

CHAPTER 3

METHODS AND PROCEDURES

3.1 METHODS

In this chapter we will discuss the methods and procedures used for the testing of the subjects in this study.

3.1.1 Subjects:

The number of subjects that participated in this study was 42 tennis players 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 South African Tennis Performance Centre (SATPC) and the International Tennis Federation (ITF) at the University of Pretoria. The individuals were well matched with regard to age, mass, activity level and intensity of training (Table 14). They were all elite tennis players, practising daily at the University of Pretoria and scheduled for standard major tournaments throughout the year. All the subjects followed specific exercise programmes, with the experimental group following an additional programme five times a week based on certain scientific exercise principles. This scientific programme focused on the prevention of shoulder injuries.

Each player completed a questionnaire on his or her tennis and medical history. The players were then divided into a control group and an experimental group.

First, the males and females were separated. In each group, all players that had a history of shoulder injuries or shoulder pain were numbered separately. Firstly, the numbers of the players with a medical history from the male group were thrown into a hat. The first number drawn went to group 1, where after the name went back into the hat. If the same number was drawn again, it was just thrown back into the hat. The next new number to be drawn went to group 2 and was

then thrown back into the hat. This went on until all the numbers were drawn. After the players with a medical history were divided, the remaining males were divided in the same way. The same procedure was followed to divide the female group. From this point further, no distinction was made between the males and females throughout the period of evaluation and training.

Both groups completed a series of physical scientific tests, consisting of:

1. Posture analysis;
2. Body composition;
3. Flexibility tests;
4. Functional strength of the upper body; and
5. Isokinetic power and endurance of the shoulder muscles.

These tests were done every three months over a nine-month period and the results of each battery of tests were used to upgrade the new programmes. The experimental group did specific preventative shoulder exercises 5 times a week in addition to their gymnasium programme twice a week, while the control group followed a normal strengthening program twice a week. On the two days of gymnasium work, the preventative exercises were incorporated into the experimental group's gymnasium programmes. A medical doctor evaluated all kinds of muscle stresses or pains immediately throughout the research period. All the injuries and muscular problems for both the control group and the experimental group were documented carefully. At the end of the research period the data was compared to determine the difference in injury occurrence between the two groups, as well as the effect of a proper rehabilitation programme.

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

EXPERIMENTAL AND CONTROL GROUP		
	X+/- SD	
	Experimental Group	Control Group
Age	15,2 +/-1.6	15.6 +/-2.6
Body Weight	58.2 +/-8.5	59.7 +/-11.1
Height	172.3 +/-10.7	170.4 +/-10.8
Fat Percentage	12.7 +/-2.7	12.8 +/-3.8
Muscle Percentage	42.7 +/-2.4	42.1 +/-5.6
Lean Body Mass	46.5 +/-8.1	47.8 +/-7.8

The following inclusion criteria were used to determine the subject's eligibility for the study:

- a. South African Tennis Performance Centre and International Tennis Federation: All participants were to train at one of these two centres at the University of Pretoria in order to control their training programmes both on and off the tennis court;
- b. Age: All the subjects were aged between 14 and 18 years;
- c. Activity indices: The subjects were not allowed to do any gymnasium or other high- intensity activities 48 hours prior to the tests; and
- d. Conditioning programmes: The subjects were not allowed to do any additional strengthening exercises throughout the research period but those prescribed to them.

3.1.2 Testing Environment:

All the tests were done inside the laboratory at the Institute for Sport Research at the University of Pretoria. The temperature was measured at 21 degrees Celsius and the Barometric pressure at 662mmHg. No tests were done out in the field where wind and temperature could influence the results. It can thus be stated that all tests were done in a controlled environment.

3.1.3 Testing Equipment:

The following equipment was utilized in the study:

- a. The **Harpenden Anthropometer** was used to measure the subject's standing height and **a model D2391 Detecto standing scale** was used to measure the total body weight.



Figure 31: Harpenden Anthropometer.



Figure 32: Model D2391 Detecto standing scale.

- b. The **Drinkwater Ross** method was used to determine fat percentage at the first and the last tests (Roy & Irvin, 1983). Equipment used for this method were:
- i. Skinfold Caliper;
 - ii. Steel retractable measuring tape; and
 - iii. Wide-Spreading Calipers.

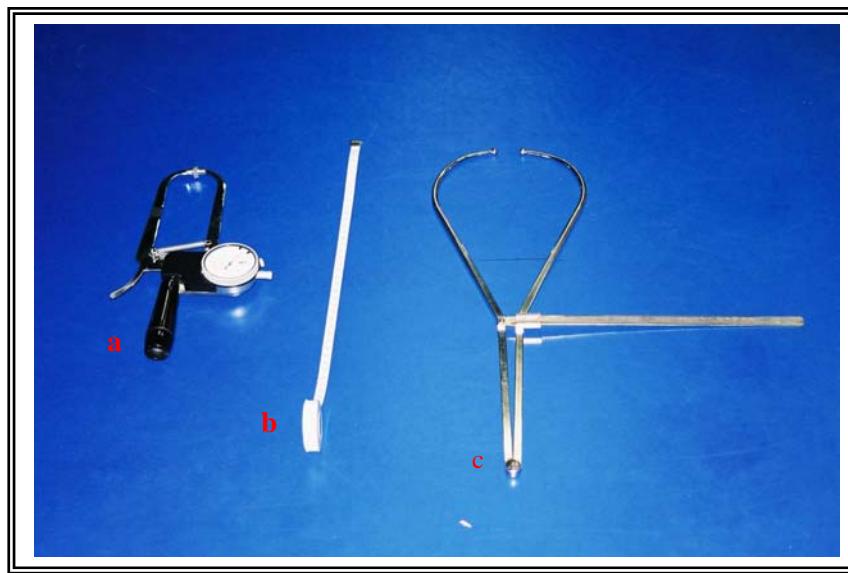


Figure 33: Equipment used for measuring body composition. (a) Skinfold caliper, (b) Steel retractable measuring tape, and (c) Wide-Spreading Caliper.

- c. A **black pen and measuring tape** were used to determine whether scoliosis was present.
- d. A **back evaluation door** was used to determine the difference in shoulder and hip height (**Figure 34**).
- e. A **protractor** was used to determine flexibility of the shoulder's internal and external rotators.

- f. **Steel retractable measuring tape** and a **stick** were used to determine shoulder flexibility.



Figure 34: Back evaluation door.

- g. A **stopwatch** was used to measure functional strength and endurance.
- h. The **Cybex Norm (Figure 35)** was used to measure isokinetic power and endurance in shoulder internal and external rotation, shoulder flexion and extension as well as elbow flexion and extension.



Figure 35: The Cybex Norm.

3.2 PROCEDURES

3.2.1 The questionnaire:

Before the physical tests could start, the subjects had to complete a questionnaire documenting their tennis history as well as their medical history. The information retrieved from the questionnaire was used to divide the subjects into a control group and an experimental group. At the end of the questionnaire a detailed explanation followed that clearly outlined the purpose of the research, what was to happen with the results obtained from the study, and also what was expected of the subjects. At the end of the questionnaire they had to sign a declaration that they agreed to take part in the research according to the set conditions (See Appendix A).

3.2.2 Sub-dividing of subjects into groups:

The subjects were divided into a control group and an experimental group as described in 3.1.1.

3.2.3 Physical Testing procedures:

The tests commenced with a postural and body composition analysis, followed by other scientific tests.

3.2.3.1 Postural Analysis:

The screening procedure that was used to examine the back included various observations. Firstly, the athlete stood in an erect position, and thereafter in the forward bending position. In the standing position observations were made for asymmetries of the lateral contours of the trunk, the shoulders, scapula, and lateral deviations of the spinal process (Becker, 1986).

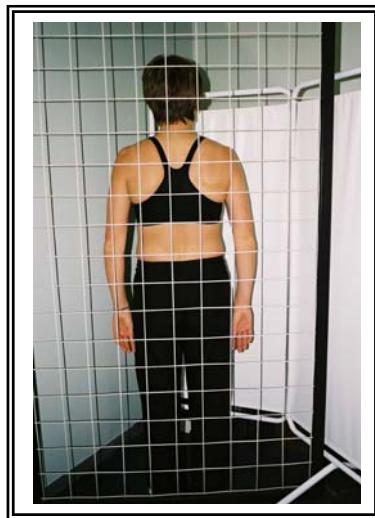


Figure 36: Postural analysis: The athlete standing in an erect position in order to determine asymmetries of the neck, shoulders, back and hips.

Schober's test (Becker, 1986; Smith, 2003) was used to identify normal thoracic spine motion. According to Schober's test, spine motion is normal when a mark

10 cm above the sacral dimples increased with 5 cm in full flexion. This is the procedure used in the test to identify scoliosis. A pen was used to mark the sacral dimples and a mark was made 10 cm above the dimples. With the subject in full flexion of the back, the distance between the two marks was taken again. If the distance did not increase by 5 cm, it was an indication that scoliosis was present (Becker, 1986).



Figure 37: Shrober's test were used to determine thoracic spine motion.

(a) Marking the sacral dimples. (b) Measuring the distance between the sacral dimples and the 10cm mark in a bending position.

3.2.3.2 Body Composition:

a. Height measurement:

The Harpenden anthropometer was used to measure normal standing height. The subject stood barefoot in a normal standing position with the feet together and the back straight against the wall, as seen in **figure 38**.



Figure 38: Height measurement using the Harpenden Antropometer.

b. Body mass measurement:

The Detecto Standing scale was used to measure total body weight to the nearest 0.1 kilogram with the subject standing barefoot on the scale as seen in **figure 39**.



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

c. Fat Percentage:

The fat percentage of the subject was measured by using the Drinkwater Ross method for testing athletes. This measurement consists of 7 skinfolds, 9 circumferences and 6 sites of breadths.

Specifications for obtaining fat percentage:

Marking Midacromial-Radiale: Arm girth, triceps, and biceps: A line was marked horizontally to the long axis of the humerus at the mid-acromiale-radiale distance, which was determined by an anthropometric tape. The horizontal line was then extended to the posterior surface of the arm. A

vertical line at the most posterior surface was then made to intersect with the horizontal line to mark the site where the triceps skinfold was raised. The biceps were marked by following the same procedure on the anterior side of the arm (MacDougall *et al.*, 1991).

- **Skinfolds:**

The right hand side is used for the purpose of the description of the measuring sites. In the actual test, the dominant side of the subjects was used.

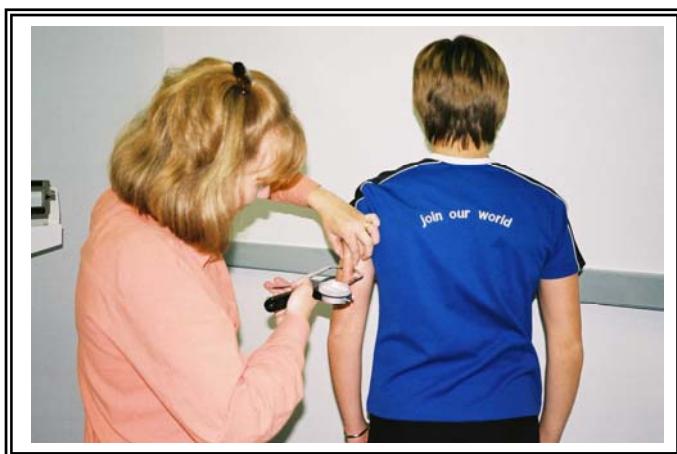


Figure 40: Measuring the skinfold of the Triceps muscle with the Skinfold Caliper.

→ **Biceps:** The caliper was applied 1 cm distally from the left thumb and the index finger and a vertical fold was raised at the marked mid-acromial-radiale line on the anterior surface of the right arm (MacDougall *et al.*, 1991).

→ **Triceps:** The caliper was applied 1 cm distally from the index finger and the left thumb, raising a vertical fold at the marked mid-acromiale-radiale line on the posterior surface of the arm (Roy & Irvin, 1983; MacDougall *et al.*, 1991).

→ **Subscapula:** The caliper was applied 1cm distally from the left thumb and index finger, raising a fold oblique to the inferior angle of the scapula in a direction running obliquely downwards and laterally at an angle of about 45° from the horizontal (Roy & Irvin, 1983; MacDougall *et al.*, 1991).

→ **Supra iliac:** The caliper was applied 1cm anteriorly from the left thumb and the index finger, raising a fold immediately superior to the iliac crest at the midaxillary line. This fold goes anteriorly downward and usually becomes progressively smaller as you move away from this point (Roy & Irvin, 1983; MacDougall *et al.*, 1991).

→ **Para umbilicus:** The caliper was applied 1cm inferiorly to the left thumb and index finger. A fold was raised 5cm laterally to the omphalion (midpoint of the navel) (Roy & Irvin, 1983; MacDougall *et al.*, 1991).

→ **Medial thigh:** The caliper was applied 1cm distally to the left thumb and index finger, raising a fold anteriorly on the right thigh along the long axis of the femur with the leg flexed at a 90° angle at the knee by placing the foot on a box. The measuring site is estimated at half-distance between the inguinal crease and the anterior patellae (Roy & Irvin, 1983; MacDougall *et al.*, 1991).

→ **Calf:** The caliper was applied 1cm distally to the left thumb and index finger, raising a vertical fold on the relaxed medial aspect of the right calf at the estimated greatest circumference. The subject's knee was flexed at 90° and the foot placed on a box (Roy & Irvin, 1983; MacDougall *et al.*, 1991).

- **Girths:**

→ **Biceps relaxed:** This measurement was taken at the marked mid-acromiale-radiale distance with the subject standing in an erect position with the relaxed arm hanging at the side (MacDougall *et al.*, 1991).

→ **Biceps flexed and tense:** This measurement was taken at the maximum circumference of the dominant arm. The arm was raised to the horizontal position in the sagittal plane with a fully supinated forearm flexed at the elbow to approximately 45°. The subject made a muscle by fully tensing the biceps while the tape was adjusted to the maximal girth where the reading was taken (Roy & Irvin, 1983; MacDougall *et al.*, 1991).

→ **Fore arm girth:** This was the maximal girth measurement taken from the dominant forearm with the hand held palm up and relaxed. This measurement was made no more than 6cm distal from the radiale (MacDougall *et al.*, 1991).

→ **Wrist girth:** This is the perimeter that was taken of the right wrist distal to the styloid processes (Roy & Irvin, 1983; MacDougall *et al.*, 1991).

→ **Chest girth:** The perimeter was taken at the mesosternale. The subject abducted the arms slightly while the measuring tape was placed to the horizontal level of the marked mesosternale. The reading was obtained at the end of a normal expiration (end tidal) (MacDougall *et al.*, 1991).

→ **Waist girth:** The perimeter was taken at the noticeable waist narrowing and was located approximately halfway between the costal border and the iliac crest (Roy & Irvin, 1983; MacDougall *et al.*, 1991).

→ **Hip girth (Gluteal):** This perimeter was taken at the greatest posterior protuberance, approximately at the level of the symphysis pubis. The subject stood in an erect position with the gluteal muscles relaxed (Roy & Irvin, 1983).

→ **Thigh girth:** This perimeter was taken of the dominant thigh with the subject standing erect with the feet shoulder-width apart and the weight

evenly distributed on both feet. The tape was raised to a level 1 to 2 cm below the gluteal line (Roy & Irvin, 1983; MacDougall *et al.*, 1991).

➔ **Calf girth:** This perimeter was taken of the dominant thigh with the subject standing erect with the feet shoulder-width apart and the weight evenly distributed on both feet. Moving the tape and making a series of girth measurements to ensure the largest value obtained this measurement (Roy & Irvin, 1983; MacDougall *et al.*, 1991).

➔ **Ankle girth:** This perimeter was taken at the narrowest part of the lower leg superior to the sphyriion tibiale. Loosening and tightening in order to obtain the minimal girth measurement manipulated the tape (Roy & Irvin, 1983).

- **Obtaining Breadths:**



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

➔ **Biacromial breadth:** This is the distance taken between the most lateral points on the acromion processes with the subject standing erect with the arms hanging relaxed at the sides. The branches of the caliper pointed upwards at an angle of about 45° from the horizontal to encompass the largest diameter between the acromial processes (MacDougall *et al.*, 1991).

➔ **Transverse chest width:** This is the distance taken of the lateral aspect of the thorax at the level of the most lateral aspect of the fourth rib. The measurement was taken from the front with the subject sitting erect. The caliper was applied at an angle of about 30° downward from the horizontal in order to avoid the pectoral and the lattisimus dorsi muscles contours. The measurement was taken at the end of the normal expiratory excursion (end tidal) (Roy & Irvin, 1983; MacDougall *et al.*, 1991).

➔ **Iliocristal breadth:** This is the distance taken between the most lateral points on the superior border of the iliac crest. The branches of the caliper pointed upward at a 45° angle from the horizontal to encompass the largest diameter between the lateral aspects of the iliac crest (Roy & Irvin, 1983).

➔ **Anterior/posterior chest depth:** This is the depth of the test that was measured at mesosternale level. The measurement was obtained with the subject sitting erect. The caliper was applied over the right shoulder in a downward direction. The one end of the caliper was placed on the mesosternale and the other point on the spinous process of the vertebra at the level of the mesosternale (Roy & Irvin, 1983; MacDougall *et al.*, 1991).

➔ **Humerus width:** This is the distance taken between the medial and lateral epicondyles of the humerus. The arm was raised forward to the horizontal and the forearm flexed 90° at the elbow (MacDougall *et al.*, 1991).

➔ **Femur width:** This is the distance taken between the medial and lateral epicondyles of the femur. The subject was in a sitting position with the leg flexed at the knee to form a right angle with the thigh (Roy & Irvin, 1983).

3.2.3.3 Flexibility:

Flexibility tests were used to measure the range of motion of the shoulder. The following flexibility tests were done:

i) Shoulder internal and external rotation:



(a)



(b)



(c)

Figure 42: Measuring flexibility of the shoulder rotators: (a) neutral position, (b) external rotation, and (c) internal rotation.

→ **Starting position:** The subject lied in a supine position on the bed with the arm bent 90° with the elbow in line with the shoulder. The arm stayed 90° bend throughout the process.

→ **Movement:** The hand and forearm first moved downward and forward in an arc as far as possible and the reading were taken for internal rotation. The hand and forearm were then moved back and upwards in an arc as far

as possible. The reading was then taken for external rotation. The radial ulnar joint stayed supinated throughout the measurements.

ii) Shoulder flexion and extension:

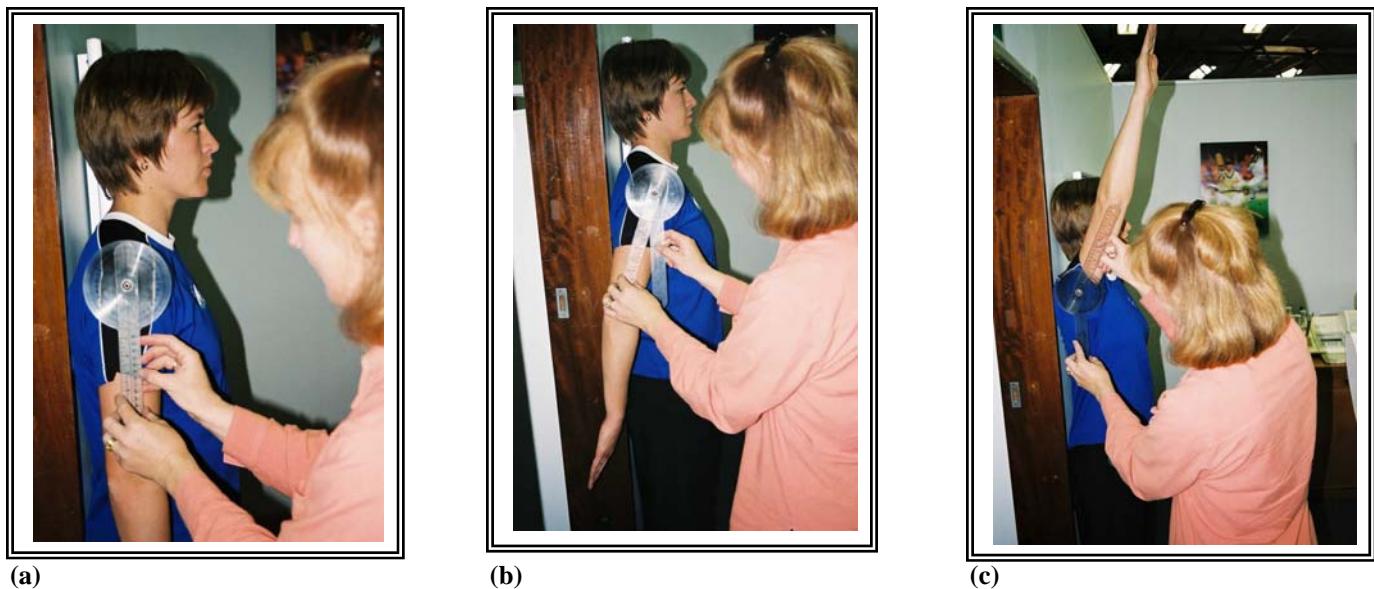


Figure 43: Measuring flexibility of the shoulder flexors and extensors.

(a) Neutral position. **(b)** Shoulder extension. **(c)** Shoulder flexion.

➔ **Starting position:** The subject stood at a projecting corner of a wall, with the arm to be measured extending just beyond the projecting corner. The back stayed flat against the wall with the shoulder blades, buttocks and the heels touching the wall.

➔ **Movement:** The arm was first moved forward and upwards in an arc as far as possible and the reading were taken for shoulder flexion. Thereafter the arm moved downwards and backwards in an arc as far as possible and reading was taken for shoulder extension. The elbow stayed in an extended position throughout the measurements.

3.2.3.4 Functional strength:

Functional shoulder muscle strength and endurance were determined by measuring:

→ **Maximum push-ups in 1 minute:** All subjects were to hold the proper push-up position. The hands were just more than shoulder width apart with the fingers pointing forwards. The whole body went down as one unit with the hips staying in line with the feet and shoulders. The chest had to stop 10cm above the floor.

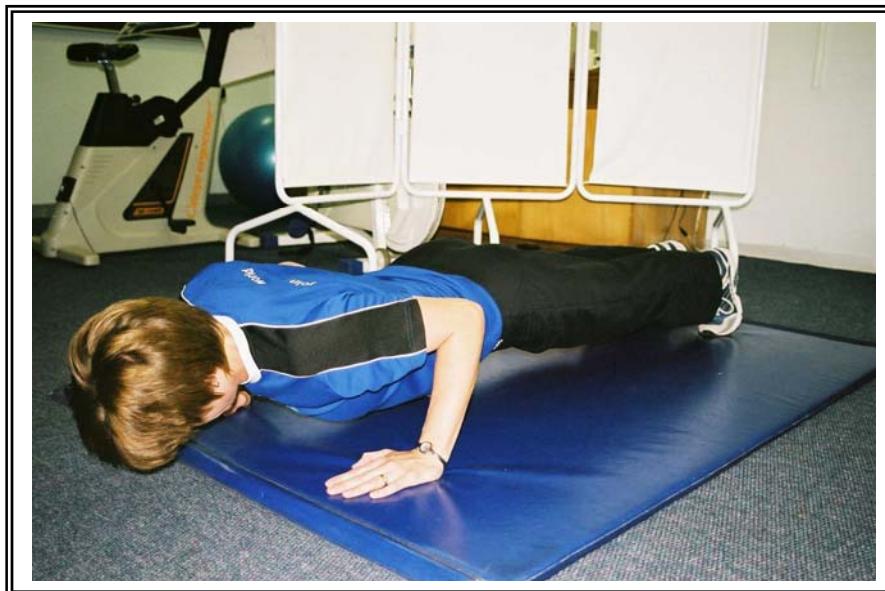


Figure 44: Demonstrating the correct push-up position.

3.2.3.5 Isokinetic strength:

The Cybex Norm was used to measure muscle strength and endurance in the shoulder girdle. The following movements were recorded:

→ **Shoulder flexion & extension:**

60°: 3 Warm-ups at 50%, 75% and 100% respectively;
5 maximal efforts recorded.

180°: 3 Warm-ups at 50%, 75% and 100% respectively;
20 maximal efforts recorded



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

→ **Shoulder abduction & adduction:**

60°: 3 Warm-ups at 50%, 75% and 100% respectively;
5 maximal efforts recorded.
180°: 3 Warm-ups at 50%, 75% and 100% respectively;
20 maximal efforts recorded

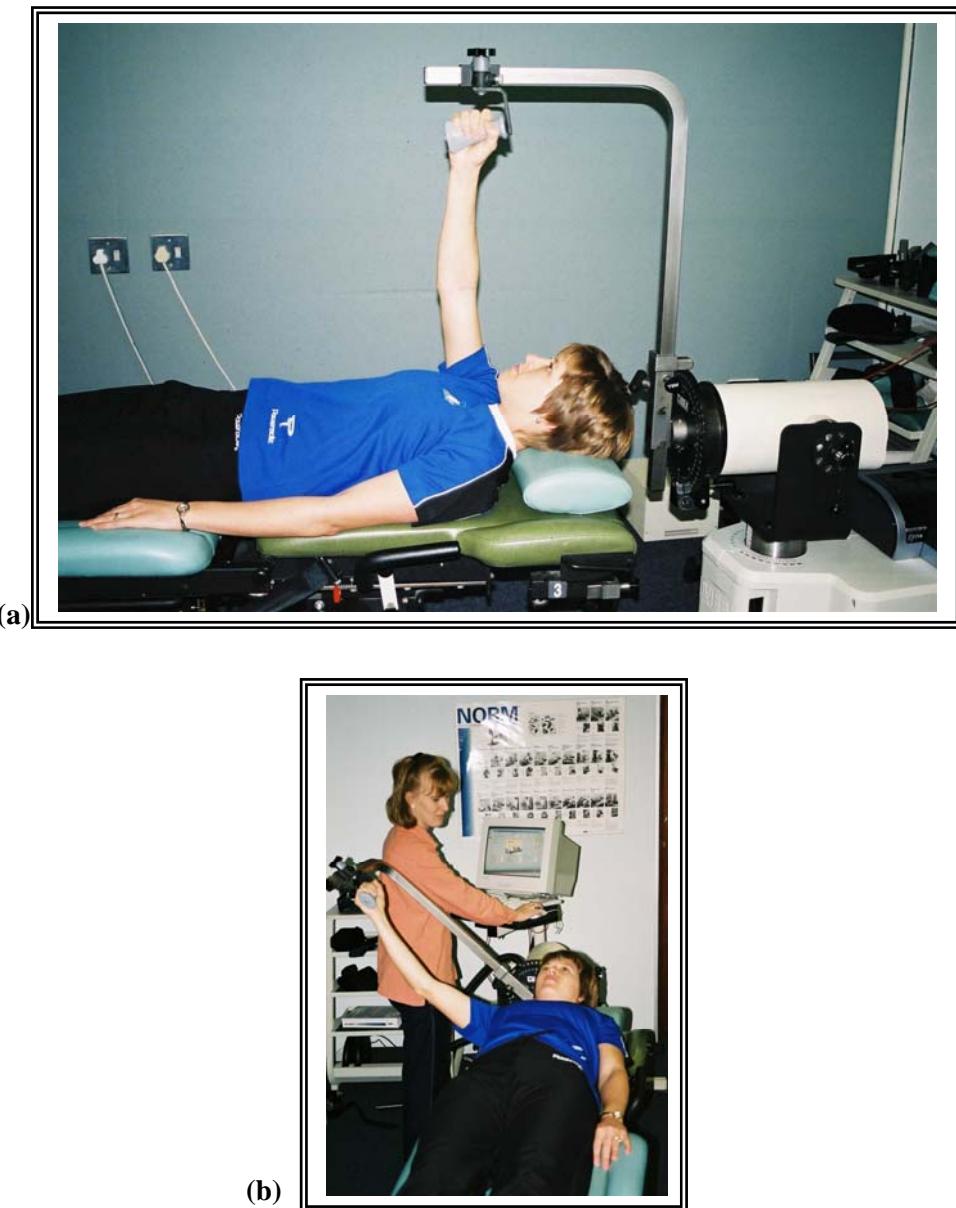


Figure 46: Isokinetic muscles strength of the (a) shoulder adductors and (b) shoulder abductors measured on the Cybex Norm.

→ **Shoulder internal & external rotation:**

- 60°: 3 Warm-ups at 50%, 75% and 100% respectively;
5 maximal efforts recorded.
- 180°: 3 Warm-ups at 50%, 75% and 100% respectively;
20 maximal efforts recorded



Figure 47: Isokinetic muscle strength of the shoulder. (a) Internal rotators. (b) External rotation, measured on the Cybex Norm.

As an indication of the correct muscle balance in the shoulder, the external rotator muscles have to produce approximately 60% to 80% of the torque values that is generated by the internal rotators (Perrin, 1993).

Table 15: Normative Values of the Shoulder Internal and External Rotation Peak Torque (ft-lb.) (Perrin, 1993).

Gender	Speed %/sec	Dominan t Internal rotation	Non- dominant Internal rotation	Dominant External rotation	Non- dominant external rotation	Dominant external / internal rotation ratio	Non- dominant external / internal rotation ratio
M	60	42.0	39.0	26.0	24.0	.63	.62
F	60	17.0	17.0	12.0	11.0	.70	.71
M	180	32.7		21.1		.70	.81

F	180	17.1		11.2		17	.80
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Table 16: Normative Values of the Shoulder Flexion and Extension Peak

Torque (ft-lb.) (Perrin, 1993).

Gender	Speed °/sec	Dominan t Flexion	Non- dominant Flexion	Dominant Extension	Non- dominant Extension	Dominant Flexion / Extensio n ratio	Non- dominant Flexion / Extensio n ratio
M	60	57.0		39.0			
F	60	28.0		18.0		.77	.81
M	180	49.0		30.0		.74	.81
F	180	19.0		11.0		.84	.82

Table 17: Normative Values of the Shoulder Abduction and Adduction Peak

Torque (ft-lb.) (Perrin, 1993).

Gender	Speed °/sec	Dominan t Abduction	Non- dominant Adduction	Dominant Abduction	Non- dominant Adduction	Dominant Abductio n / adductio n ratio	Non- dominant Abductio n / Adductio n ratio
M	60	39.0	37.0	63.	60.0	.66	.65
F	60	19.0	19.0	32.0	30.0	.61	.66
M	180	35.2	32.6	55.9	47.6	.49	.56
F	180	22.5	22.0	39.0	38	.74	.82

3.3 RESEARCH DESIGN

The type of research done in this study, was “theory testing” research (Mouton & Marais, 1992) where the data of the research was based on existing theories and models. The aim of the researcher is to test the effect of scientific exercise programmes in the sport world.

The researcher needed proof that by following specific scientific exercises it will prepare the tennis player for the stresses of the game and in this way reduce the occurrence of shoulder injuries throughout the year. Following basic existing models and concepts of tennis strengthening helped to achieve this.

The specific tests that were applied included:

- Posture analysis;
- Body composition;
- Flexibility;
- Functional strength of the upper body; and
- Isokinetic power and endurance of the shoulder muscles.

According to Mouton & Marais (1992) the following two aspects are necessary in order to achieve internal validity:

- a. The connections of the central concepts have to be very clear, unambiguous and articulated; and
- b. The denotations of the central concepts in the problem setting have to be accurate indicators of the connections that are used.

The aim and purpose of this kind of design for a research study was to determine the effect of a specifically designed Biokinetic programme on the prevention and rehabilitation of shoulder injuries in junior tennis players. The question had to be answered, whether there is a difference between the occurrence of shoulder

injuries in tennis players who follow a specific shoulder exercise programme and those players who just do the normal gymnasium exercise programmes.

3.4 STATISTICAL ANALYSIS

In research it is very important that the number of subjects, their characteristics as well as their representative nature of the sample are taken into consideration. In this universal study done, a group of subjects was measured and the results are representative of elite tennis players (Mouton & Marais, 1992).

The data analysis had the following aims:

- to determine whether significant differences existed between the 2 groups on all variables measured;
- to determine whether significant differences existed between the T1 and T3 measurements within the same group; and
- to determine whether there were significant changes in the measurements taken at different time intervals within the same group.

Since the sample was relatively small and consisted of only 22 and 20 respondents per group respectively, use was made of non-parametric statistics to analyze the data. Non-parametric tests, also known as distribution-free tests, are a class of tests that does not rely on a parameter estimation and/or distribution assumptions (Howell, 1992). The major advantage attributed to these tests is that they do not rely on any seriously restrictive assumptions concerning the shape of the sampled populations and thus accommodates small samples as in the case of this study.

3.4.1 The following statistical data analysis procedures were used:**a. Descriptive statistics:**

Descriptive statistics are primarily aimed at describing the data. The mean, standard deviation, minimum and maximum scores for each measurement per group were determined for reference purposes (Howel, 1992).

b. Inferential statistics:

Inferential statistics test the hypotheses about differences in populations on the basis of measurements made on samples of subjects (Tabachnick & Fidell, 1996).

c. The Mann-Whitney Test:

The Mann-Whitney test is used for testing differences between means when there are two conditions and different subjects have been used in each condition. This test is a distribution-free alternative to the independent samples t-test. Like the t-test, Mann-Whitney tests the null hypothesis that two independent samples (groups) come from the same population (not just populations with the same mean). Rather than being based on parameters of a normal distribution like mean and variance, Mann-Whitney statistics are based on ranks. The Mann-Whitney statistic is obtained by counting the number of times an observation from the group with the smaller sample size precedes an observation from the larger group. It is especially sensitive to population differences in central tendency (Howell, 1992). The rejection of the null hypothesis is generally interpreted to mean that the two distributions had different central tendencies. This test was used to determine significant differences between the experimental group and the control group on all variables measured.

d. The Wilcoxon Signed Ranks Test:

The Wilcoxon Signed Ranks test is used in situations in which there are two sets of scores to compare, but these scores come from the same subjects. This test is the distribution-free analogue of the t-test for related samples. According to Howell (1992) it tests the null hypothesis that two related (matched) samples were drawn either from identical populations or from symmetric populations with the same mean. This test was used to determine whether statistically significant differences existed between the T1 and T3 measurements obtained for various measures within the same group.

e. Friedman's rank test for correlated samples:

This test is the distribution free analogue of the one-way repeated measure analysis of variance. “*It is a test on the null hypothesis that the scores of each treatment were drawn from identical populations, and it is especially sensitive to population differences in central tendency*” (Howell, 1992). This test was used to determine whether statistically significant differences existed between the measurements obtained at the different periods within the same group.

In this research, the 95% level of confidence ($p < 0,05$), as required by Thomas & Nelson (1990), has been used as the minimum to determine significant differences among various sets of data.