27 (16.3)	} 2.45	
	Non-Braced	159.36 (14.8)		
5	Braced	171.91 (15.6)	} 3.34	} *
	Non-Braced	166.36 (12.7)		
6	Braced	179.64 (14.1)	} 3.68	} *
	Non-Braced	173.27 (12.5)		
7	Braced	182.00 (9.4)	} 3.17	} *
	Non-Braced	177.00 (9.0)		
8	Braced	187.70 (9.2)	} 3.25	} *
	Non-Braced	181.80 (8.6)		
9	Braced	192.60 (8.3)	} 3.16	} *
	Non-Braced	186.70 (8.3)		

\* Indicates a significant difference at level  $p < 0.05$

\*\* Indicates a significant difference at level  $p < 0.01$

Figure 23B illustrates the heart rates of all nine levels and it is clear from the graph that the bracing heart rates increased for all nine levels. From results in Table XIV, it was clear that the backline players struggled significantly ( $p < 0.05$ ) with bracing from the level five to nine of the 20m MST test. It was expected that bracing would have some affect on economy of running (heart rates) of the backline players. Table XV illustrates that the forwards' heart rate response was only significantly ( $p < 0.05$ ) different at level nine. Although heart rate is an individualistic response, it seems that the brace affected backs more than the forwards. There are two possible reasons for this, the first one was mentioned before, the difference in leg length between forwards and backs and the length of the brace (30 cm). Thus in comparison a larger surface area is covered by the brace than in the case of the forwards, which might increase the tactile sensation of the limbs. Therefore, the brace might affect the backs more than the forwards in the economy test. The second reason is the fact that the number of subjects tested could have played a role in the power of the test. For example twenty backs and ten forwards were tested, the t-critical value decreases with the increase in subjects tested. This can be observed in results of all groups, the power of significance is the biggest in the combined subjects then the backs and last in the forwards.

The same factors as discussed for the combined group, adding of extra weight to the body, interference with the normal mechanics of motion and running style and the external compression of the brace, could have had an effect on heart rate response and thus economy of running.

In conclusion, the heart rate response of backline players increased with brace application and the decrease in economy of running was noticeable from level five to level nine of the MST. Thus, the decrease in economy of running leads to an increased rate of fatigue, and the increased rate of fatigue resulted in the decrease of sprint and agility performance of backline players. Backline players rely on their speed and agility, to perform as players. Therefore, economy of running is very important even to backline players.

## Economy of Running for Forward Players

The backline players' economy of running was significantly ( $p < 0.05$ ) influenced with bracing from level 5-9 and therefore one would expect the forwards' performance to have similar results. The results in Table XV show that the heart rates for forwards in the 20-meter MST with bracing and without bracing were very similar compare to the backline players.

Figure 24 illustrates the heart rates for all nine levels. The heart rates at all nine levels were increased with brace application, but only significantly ( $p < 0.05$ ) increased at level nine. It was expected that bracing would have some affect on economy of running (heart rates) of the forward players because of the affect of bracing on the group and backline players. If the factors mentioned previously (adding weight, interference to the normal mechanics, and external compression) had an effect on economy performance of the group and backs, surely they would have the same affect on economy performance of the forwards.

The example used in economy of running of backs, about the power of the tests and number of subjects is well illustrated in results of forwards. The forwards' ( $N=10$ ) result was only significant ( $p < 0.05$ ) at level nine and the backs ( $N=20$ ) significantly different from level five. The t-critical value decreases with the increase in subjects tested, but the combined group ( $N=30$ ) was only significant ( $p < 0.05$ ) at level nine. Therefore, there must be another reason why backs performed worse with bracing than the forwards. The only other explanation for the results could be the mid-thigh calf ratio between the medium brace and that of the backline players legs discussed before. The backline players also indicated that the brace felt to tight at levels five to nine and that the feeling of pins and needles was felt during these levels.

**TABLE XV.** Means and standard deviations (SD) for exercise heart rates in beats per minute for each MST level in Braced versus Non-Braced of Forwards (N=10).

MST Levels	Variables	Forwards b/min	% difference	Significant difference
Rest	Braced	80.00 (16.4)	} 1.27	
	Non-Braced	79.00 (13.1)		
1	Braced	134.43 (16.7)	} 0.23	
	Non-Braced	134.13 (15.2)		
2	Braced	148.00 (14.5)	} 0.58	
	Non-Braced	148.86 (16.4)		
3	Braced	154.86 (15.1)	} 0.28	
	Non-Braced	155.43 (15.5)		
4	Braced	163.43 (13.6)	} 1.37	
	Non-Braced	161.23 (14.8)		
5	Braced	170.57 (12.0)	} 1.45	
	Non-Braced	168.14 (13.4)		
6	Braced	175.71 (11.9)	} 0.91	
	Non-Braced	174.14 (12.6)		
7	Braced	181.57 (11.2)	} 1.44	
	Non-Braced	179.00 (12.0)		
8	Braced	187.14 (10.4)	} 2.10	
	Non-Braced	183.29 (10.4)		
9	Braced	193.29 (9.3)	} 3.13	} *
	Non-Braced	187.43 (9.4)		

\* Indicates a significant difference at level  $p < 0.05$

\*\* Indicates a significant difference at level  $p < 0.01$

The major conclusion on bracing and economy of running performance for the forwards, is that no matter the size and weight of the player, the brace appears to increase the exercise heart rates. This is indicative of increased oxygen consumption, and an explanation for the decreased economy of running of the forwards. These increases in heart rates and oxygen consumption were insignificant in the present study, but could have different results with the individual.

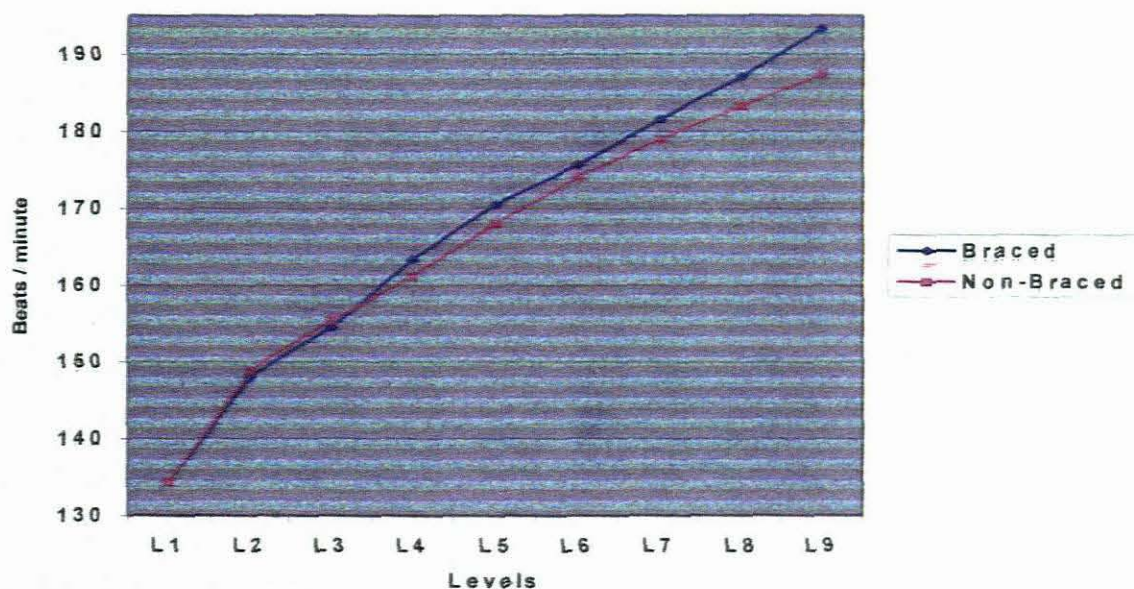


Figure 24. Mean heart rates in beats per minute for Braced and Non-Braced forwards for each level of the 20 MST.

## CHAPTER 5

### CONCLUSION AND RECOMMENDATIONS

Bracing and taping have long been standard treatments for improving joint stability and allowing injured athletes to return to competition. However, in the last decade prophylactic bracing of the knee has gained tremendous popularity. Many team physicians and coaches have prescribed or required brace wearing by athletes in the hope of preventing injury and improving performance (Sforzo et al., 1989). Prophylactic knee braces are designed to prevent or reduce the severity of knee injuries by absorbing valgus producing forces (Millet et al., 1988). Beyond the need for objective evidence of protection offered by knee braces, it is also necessary to show that they do not hamper performance, or that any detriment to performance is acceptable in light of decreased injury rates or severity (Valias & Pink, 1991).

The two major questions of the present study were to investigate if rugby players should use prophylactic bracing to prevent or reduce injuries to the knee, and will the brace affect forwards differently from backline players. The individual should after reading the following arguments, be in a better position to make informed decisions whether to use prophylactic bracing or not.

#### **Morphological Composition**

The morphological composition illustrated a significant difference between forwards and backline players in their stature, mass, percentage body fat, leg girth measurements and the MTCR. Van Heerden (1996) mentioned that it is the typical selection policy of coaches to select those players with superior

morphological size to be forwards. Van Heerden (1996) also illustrated that among all levels of rugby players 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 do. Due to the greater body fat of forwards and thus greater body mass than backs, one would have expected forwards to have more muscle strength and thus stronger legs than backs to transport their weight. With stronger legs one would also expect greater girth measurements. However, even with forwards having greater girth measurements, the MTCR of backs in the present study showed up greater than the forwards' MTCR, this is an important consideration for the manufacturers, which are discussed later in this chapter.

The results of Van Heerden (1996) and the present study illustrate that the morphological composition of forwards and backline players is different. This trend is not coincidental because Van Heerden (1996) said that coaches select players to certain positions due to their morphological composition. Therefore one might tentatively suggest that prophylactic bracing could affect forwards and backline players differently.

## **Positive Effects of Prophylactic Bracing**

### **Valgus Forces**

The positive effects of bracing on performance from previous studies as well as the present study can be summarized as follows. Firstly, prophylactic knee braces are designed to prevent or reduce the severity of knee injuries by absorbing valgus producing forces (Millet et al., 1988). Epidemiological studies of the efficiency of prophylactic braces in absorbing valgus forces have produced promising results (Cowell, 1987; Rovere et al. 1987; Teitz et al. 1987; Baker et al. 1989; Sitler et al. 1990; Albright et al. 1994; Gerrard, 1998). Thus,

the possibility is there that these braces do absorb valgus forces, and as long as the possibility exists it might have a positive effect on the individual.

### **Strength Performance**

Strength is defined generally as the muscular force exerted against movable and immovable objects, and is best measured by tests that require one maximum effort for a given movement or position (Davies, 1987). In the present study isokinetic tests were used to determine the influence of bracing on strength performance. Extension and flexion strength performance of the knee indicated no significant difference between bracing and non-bracing for the combined group, the forwards and the backline players. However, a significant difference was found between forwards and backline players in peak strength (Nm) but not in relative strength ( $\text{Nm} \cdot \text{kg}^{-1}$ ). No significant difference was found on the effect of bracing on performance between forwards and backs, thus the brace affects both forwards and backs equally.

If bracing does not interfere with strength performance then it should be seen as a positive result, the more factors that are not influenced negatively with brace application, the more reason to experiment with bracing. This increases the possibility of players using prophylactic braces.

### **Improved Proprioception**

Results from previous studies concur with the result of the present study concerning improved proprioception with prophylactic brace application (Ferrell et al. 1985; Guyton, 1986; Ferrell et al. 1987; Perla et al. 1995; McNaire et al. 1996). Both forwards and backline players improved proprioception significantly with brace application, however, the backs were significant at level ( $p < 0.01$ ) and the forwards at level ( $p < 0.05$ ). One might suggest that the backs were

influenced more with brace application, this suggestion was supported statistically. From the literature on proprioception, proprioception is seen as the action-reaction mechanism in the body that reacts to forces and protects the body against harmful forces. If this action-reaction mechanism improves with bracing, it will tentatively result in the improvement of the stability of the knee. Improvement in stability is supposed to be created with improved proprioception, and thus action-reaction of the muscles of the knee was not observed in the agility performance. However Perry (1989) supported subjects/rugby players of the present study when they experienced the feeling of improved stability around corners, and even the side ways and backwards running in the modified SEMO agility test.

### **Psychological Effect**

Prophylactic bracing might have a psychological effect on the individual using the brace. Rugby players use braces due to the common belief that the brace protects them, it gives them a sense of security. The fact of improved stability felt with brace application increases the belief of protection, and might have a positive psychological effect on all players (forwards & backs).

### **Negative Effects of Prophylactic Bracing**

#### **Effect on Speed**

There were some negative effects of prophylactic knee bracing on the performance of rugby players.

Speed testing illustrated an insignificant difference between bracing and non-bracing for the combined group, backline players and the forwards. However in all three groups did the speed performance decreased with bracing, but the

decrease was statistically insignificant. Results from the present study were supported by previous research which indicated that prophylactic knee bracing significantly slows players down (Knutzen et al. 1983; Knutzen et al. 1987; Wojtys et al. 1996). If players are slowed down with prophylactic brace application, one might suggest that the performance of the player and team could decrease. The significant decrease in speed is an important factor that brace users should consider in making the decision whether to use prophylactic bracing or not. However people are individualistic and should therefore investigate the effect of bracing on their own speed as to the overall effect on their playing performance before making their decision.

### **Effect on Agility**

Agility is defined as the physical ability that enables rapid and precise change of body position and direction. Agility is important in many sport activities, as exemplified by rugby players in today's professional era (Johnson et al., 1986). Results indicated that agility performance was insignificantly decreased with the application of a prophylactic knee brace for the combined group, the forwards and the backline players. However forwards were significantly slower than the backline players for both variables, braced and non-braced. Speed and agility goes hand in hand in rugby performance and if both are affected negatively with bracing one could tentatively suggest that performance of players will decrease.

### **Effect on Economy of Running**

Economy of running or the efficiency of human movement is the relationship between the amount of energy required to perform a particular task to the actual work accomplished. In a sense, this evaluation occurs when assessing the ease of movement of elite athletes (McArdle et al., 1996). The economy of running (assessed by heart rate responses) of the subjects at any given level of the MST was lower with bracing of the knee than without bracing for the

combined group, the forwards and the backline players. However significant difference was only found at level 9 for the combined group and forwards, and from levels 5-9 for the backline players. This was supported by McArdle et al. (1996) who found that adding an additional 100 grams to each shoe causes a one percent increase in oxygen uptake during moderate running. The braces used in the present study weigh between 0.425 kg and 0.480 kg. The decrease in economy of running, oxygen used and thus energy needed to complete the task are very important considerations for brace users. However, players can improve their brace-wearing fitness level to counteract this factor.

### **Psychological Effect**

Psychological factors can also play a negative role. Some subjects in the present study complained prior to testing that the brace was uncomfortable and that the range of motion (flexion/extension) was affected with brace application. After testing was completed, subjects still complained about discomfort of the brace. Consequently, one might tentatively suggest that subconsciously these two factors could have a negative psychological effect on their performance.

The above-mentioned factors do not allow one to say yes or no to the question "should a rugby player use a prophylactic brace", however it allows one to compare the negative and positive effects of prophylactic knee brace usage. The individual should compare these factors and maybe experiment with the brace himself, then make an informed decision whether to use a prophylactic brace or not.

In the light of these results the following conclusions can be drawn:

**Hypothesis One** : A rejection of the null hypothesis. The findings of this study lead one to tentatively accept the Alternative Hypothesis as follows: that there is a difference between bracing and non-bracing with regard to selected functional measures of speed.

**Hypothesis Two** : A rejection of the null hypothesis. The findings of this study lead one to tentatively accept the Alternative Hypothesis as follows: that there is a difference between bracing and non-bracing with regard to selected functional measures of agility.

**Hypothesis Three** : A rejection of the null hypothesis. The findings of this study lead one to tentatively accept the Alternative Hypothesis as follows: that there is a difference between bracing and non-bracing with regard to selected functional measures of proprioception.

**Hypothesis Four** : Accept the null hypothesis. The findings of this study lead one to tentatively accept the null Hypothesis as follows: that there is no significant difference between bracing and non-bracing with regard to selected functional measures of strength.

**Hypothesis Five** : A rejection of the null hypothesis. The findings of this study lead one to tentatively accept the Alternative Hypothesis as follows: that there is a difference between bracing and non-bracing with regard to selected functional measures of economy of running.

## RECOMMENDATIONS TO THE MANUFACTURERS

The Middle Thigh Calf Ratio (MTCR) was calculated to compare the relation between the mean girth of the middle thigh and the calf, between forwards and backline players. This revealed that the backline players' ratio was slightly bigger at 0.68 compared to the forwards' ratio of 0.65. If the MTCR is calculated from the braces used in the present study, the large brace used for forwards had a ratio of 0.83 compare to the ratio of the medium brace used for the backline players of 0.81. Thus forwards with the smaller leg MTCR used the brace with the bigger MTCR and the backline players with the bigger leg MTCR had to use the brace with the smaller MTCR. This could result in an increased external compression exerted by the brace and a decreased blood flow and poor performance.

The prophylactic brace used in present study had a set maximum size, and could only be tightened with thigh and calf straps. Thus limited adjustment was possible if the subject/player's leg was slightly smaller than the brace. However, if the subject/player's leg was slightly bigger than the brace no alterations or changes could be made. If the large brace was too loose and the medium brace was too tight, the subject/player was forced to use the slightly too tight brace for protection.

It is important to remember that each rugby player is unique and his or her morphological composition is most likely to differ from that of others, as observed in the MTCR of the present study. Therefore, if the ratios of these braces are not compatible with the legs of their users/target group, then the brace may be inadequate and will not perform to its optimal intended function. The problem with the MTCR is not only the ratio problem, but in most instances the calf girth of the backline players was too big for the calf girth of the medium brace. This created the feeling of pins and needles in the braced leg due to increased external compression and thus decreased blood flow. In some instances the thigh girth of the large brace was too small for the thigh girth of the

forwards. If this is the case, the manufacturers should realize that rugby players are becoming bigger and stronger because of the professionalism in the sport. Re-evaluation of rugby players' legs and thus girths, and the MTCR of the braces are necessary to make them more compatible with their target group.

After the re-evaluation of the calf and thigh girths of rugby players and prophylactic braces and thus the MTCR of the braces, the next steps to improve the compatibility of prophylactic braces would most likely be, to increase the size range on the market (not only small, medium and large), and to have proper fittings with players before braces are sold to players.

## **RECOMMENDATIONS TO FUTURE RESEARCHERS**

The present study appears to have been largely successful in presenting a more enlightened and informed understanding of the effects of bracing on selected proprioceptive, fitness and skill components of rugby players (forwards, backline players and the combined group). However, due to logistical constraints experienced in the present study, such as geographic location, demographic composition of the rugby players examined, and a limit on time to complete tests, it is suggested that the following recommendations for future research be considered.

1. During the present study only subjects from three rugby teams in one province were assessed. It may be necessary to assess more teams from different provinces or even nationalities to provide a fuller understanding of the effects of bracing on selected proprioceptive, fitness and skill components of rugby.

2. The present sample was largely comprised of white rugby players. It is suggested that further studies in this research area should also identify other ethnic groups within the South African population.
3. The speed test was initiated from a standing position, but if one compares it to the real situation on the rugby field there are few times that you would start sprinting from a standing position. It is suggested that further studies should include acceleration testing with brace application.
4. The agility test included rugby components such as tackling, picking up balls and even short sprints. For further research on agility it is suggested that researchers should attempt to isolate agility from sprinting to limit the influence of the sprint factor on agility results.
5. Proprioception testing involved subjects balancing on the Wilknox Quad Time Logger which is a modified wobble board. If one compares this to a real situation on the rugby field there is no time where subjects' proprioceptive ability is tested while static. Therefore it is suggested that further studies involve proprioceptive testing while subjects are actually jogging or running.
6. Strength testing on the Akron isokinetic device was done at a speed of 60 degrees per second. It is suggested that further research include more than one speed of testing.
7. Economy of running was determined by monitoring the heart rates at each level of the MST, which is a good indication of oxygen consumed. However, it is suggested that further studies in this research area should measure oxygen consumed, together with monitoring heart rates at each level of the MST.

**APPENDIX A**

**INFORMED CONSENT**

## **Subject Informed Consent Form**

I,....., having been fully informed of the nature as to the research entitled **“The Application of Prophylactic Knee Bracing to Selected Proprioceptive, and Fitness and Skill Parameters in First League South African Rugby Players”**, do hereby give my consent to act as a subject in the above named research.

### **TESTING WILL INVOLVE THE FOLLOWING**

#### **A. Field Testing**

- i) Speed evaluation will be done via two sprint tests over the distance of 35 meters, sprint time will be taken at the 30-meter mark.
- ii) Agility evaluation will be done via two timed completions of the modified SEMO agility test.
- iii) These tests will be done without knee bracing, and with the application of a prophylactic knee brace on a randomly selected knee.
- iv) All testing will take place on the rugby field of the Empangeni Rugby Club, while wearing full rugby kit and boots.

## **B. Laboratory Testing**

- i) The University of Zululand will do a proprioceptive evaluation on a device called the WILKNOX QUAD TIME LOGGER specially built to measure the total time that subjects' is unbalanced.
- ii) Leg strength evaluation will be done by using the Akron isokinetic tester, during the full extension/flexion movement of the knee joint.
- iii) Economy of running will be evaluated by monitoring heart rates during each level of the 20-meter shuttle run test (20 MST).
- iv) These tests will be done without subjects being braced and with the application of a prophylactic knee brace on a randomly selected knee joint.
- v) All testing will take place in the Human Movement Science Laboratory of the University of Zululand, while wearing full rugby kit and boots, except the economy of running test, that will be completed with running shoes.

## **C. Risk Factors**

The risks you may encounter during the research are similar to a gym training session, and intense bouts of the rugby game. Prior to any testing, a full warm-up session will be done by their fitness trainer. Subjects will be required to report on previous knee injuries. This will serve to select subjects for participation.

#### **D. Benefits**

Benefits you will obtain include personal information on your speed, agility, proprioceptive, strength and economy of running performance without bracing. It will also inform subjects' on their performance with the application of the prophylactic brace. This will allow subjects' to experiment with bracing and to be able to make an informed decision whether to use prophylactic bracing or not if necessary.



**APPENDIX B**

**ANTHROPOMETRIC SCORING SHEETS**

# ANTHROPOMETRIC MEASURES

## BODYFAT SKINFOLDS

SUBJECTS	STATURE (CM)	MASS (KG)	TRICEPS (MM)	SUBSCAP (MM)	BICEPS (MM)	SUPRA ILAC (MM)	FAT % (%)
1. J.J							
2. A.T							
3. T.K							
4. D.B							
5. J.B							
6. W.J							
7. J.VI							
8. G.B							
9. H.vM							
10. J.D							

# ANTHROPOMETRY MEASUREMENTS

## GIRTHS

SUBJECTS	UPPER THIGH (CM)	MID THIGH (CM)	ABOVE KNEE (CM)	CALF (CM)
1. J.J				
2. A.T				
3. T.K				
4. D.B				
5. J.B				
6. W.J				
7. J.Vi				
8. G.B				
9. HvM				
10. J.D				
11. T.M				
12. P.L				
13. R.F				
14. H.L				
15. M.K				

**APPENDIX C**

**SPRINT TEST SCORING SHEET**

## SPRINT TEST (NON-BRACED)

		Time 1	Time 2	FINAL
<b>Subject 1.</b>				
J.J	Sprint 1			
	Sprint 2			
<b>Subject 2.</b>				
A.T	Sprint 1			
	Sprint 2			
<b>Subject 3.</b>				
T.K	Sprint 1			
	Sprint 2			
<b>Subject 4.</b>				
D.B	Sprint 1			
	Sprint 2			
<b>Subject 5.</b>				
J.B	Sprint 1			
	Sprint 2			
<b>Subject 6.</b>				
W.J	Sprint 1			
	Sprint 2			
<b>Subject 7.</b>				
J.Vi	Sprint 1			
	Sprint 2			
<b>Subject 8.</b>				
G.B	Sprint 1			
	Sprint 2			
<b>Subject 9.</b>				
H.Vm	Sprint 1			
	Sprint 2			
<b>Subject 10.</b>				
J.D	Sprint 1			
	Sprint 2			

**APPENDIX D**

**AGILITY TEST SCORING SHEET**

## AGILITY TEST (NON-BRACED)

		Time 1	Time 2	FINAL
<b>Subject 1.</b>				
J.J	Agility 1			
	Agility 2			
<b>Subject 2.</b>				
A.T	Agility 1			
	Agility 2			
<b>Subject 3.</b>				
T.K	Agility 1			
	Agility 2			
<b>Subject 4.</b>				
D.B	Agility 1			
	Agility 2			
<b>Subject 5.</b>				
J.B	Agility 1			
	Agility 2			
<b>Subject 6.</b>				
W.J	Agility 1			
	Agility 2			
<b>Subject 7.</b>				
J.Vi	Agility 1			
	Agility 2			
<b>Subject 8.</b>				
G.B	Agility 1			
	Agility 2			
<b>Subject 9.</b>				
H.vM	Agility 1			
	Agility 2			
<b>Subject 10.</b>				
J.D	Agility 1			
	Agility 2			

**APPENDIX E**

**PROPRIOCEPTION TEST SCORING SHEET**

## PROPRIOCEPTION TEST (NON-BRACED)

	TEST 1	TEST 2	TEST 3	FINAL
<b>S1 JJ</b>				
Braced				
N-brace				
<b>S2 AT</b>				
Braced				
N-brace				
<b>S3 TK</b>				
Braced				
N-brace				
<b>S4 DB</b>				
Braced				
N-brace				
<b>S5 JB</b>				
Braced				
N-brace				
<b>S6 WJ</b>				
Braced				
N-brace				
<b>S7 JVi</b>				
Braced				
N-brace				
<b>S8 GB</b>				
Braced				
N-brace				
<b>S9 HM</b>				
Braced				
N-brace				
<b>S10 JD</b>				
Braced				
N-brace				

**APPENDIX F**

**ISOKINETIC STRENGTH TEST, AKRON REPORT**

Akron Therapy Products Ltd.  
 1 Farthing Road,  
 Ipswich,  
 Suffolk,  
 IP1 5AP,  
 United Kingdom

Session Analysis V2.3  
 Tel: (+44) 0473-749544  
 Fax: (+44) 0473-463096  
 Telex: 987597 AKRON G  
 Date: 21/10/80  
 Time: 10:36:39

First Session Analysis

Filename : RB20.AIS  
 Subject : Jacques  
 Sex : M  
 Age : 24.0 yr  
 Weight : 102.0 kg  
 Height : 184.0 cm

Session number : 0  
 Date : 22/06/80  
 Time : 05:35:44  
 Operator : THEO

Subject's history :  
 Limb under test : rknee  
 Machine Mode :  
 Session duration : 10.0 s  
 Trolley position : 23.0  
 Pivot height : 0.0  
 Lever length : 6.0  
 Seat length : 3.5  
 Seat height : 0.5  
 Backrest angle : 70.0 x  
 Torque setting : 300.0 Nm  
 Speed 1 setting : 60.0 x/s  
 Speed 2 setting : 60.0 x/s

Goniometer port : COM1:  
 Printer : FRN: Epson mode 9 pin  
 Language : English

Software version : V2.30

Measured Swing :	102.50 x	:	102.50 x
Peak Flexion Torque :	278.82 Nm	:	205.66 ft lb
Angle of Occurrence :	39.00 x	:	39.00 x
Work Done during Flexion :	1351.03 J	:	996.52 ft lb
Total Flexion Power :	268.36 W	:	268.36 W
Endurance Ratio for Flexion :	88.47 %	:	88.47 %
Flexion Torque to Body Weight :	2.73 Nm/kg	:	0.91 ft lb/lb
Peak Extension Torque :	275.29 Nm	:	203.06 ft lb
Angle of Occurrence :	62.00 x	:	62.00 x
Work Done during Extension :	985.87 J	:	727.17 ft lb
Total Extension Power :	210.22 W	:	210.22 W
Endurance Ratio for Extension :	95.20 %	:	95.20 %
Extension Torque to Body Weight :	2.70 Nm/kg	:	0.90 ft lb/lb
Peak Flexion to Extension Torque :	101.28 %	:	101.28 %

Full Analysis of each Movement

Cycle Direction	Tmax (Nm)	Amax (deg)	Swing (deg)	Time (sec)	Work (J)	Power (W)	Speed (deg/s)
000 Extension	237.6	46.0	53.5	0.76	113.9	150.1	75.1
001 Flexion	192.9	-5.0	98.5	1.34	262.7	195.3	72.9
002 Extension	255.3	63.0	99.5	1.28	281.7	220.8	77.6
003 Flexion	225.9	20.5	98.5	1.34	349.8	260.1	71.4

**APPENDIX G**

**ECONOMY OF RUNNING SCORING SHEET**

## ECONOMY OF RUNNING WITH THE (20MST)

Levels		Rest	1	2	3	4	5	6	7	8	9	10	11	12
<b>Subjects</b>														
<b>1 JJ</b>	<b>Brace</b>													
	<b>Nbrace</b>													
<b>2 AT</b>	<b>Brace</b>													
	<b>Nbrace</b>													
<b>3 TK</b>	<b>Brace</b>													
	<b>Nbrace</b>													
<b>4 DB</b>	<b>Brace</b>													
	<b>Nbrace</b>													
<b>5 JB</b>	<b>Brace</b>													
	<b>Nbrace</b>													
<b>6 WJ</b>	<b>Brace</b>													
	<b>Nbrace</b>													
<b>7 JVI</b>	<b>Brace</b>													
	<b>Nbrace</b>													
<b>8 ME</b>	<b>Brace</b>													
	<b>Nbrace</b>													
<b>9 HVM</b>	<b>Brace</b>													
	<b>Nbrace</b>													
<b>10 JD</b>	<b>Brace</b>													

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