A BIOKINETIC APPROACH TO THE PREVENTION AND REHABILITATION OF SHOULDER INJURIES IN TENNIS PLAYERS

by

KARIEN GOUWS

submitted in partial fulfillment of the requirements for the degree DOCTOR PHILOSOPHIAE in the FACULTY OF HUMANITIES (DEPARTMENT OF BIOKINETICS, SPORT AND LEISURE SCIENCES)

UNIVERSITY OF PRETORIA

NOVEMBER 2005
DEDICATION

This dissertation is dedicated to my husband!
ACKNOWLEDGEMENTS

I would like to thank all those people and institutions that helped me to successfully complete this study. Thank you for your guidance by sharing your knowledge, and all your loving care.

**Prof. P.E. Krüger (Promotor):** (Department Biokinetics, Sport and Leisure Sciences, University of Pretoria). For his continuous guidance and support throughout the study. I would also like to thank him for helping me through situations where I was not able to travel to Pretoria. It was an honor to be his student.

**Wilmarie Visagie:** For all the arrangements with the tennis players, help with the testing and implementation of the training and rehabilitation programmes.

**Sport Research Institute, University of Pretoria:** For the help and support of all my colleagues and Biokinetic Honours’ students (2003).

**Subjects who participated in this study:** For their time, co-operation and their willingness to take part in this study.

**South African Tennis Performance Centre:** For making it possible to use their tennis players in this study.

**International Tennis Federation:** For making it possible to use their tennis players in this study.

**Marlize Alexander:** For her guidance and work done in the analysis of the statistical data obtained.
Charles Skeen: For taking the photographs.

Adèle Lubbe: For posing for the photographs.

Penny Botha: For proof reading the document.

Wynand Gouws: Without the continuous support of my husband and his assistance with our children at home, it would have been impossible for me to complete this study.

My Parents: My parents have always been there for me, to motivate and support me in order to make my dreams come true.

Miriam: For all the extra hours spent in looking after the children.

Jesus Christ: His strength carried me through this study!
SYNOPSIS

<table>
<thead>
<tr>
<th>TITLE</th>
<th>A Biokinetic Approach to the Prevention and Rehabilitation of Shoulder Injuries in Tennis Players.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CANDIDATE</td>
<td>Karien Gouws</td>
</tr>
<tr>
<td>PROMOTOR</td>
<td>Prof. P.E. Krüger</td>
</tr>
<tr>
<td>DEGREE</td>
<td>DPhil (MBK) Biokinetics</td>
</tr>
</tbody>
</table>

Sports scientists and trainers generally agree that the multidimensional training in tennis should start during early childhood in order to ultimately reach a professional playing standard. Evidence suggests that motor skills, including power, strength, agility, speed and explosive power, as well as mental strength and a highly developed neuromuscular coordinating ability are strongly correlated with the level of tournament performance. Turner & Dent (1996) found that 27% of all tennis injuries in junior players occur in the shoulder region. The shoulder girdle is prone to injury because of its ability to maximally accelerate and decelerate the arm while the arm maintains precise control over the racquet at ball contact.

The purpose of this study was to determine whether the occurrence of shoulder injuries could be minimized in tennis players by following a specific exercise programme, focusing on the shoulder girdle.

A total of 42 tennis players participated in this study. They were all aged between 14 and 18 years. Both males and females were used for the purpose of this study. All the players were training at the SA Tennis Performance Centre and the International Tennis Federation at the University of Pretoria. They were all elite tennis players practising daily and scheduled for standard major tournaments throughout the year.
Each subject completed a questionnaire of his or her tennis and medical history. The players were then divided into a control group and an experimental group. Both groups completed a series of physical scientific tests, consisting of posture analysis, body composition, flexibility, functional strength of the upper body; and isokinetic power and endurance of the shoulder muscles.

These tests were executed every 3 months over a 9-month period and the results of each battery of tests were used to adjust and upgrade the new programmes. The experimental group did specific preventative shoulder exercises 5 times a week in addition to their usual gymnasium programme twice a week, while the control group followed a normal strengthening programme twice a week. A medical doctor immediately evaluated any muscle stresses or pains throughout the year. At the end of the year the data was compared to determine the difference in injury occurrence between the two groups.

There was a significant difference (p<0.05) in the distribution of the lean body mass with the Lean body mass at T1 being lower than the Lean body mass at T3 in the control group. In the experimental group the fat percentage showed a significant decrease (p<0.05) from T1 to T3. The distribution of the muscle percentage at T1 was significantly different (p<0.05) from the distribution of the muscle percentage at T3 in the experimental group with the muscle percentage at T1 being lower than the muscle percentage at T3.

There was a significant difference between the control and experimental group for 1RM bench press (p<0.05) with the 1RM bench press measurements at T3 being lower for the control group than for the experimental group. Also, the 1RM bench press at T1 was lower than the 1RM bench press at T3 in the experimental group. The experimental group showed a significant increase from T1 to T3, peaking at T3 with the 1RM bench press.
Results of the tests done to determine **isokinetic muscle strength** showed that a statistical significant correlation (p<0.05) was found with regard to the strength of the **internal rotators** of the non-dominant shoulder at T3, with the experimental group having a higher measurement than the control group. The **internal rotators** and **external rotators** of both the dominant and non-dominant shoulders were lower at T1 than at T3 in the **experimental group** (p<0.05). The **external rotators** of the non-dominant shoulder at T1 were lower than the external rotators of the non-dominant shoulder at T3 in the **control group**.

Results of the tests done to determine **flexibility** showed a statistically significant difference with the **internal rotators** and **external rotators** of the dominant as well as the non-dominant shoulders being lower at T1 than at T3 in the **experimental group**. Also, the external rotators of the non-dominant shoulder of the **control group** were lower at T1 than at T3.

Results of the tests done to determine **posture** showed that in the control group, 54.5% of the players had **scoliosis** at T1 as opposed to 40.9% at T3. In the **experimental group** 55% had scoliosis at T1 compared to the 30% at T3. In the experimental group, 55% of the players’ **shoulder heights** were not level at T1, compared to 30% at T3. 63.6% of the control group’s non-dominant shoulders were higher than the dominant shoulder at T1, compared to the 40.9% of subjects at T3. Among the subjects in the **experimental group**, 50% had a higher non-dominant shoulder and 5% a higher dominant shoulder at T1, compared to 25% and 5% respectively in the **control group**, at T3.

Results of the tests done to determine the occurrence of injuries, showed that the subjects with **no injuries** in the **control group** stayed stable from T1 (54.5%) to T2 (54.5%) whereafter it increased to 59.1% at T3. The experimental group stayed stable from T1 (55.0%) to T2 (55.0%) whereafter it increased to 85% at T3. In the **control group** the percentage **grade 1 and 2** injuries was 13.6% at T1, increasing to 18.2% at T2, and decreasing to 13.6% at T3. In the **experimental group**...
group 15% of the subjects had grade 1 injuries at T1. This percentage increased to 30% at T2 where after it decreased to 15% at T3 again. The percentage of subjects with grade 2 injuries in the experimental group remained stable at 10.0% from T1 to T2. None of the subjects had grade 2 injuries at T3. In the control group 9% had grade 3 injuries at T1, with none at T2 and T3. In the experimental group the percentage of subjects with grade 3 injuries remained stable at 5.0% from T1 to T2. None of the subjects had grade 3 injuries at T3. In the control group 4.5% of subjects had grade 4 injuries at T1. This stayed more or less stable at T2 (4.6%) and increased to 9.1% at T3. In the experimental group 10.0% had grade 4 injuries at T1. None of the subjects had grade 4 injuries at either T2 or T3. In the control group 4.5% had grade 5 injuries at T1, none had it at T2, and 4.5% had it at T3. In the experimental group none of the subjects had grade 5 injuries at T1, T2 or T3. In the control group none of the subjects had grade 6 injuries at T1 or T3. At T2, however, 4.6% had grade 6 injuries. In the experimental group 5.0% of the subjects had grade 6 injuries at T1 and none had this type of injury at T2 or T3.

In conclusion, the results indicate that a specifically designed exercise programme can help to diminish the risk of shoulder injuries in tennis players. It can also improve bi-lateral muscle strength in opposing muscle groups which are used in tennis.

KEY WORDS: Tennis, shoulder injuries, training programmes, rehabilitation programmes, tennis strokes, biomechanics of tennis, elbow injuries, posture, skoliosis, muscle strength.
SAMEVATTING

<table>
<thead>
<tr>
<th>TITEL</th>
<th>'n Biokinetiese benadering tot die voorkoming en rehabilitasie van skouer beserings in tennisspelers.</th>
</tr>
</thead>
<tbody>
<tr>
<td>KANDIDAAT</td>
<td>Karien Gouws</td>
</tr>
<tr>
<td>PROMOTOR</td>
<td>Prof. P.E. Krüger</td>
</tr>
<tr>
<td>GRAAD</td>
<td>DPhil (MBK) Biokinetika</td>
</tr>
</tbody>
</table>

Sportwetenskaplikes en afgrieters stem saam dat multi-dimensionele afgrieting in tennis reeds tydens die vroeë kinderjare moet begin om sodoende 'n professionele standaard te bereik. Navorsing toon dat motorvaardighede soos krag, ratsheid, spoed en plofkrag asook breinkrag en 'n hoogs ontwikkelde neuromuskulure koördinasie vermoë 'n sterk ooreenkoms toon met prestasie in toernooie. Turner & Dent (1996) het bevind dat 27% van alle tennisbeserings in junior spelers in die skouerarea voorkom. Die skouergordel is baie vatbaar vir beserings as gevolg van sy funksie om die arm maksimaal te versnel en spoed te verminder terwyl die arm goeie beheer oor die racket uitoefen tydens balkontak.

Die doel van die eksperimentele studie was om vas te stel of skouerbeserings by tennisspelers verminder kan word deur 'n spesifieke oefenprogram te volg wat fokus op die versterking van die skouergordel.

In die studie is daar van 42 tennisspelers gebruik gemaak. Al die spelers was tussen 14 en 18 jaar oud. Beide seuns en dogters is gebruik vir die studie. Al die spelers het geoefen by die "SA Tennis Performance Centre" en die Internasionale Tennis Federasie by die Universiteit van Pretoria. Almal was elite tennisspelers wat daagliks geoefen het en geskeduleer was vir sekere groot toernooie deur die loop van die jaar.
Elke proefpersoon het ‘n vraelys voltooi rakende sy of haar tennis- en mediese geskiedenis. Daarna is die proefpersone in ‘n kontrole- en eksperimentele groep verdeel. Beide die groepe het ‘n reeks sportwetenskaplike toetse voltooi, bestaande uit postuur analise, liggaamsamestelling, soepelheid, funksionele krag van die bolyf, en isokinetiese krag en uithouvermoë van die bolyf.

Die toetse is elke 3 maande oor ‘n tydperk van 9 maande uitgevoer. Die resultate van elke reeks toetse is gebruik om die nuwe programme aan te pas. Die eksperimentele groep het 5 maal per week spesifieke voorkomende skouer oefeninge gedoen additioneel tot hul gewone gimnasium program twee maal per week. ‘n Mediese dokter het alle spierpyne en beserings onmiddellik geëvalueer reg deur die toetsperiode. Aan die einde van die toetsperiode is die data gebruik om die voorkoms in beserings tussen die twee groepe te vergelyk.

Daar was ‘n beduidende verskil (p<0.05) in die verspreiding van vetvrye massa met ‘n laer vetvrye massa by T1 (toets1) teenoor T3 (toets 3) in die kontrole groep. Die vetpersentasie van die eksperimentele groep het ‘n beduidende afname getoon vanaf T1 na T3 (p<0.05). Die verspreiding van spierpersentasie was beduidend laer in die eksperimentele groep tydens T1 teenoor T3 (p<0.05).

Daar was ‘n beduidende verskil tussen die kontrole en die eksperimentele groep se 1RM (Een Maksimale Repetisie) borsstootkrag waardes (p<0.05). Die 1RM borsstootkrag van die kontrole groep was laer as die van die eksperimentele groep tydens T3. Die eksperimentele groep het ‘n beduidende toename getoon vanaf T1 tot T3 in 1RM borsstootkrag.

Die resultate van isokinetiese spierkrag dui op ‘n statisties beduidende korrelasie (p<0.05) vir die krag van die interne rotators van die nie-dominante skouer tydens T3, met die eksperimentele groep wat ‘n hoër waarde as die kontrole groep behaal het. Die interne en eksterne rotators van beide die
dominante and nie-dominante skouers was laer tydens T1 as T3 (p<0.05). Die **eksterne rotators** van die *kontrole groep* was laer by T1 as by T3.

Die soepelheidstoetse het getoon dat die **interne rotators** en die **eksterne rotators** van die dominante sowel as die nie-dominante skouers betydelik laer was tydens T1 as T3 by die *eksperimentele groep*. By die *kontrole groep* was die **externe rotators** van die nie-dominante skouer laer by T1 as by T3.

Die **postuur analise** dui daarop dat skoliose by 54.5% van die proefpersone in die *kontrole groep* tydens T1 teenwoordig was teenoor 40.9% tydens T3. By die *eksperimentele groep* het 55% skoliose gehad tydens T1 teenoor die 30% tydens T3. In die *eksperimentele groep* was 55% van die proefpersone se skouerhoogtes oneweredig in T1 teenoor die 30% in T3. In die *kontrole groep* was 63.6% se nie-dominante skouer hoër as die dominante skouer tydens T1 teenoor 40.9% tydens T3. In die eksperimentele groep was 50% van die proefpersone se nie-dominante skouer hoër en 5% se dominante skouer hoër tydens T1, teenoor 25% en 5% respektiewlik tydens T3.

Die resultate van die voorkoms van beserings, dui dat die persentasie met **geen beserings** in die *kontrole groep* konstant gebly het vanaf T1 (54.5%) tot T2 (54.5%) waarna dit toegeneneem het tot 69.1% in T3. In die *eksperimentele groep* het die **geen beserings** ook konstant gebly vanaf T1 (55%) na T2 (55%) waarna dit toegeneneem het tot 85% in T3. In die *kontrole groep* was die proefpersone met graad 1 en 2 beserings 13.6% in T1, dit het toegeneneem tot 18.2% in T2 en weer afgeneem tot 13.6% in T3. In die *eksperimentele groep* het die 15% van die proefpersone graad 1 beserings gehad met T1, dit het toegeneneem tot 30% met T2 en weer afgeneem tot 15% in T3. Die graad 2 beserings van die *eksperimentele groep* het konstant gebly met 10% tydens T1 en T2, met geen Graad 2 beserings tydens T3 nie. In die *kontrole groep* was daar 9% graad 3 beserings tydens T1, en geen tydens T2 en T3 nie. In die *eksperimentele groep* het die **graad 3 beserings** konstant gebly met 5%
vanaf T1 tot T2, met geen **graad 3** beserings tydens T3 nie. In die **kontrole groep** het 4.5% **graad 4** beserings gehad tydens T1. Dit het min of meer konstant gebly met 4.6% tydens T2 en gestyg tot 9.1% met T3. Die **eksperimentele groep** het 10% **graad 4** beserings gehad tydens T1, maar geen tydens T2 en T3 nie. In die **kontrole groep** was daar 4.5% **graad 5** beserings tydens T1, geen tydens T2 nie en weer 4.5% tydens T3. In die **eksperimentele groep** was daar geen **graad 5** beserings tydens T1, T2 of T3 nie. In die **kontrole groep** was daar geen **graad 6** beserings tydens T1 en T3 nie, maar 4.6% van die proefpersone het **graad 6** beserings tydens T2 gehad. In die **eksperimentele groep** het 5% **graad 6** beserings gehad met T1, maar geen tydens T2 en T3 nie.

Om saam te vat, die resultate dui daarop dat ’n spesifiek ontwerp oefenprogram wel kan bydra om die risiko vir skouerbaserings te verminder. Dit kan ook help om die bi-laterale spierkrag in antagonistiese spiergroepe, wat in tennis gebruik word, te verbeter.

---

**SLEUTELWOORDE:** Tennis, skouerbaserings, oefenprogramme, rehabilitasie programme, tennis tegnieke, biomekanika van tennis, elmboogbeserings, skoliose, spierkrag.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>PAGE NO</th>
<th>TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>TITLE PAGE</td>
</tr>
<tr>
<td>ii</td>
<td>DEDICATION</td>
</tr>
<tr>
<td>iii</td>
<td>ACKNOWLEDGEMENTS</td>
</tr>
<tr>
<td>v</td>
<td>SYNOPSIS</td>
</tr>
<tr>
<td>ix</td>
<td>SAMEVATTING</td>
</tr>
<tr>
<td>xiii</td>
<td>TABLE OF CONTENTS</td>
</tr>
<tr>
<td>xix</td>
<td>LIST OF FIGURES</td>
</tr>
<tr>
<td>xxv</td>
<td>LIST OF TABLES</td>
</tr>
</tbody>
</table>

## CHAPTER 1: THE PROBLEM

1.1 INTRODUCTION .................................................1
1.2 PROBLEM SETTING ............................................4
1.3 RESEARCH HYPOTHESES .......................................6
1.4 PURPOSE AND AIM OF THE STUDY ...........................6
   1.4.1 Primary objectives ...............................7
   1.4.2 Secondary objectives .........................7

## CHAPTER 2: LITERATURE REVIEW

2.1 THE HISTORY OF TENNIS ....................................8
   2.1.1 Ancient tennis ..................................8
   2.1.2 South Africa’s tennis history ...............11

2.2 ANATOMY OF THE SHOULDER ................................12
   2.2.1 Synovial Joints ................................13
   2.2.1.1 General structure .........................13
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.2.1.2</td>
<td>Bursae and tendon sheath</td>
<td>17</td>
</tr>
<tr>
<td>2.2.1.3</td>
<td>Factors influencing the stability of synovial joints</td>
<td>18</td>
</tr>
<tr>
<td>2.2.2</td>
<td>Structure of the shoulder (glenohumeral) joint</td>
<td>19</td>
</tr>
<tr>
<td>2.2.2.1</td>
<td>General structure</td>
<td>19</td>
</tr>
<tr>
<td>2.2.2.2</td>
<td>Ligaments</td>
<td>23</td>
</tr>
<tr>
<td>2.2.2.3</td>
<td>Tendons</td>
<td>24</td>
</tr>
<tr>
<td>2.3</td>
<td>MUSCLES AND MOVEMENTS OF THE SHOULDER GIRDLE</td>
<td>26</td>
</tr>
<tr>
<td>2.3.1</td>
<td>Movements of the shoulder girdle</td>
<td>26</td>
</tr>
<tr>
<td>2.3.2</td>
<td>Movements of the shoulder joint</td>
<td>27</td>
</tr>
<tr>
<td>2.3.3</td>
<td>Scapulohumeral rhythm</td>
<td>28</td>
</tr>
<tr>
<td>2.3.4</td>
<td>Muscles of the shoulder</td>
<td>29</td>
</tr>
<tr>
<td>2.3.5</td>
<td>Muscle groups and surface anatomy</td>
<td>36</td>
</tr>
<tr>
<td>2.3.6</td>
<td>Prime muscles used in tennis</td>
<td>40</td>
</tr>
<tr>
<td>2.4</td>
<td>ANALYSIS OF THE SHOULDER IN TENNIS-SPECIFIC MOVEMENTS</td>
<td>44</td>
</tr>
<tr>
<td>2.4.1</td>
<td>The serve</td>
<td>44</td>
</tr>
<tr>
<td>2.4.2</td>
<td>Ground strokes</td>
<td>47</td>
</tr>
<tr>
<td>2.5</td>
<td>PHYSICAL DEMANDS OF TENNIS</td>
<td>49</td>
</tr>
<tr>
<td>2.5.1</td>
<td>Physiology of flexibility</td>
<td>50</td>
</tr>
<tr>
<td>2.5.1.1</td>
<td>Types of flexibility</td>
<td>51</td>
</tr>
<tr>
<td>2.5.1.2</td>
<td>Factors influencing flexibility</td>
<td>53</td>
</tr>
<tr>
<td>2.5.1.3</td>
<td>Areas that need flexibility training</td>
<td>54</td>
</tr>
<tr>
<td>2.5.1.4</td>
<td>Benefits of flexibility</td>
<td>58</td>
</tr>
<tr>
<td>2.5.2</td>
<td>Strength and endurance</td>
<td>59</td>
</tr>
<tr>
<td>2.5.2.1</td>
<td>Weight training</td>
<td>59</td>
</tr>
<tr>
<td>2.5.3</td>
<td>Body composition</td>
<td>63</td>
</tr>
<tr>
<td>2.5.3.1</td>
<td>Characteristics of female and male tennis players</td>
<td>64</td>
</tr>
<tr>
<td></td>
<td>a. Anthropometrical aspects</td>
<td>64</td>
</tr>
</tbody>
</table>
b. Biological aspects  67

c. Developmental aspects  69

d. Psychological aspects  70

2.6 INJURIES IN TENNIS PLAYERS ............................................. 73

2.6.1 Causes of injuries in tennis players  73

2.6.2 Occurrence of tennis injuries  76

2.6.3 Prevention of shoulder injuries  78

2.6.3.1 Precautions in strengthening the rotator
cuff muscles  79

2.6.3.2 Sport-specific training programmes  79

2.6.4 Rehabilitation of the injured shoulder  80

2.6.4.1 Physical examination of the shoulder  81

2.6.4.2 Principles of functional rehabilitation  85

2.6.4.3 Guidelines for core-based functional rehabilitation  87

2.6.4.4 Phases of rehabilitation  88

2.7 TENNIS SPECIFIC SHOULDER EXERCISES .......................... 91

2.7.1 Rotator cuff programme  91

2.7.2 Additional tennis specific upper body exercises  97

2.7.3 Forearm and wrist programme  101

2.7.4 Plyometric medicine ball programme for the shoulders  106

2.8 POSTURAL DEVIATIONS ......................................................... 107

2.8.1 Scoliosis  107

2.8.1.1 Incidence of scoliosis  108

2.8.1.2 Screening for scoliosis  109

2.8.1.3 Development of the scoliotic curvature  110

CHAPTER 3: METHODS AND PROCEDURES
3.1 METHODS………………………………………………………………………………….. 112
   3.1.1 Subjects 112
   3.1.2 Testing Environment 115
   3.1.3 Equipment 115

3.2 PROCEDURES……………………………………………………………………….. 118
   3.2.1 The questionnaire 118
   3.2.2 Sub-dividing of subjects into groups 119
   3.2.3 Physical testing procedure 119
      3.2.3.1 Postural analysis 119
      3.2.3.2 Body composition 120
      3.2.3.3 Flexibility 128
      3.2.3.4 Functional strength 130
      3.2.3.5 Isokinetic strength 130

3.3 RESEARCH DESIGN…………………………………………………………….. 135

3.4 STATISTICAL ANALYSIS……………………………………………………… 136
   3.4.1 Statistical data analysis procedures 137
      a. Descriptive statistics 137
      b. Inferential statistics 137
      c. The Mann-Whitney test 137
      d. Wilcoxon signed rank test 137
      e. Friedman’s rank test for correlated samples 138

CHAPTER 4: RESULTS AND DISCUSSION

4.1 BODY COMPOSITION…………………………………………………………….. 139
   4.1.1 Results of the analysis of the comparison of measurements taken at T1 and T3 of the same group across
4.1.2 Results of the analysis of the comparison of the same group across various measurements at different time intervals 141

4.2 MUSCLE STRENGTH AND ENDURANCE ................................. 143
  4.2.1 Results of the analysis of the comparison of the two groups on various measurements 143
  4.2.2 Results of the analysis of the comparison of measurements Taken at T1 and T3 of the same group across variables 144
  4.2.3 Results of the analysis of the comparison of the same group across various measurements at different time intervals 147

4.3 ISOKINETIC MUSCLE STRENGTH ................................. 149
  4.3.1 Results of the analysis of the comparison of the two groups on various measurements 149
  4.3.2 Results of the analysis of the comparison of measurements taken at T1 and T3 of the same group across various variables 150

4.4 FLEXIBILITY ................................................................. 156
  4.4.1 Results of the analysis of the comparison of measurements taken at T1 and T3 of the same group across various time intervals 156

4.5 POSTURAL MEASUREMENTS ............................................. 159
  4.5.1 Scoliosis 159
  4.5.2 Shoulder height 161
  4.5.3 CM Bend 163
  4.5.4 Higher hip 164
  4.5.5 Kiphosis 165
4.5.6 Lordosis 166

4.6 GRADES OF INJURIES 168

a. No injuries 170
b. Grade 1 and grade 2 injuries 172
c. Grade 3 injuries 172
d. Grade 4 injuries 172
e. Grade 5 injuries 173
f. Grade 6 injuries 174

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS 176

REFERENCES 182

APPENDIXES 199

APPENDIX A: Tennis Research Project Questionnaire 199
APPENDIX B: Postural analysis for tennis players 201
APPENDIX C: Testing proforma 203
APPENDIX D: Shoulder strengthening programme 205
APPENDIX E: Additional tennis conditioning exercises 206
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>FIGURE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1: General structure of a synovial joint</td>
<td>16</td>
</tr>
<tr>
<td>Figure 2: Friction-reduction structures: Bursae and tendon Sheaths</td>
<td>17</td>
</tr>
<tr>
<td>Figure 3: Ball-and-socket joint: The shoulder</td>
<td>20</td>
</tr>
<tr>
<td>Figure 4: Shoulder joint relationships</td>
<td>21</td>
</tr>
<tr>
<td>Figure 5: Posterior view of the right scapula</td>
<td>22</td>
</tr>
<tr>
<td>Figure 6: Muscles crossing the shoulder and elbow joints, causing movement of the arm and the forearm</td>
<td>25</td>
</tr>
<tr>
<td>Figure 7: A posterior view of the scapula and the humerus during abduction of the humerus. (a) scapulothoracic angle, (b) glenohumeral angle</td>
<td>28</td>
</tr>
<tr>
<td>Figure 8: The trapezius (T) in action indicating the four heads</td>
<td>30</td>
</tr>
<tr>
<td>Figure 9: Representation of the action of the serratus anterior and the lower fibers of the trapezius as a force couple</td>
<td>33</td>
</tr>
<tr>
<td>Figure 10: Triplanar diagrammatic view of the shoulder</td>
<td>37</td>
</tr>
<tr>
<td>Figure 11: The primary muscles used during the tennis serve</td>
<td>40</td>
</tr>
<tr>
<td>Figure 12: The rotator cuff muscle</td>
<td>43</td>
</tr>
<tr>
<td>Figure 13: Trunk and shoulder stretch</td>
<td>56</td>
</tr>
</tbody>
</table>
Figure 14: Overhead stretch ..............................................................56
Figure 15: Scapular stretch ..............................................................57
Figure 16: Shoulder squeeze ...........................................................57
Figure 17: Forearm flexor stretch ..................................................58
Figure 18: Forearm extensor stretch .............................................58
Figure 19: Passive distraction test ..................................................84
Figure 20: Prone horizontal abduction .........................................92
Figure 21: 90°-90° External shoulder rotation .............................93
Figure 22: Scaption (Empty Can) ...................................................94
Figure 23: External shoulder rotation with rubber tubing ..........95
Figure 24: External shoulder rotation with abduction ...............96
Figure 25: Seated row ..................................................................97
Figure 26: Wrist curls ..................................................................101
Figure 27: Wrist curls: Flexors ....................................................102
Figure 28: Forearm supination ......................................................104
Figure 29: Ulnar deviation .............................................................105
Figure 30: Athletes screened for scoliosis ................. ..........................110

Figure 31: Harpenden Anthropometer ........................................................115

Figure 32: Model D2391 Detecto Standing scale .................................115

Figure 33: Equipment used for measuring body composition ..................116

Figure 34: Back evaluation door ...............................................................117

Figure 35: The Cybex Norm ........................................................................118

Figure 36: Postural analysis: The athlete standing in an erect position ....119

Figure 37: Shrober’s test was used to determine thoracic spine motion ....120

Figure 38: Height measurement using the Harpenden
Antrometer ......................................................................................................121

Figure 39: Body weight measurement using the Detecto
Standing Scale ..................................................................................................122

Figure 40: Measuring the skinfold of the Triceps muscle with the
Skinfold Caliper ................................................................................................123

Figure 41: Measuring the width of the humerus using a
Wide-Spreading Caliper .............................................................................126

Figure 42: Measuring flexibility of the shoulder rotators:
(a) neutral position, (b) external rotation, and (c) internal rotation ..........128
Figure 43: Measuring flexibility of the shoulder flexors and extenders (a) neutral position, (b) shoulder extension, and (c) shoulder flexion ...........................................129

Figure 44: Demonstrating the correct push-up position .........................130

Figure 45: Isokinetic muscles strength of shoulder flexion and extension measured on the Cybex Norm .......................................131

Figure 46: Isokinetic muscles strength of the (a) shoulder adductors, and (b) shoulder abductors measured on the Cybex Norm .........................132

Figure 47: Isokinetic muscle strength of (a) shoulder internal and (b) external rotation measured on the Cybex Norm .........................133

Figure 48: Statistically significant difference within groups: Body Composition (T1 and T3)..........................................................140

Figure 49: Statistically significant difference in Body Composition between T1, T2 and and T3...........................................141

Figure 50: Statistically significant difference between groups: Muscle strength and endurance ..........................................................144

Figure 51: Statistically significant difference within groups: Isokinetic muscle strength (T1 and T3)..........................................................145

Figure 52: Statistically significant difference for muscle strength and endurance between T1, T2 and T3 .................................147
Figure 53: Statistically significant difference for muscle strength and Endurance between T1, T2 and T3 (continue) ..................148

Figure 54: Statistically significant difference between groups:
Isokinetic muscle strength (T3)............................................................150

Figure 55: Statistically significant differences within groups:
Isokinetic muscle strength (T1 and T3)..............................................151

Figure 56: Statistically significant difference within groups:
Isokinetic muscle strength (continue) (T1 and T3)..............................152

Figure 57: Statistically significant difference within groups:
Flexibility (T1 and T3).........................................................................156

Figure 58: Percentage of players within each group with Kifosys at T1 and T3 ...........................................................................166

Figure 59: Percentage of players with Lordosys in both groups at T1 and T3 .................................................................167

Figure 60: Control group: Grades of shoulder injuries (T1, T2 and T3) ..169

Figure 61: Experimental group: Grades of shoulder injuries (T1 and T3) 170

Figure 62: Figure 4 hamstrings stretch ..................................................207

Figure 63: Hamstrings stretch .................................................................207

Figure 64: Hamstrings super stretch ..................................................208
Figure 65: Stork quadriceps stretch .........................................................208

Figure 66: Prone quadriceps stretch .....................................................209

Figure 67: Groin stretch ................................................................209

Figure 68: Seated groin stretch ............................................................210

Figure 69: Hip twist ........................................................................210

Figure 70: Piriformis stretch .................................................................211

Figure 71: Iliotibial band stretch ..........................................................211

Figure 72: Calf stretch .....................................................................212

Figure 73: Knee to chest flex ...............................................................212

Figure 74: Double knee to chest ...........................................................213

Figure 75: Spinal twist .....................................................................213
## LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1: Muscles acting on the shoulder girdle</td>
<td>34</td>
</tr>
<tr>
<td>Table 2: Muscle acting on the shoulder joint</td>
<td>35</td>
</tr>
<tr>
<td>Table 3: The differences in weight distribution between males and females</td>
<td>64</td>
</tr>
<tr>
<td>Table 4: The differences in bones and joints between male and female</td>
<td>64</td>
</tr>
<tr>
<td>Table 5: The differences in muscles between males and females</td>
<td>66</td>
</tr>
<tr>
<td>Table 6: The differences in fat tissue between males and females</td>
<td>66</td>
</tr>
<tr>
<td>Table 7: The differences in the respiratory system between males and females</td>
<td>68</td>
</tr>
<tr>
<td>Table 8: The differences in the circulatory system between males and females</td>
<td>68</td>
</tr>
<tr>
<td>Table 9: Characteristics that highlights differences in development between males and females</td>
<td>69</td>
</tr>
<tr>
<td>Table 10: Specific characteristics of the female body: Anatomical and functional differences in systems and organs of the body</td>
<td>70</td>
</tr>
<tr>
<td>Table 11: The differences in motivation and interest between males and females</td>
<td>71</td>
</tr>
</tbody>
</table>
Table 12: The differences in psychological variables between males and females .................................................................72

Table 13: Epidemiology of upper extremity overuse injuries in tennis players ........................................................................77

Table 14: Subject data of all the tennis players taking part in this study ................................................................................114

Table 15: Normative values of the shoulder internal and external rotation peak torque (ft-lb.) .....................................................133

Table 16: Normative values of the shoulder flexion and extension peak torque (ft-lb.) .............................................................134

Table 17: Normative values of the shoulder abduction and adduction peak torque (ft-lb.) .........................................................134

Table 18: Frequency tables for scoliosis for the control and experimental groups for T1 .............................................................160

Table 19: Frequency tables for scoliosis for the control and experimental groups for T3 .............................................................160

Table 20: Frequency tables for the control and experimental groups for shoulder height at T1 ....................................................161

Table 21: Frequency tables for the control and experimental groups for shoulder height at T3 ....................................................162
Table 22: Cross-tabulation of CM Bend at T1 with CM Bend at T3 for both the control and experimental groups ........................................163

Table 23: Frequency table for the control and experimental groups for hip height at T1 ..............................................................164

Table 24: Frequency tables for the control and experimental groups for hip height at T3 ..............................................................164