CHAPTER 4
RESULTS AND DISCUSSION

The results will be presented in the following ways:

a. Results of the analysis of the comparison of the two groups on various measurements.

b. Results of the analysis of the comparison of the T1 and T3 measurements within the same group across various variables. This analysis was repeated for both groups.

c. Results of the analysis of the comparison of the same group across various variables at different time intervals. This analysis was repeated for both groups.

d. Results of cross-tabulations and frequencies on various variables for both groups.

4.1 BODY COMPOSITION

4.1.1 Results of the analysis of the comparison of measurements taken at T1 and T3 of the same group across various variables:

The Wilcoxon Signed Ranks test was used to determine whether statistically significant changes took place between measurements taken at T1 and at T3, within the same group regarding the various variables.

The following significant differences in distribution on the 5% level of significance were found between the results at T1 and T3 in the c*ontrol* and *experimental groups.* The results are summarized in **Figure 48:**

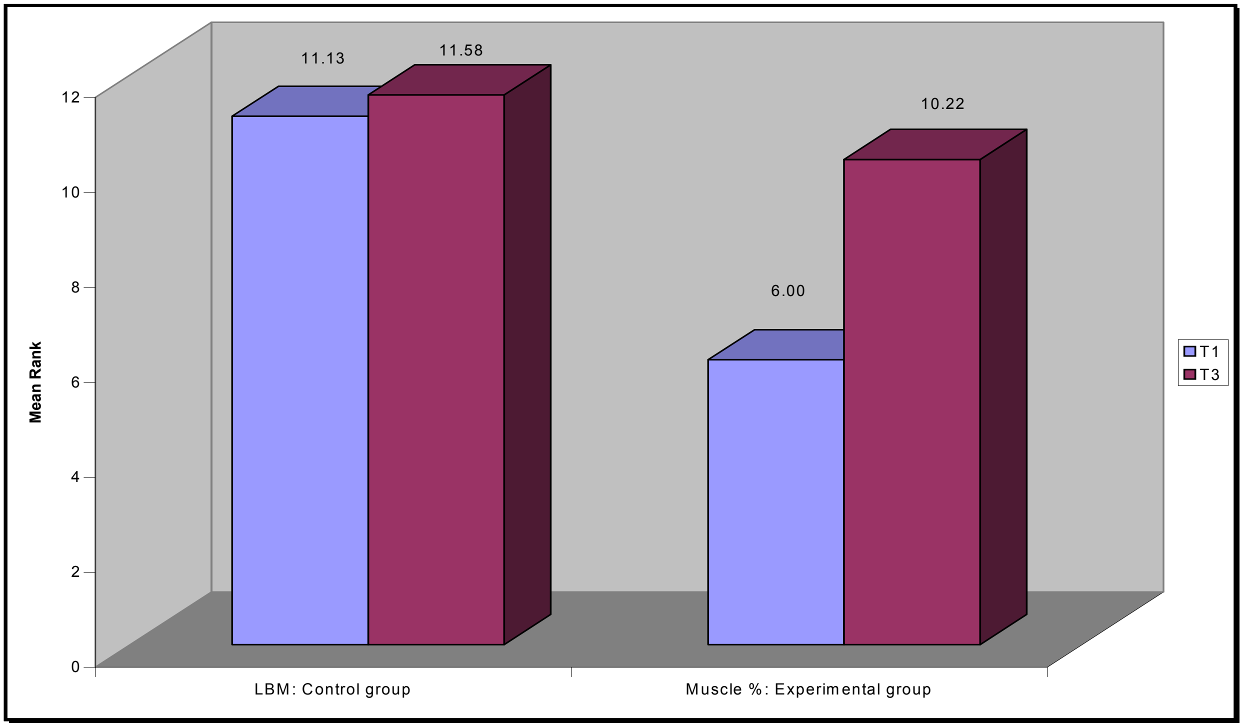

Figure 48: Statistically significant differences with groups: Body composition (T1 and T3).

The results of Figure 48 indicate the following:

a. From the distribution of the lean body mass at T3 in the *control group.* Thus, the lean body mass at T1 was therefore lower than the lean body mass at T3 in the *control group*.

b. The distribution of the muscle percentage at T1 is significantly different from the distribution of the muscle percentage at T3 in the *experimental group.* Thus, the muscle percentage at T1 was lower than the muscle percentage at T3 in the e*xperimental group*.

4.1.2 Results of the analysis of the comparison of the same group across various measurements at different time intervals:

Friedman's tests were used to determine whether statistically significant changes took place within the same group across the measurements taken at different time intervals. The results can be summarized as follows:

Statistically significant differences on the 5% level of significance were found for the experimental group for fat percentage and muscle percentage at different time intervals (T1 to T3). A statistically significant difference on the 5% level of significance was found for the control group for lean body mass at different time intervals (T1 to T3). The results of the above analysis are presented in Figure 49.

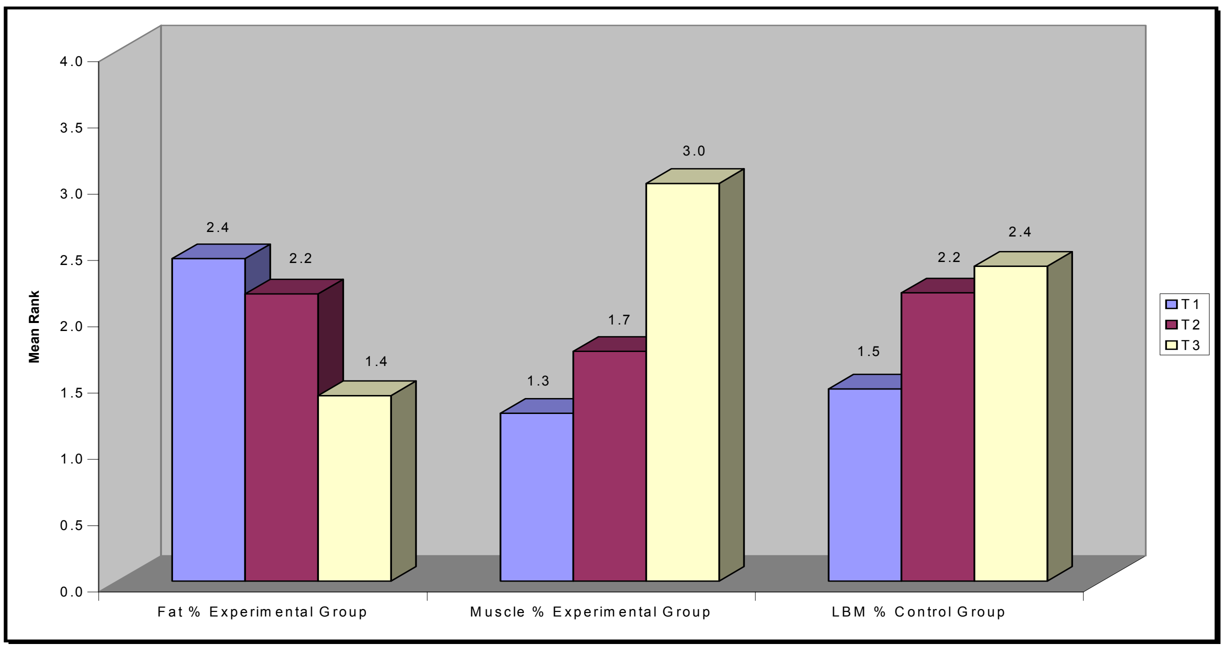

Figure 49: Statistically significant differences in Body Composition between T1, T2 and T3.

The results of Figure 49 indicate the following:

a. For the experimental group the fat percentage showed a significant decrease from T1 to T3;
b. For the experimental group, the muscle percentage showed a significant increase from T1 to T3; and
c. For the control group, the lean body mass showed a significant increase from T1 to T3.

Discussion: Lean Body Mass and fat percentage:

Researchers such as Roetert & Ellenbecker (1998) and Gokeler *et al*. (2001) characterize tennis as a sport in which players must respond to a continuous series of emergencies. This includes sprinting to the ball, changing direction, reaching, stretching, lunging, stopping and starting (Muller *et al*., 2000; Gokeler *et al*., 2001). Taking all these characteristics into consideration, players must address flexibility, strength training and *endurance*, power, agility and speed, body composition, *aerobic* and *anaerobic fitness* in order to improve their tennis (Roetert, 2003). The mean heart rate in trained players ranges between 140 and 160 beats per minute, which indicates overall intensity of 60 to 70% of the VO_2-max (Elliott *et al*., 1985; Bergeron *et al*., 1991, Konig *et al*., 2001). In professional players, this corresponds to an ergometrically-determined workload within an aerobic/anaerobic transition range of the treadmill of 13km/h for woman and 14km/h for men at a 1.5º slope (Konig *et al*., 2001). Apart from the weight-training programme, both the control and the experimental group still followed their normal aerobic training programme, therefore the increase in Lean Body Mass of the control group and the decrease in fat percentage of the experimental group. According to McArdle *et al*. (1991) adipose tissue increases either by cell hypertrophy or fat cell hyperplacia. With a loss in body mass, there is only a decrease in cell size, but never a decrease in cell number. An increased caloric output through endurance type exercise provides a significant option of unbalancing the energy balance equation to bring about weight loss as well as a desirable modification in body composition (Craig, 1983). The performance of conventional resistance training programmes combined with caloric restriction, results in the maintenance of lean body mass compared to a programme that relies only on diet (McArdle *et al*., 1991).

Discussion: Muscle percentage:

As mentioned earlier, resistance training has become a very important training tool in tennis (Kraemer *et al*., 2003). According to Konig *et al*. (2001) the progressive adaptation of top ranked players, induced by years of training and match play, includes an increase in the muscle mass of the dominant arm. According to Wilmore (1974), Gollnick (1983), Hakkinen (1988) and McArdle *et al*. (1991) this fundamental biological adaptation that takes place in response to overload training occurs primarily from the enlargement of hypertrophy on the individual muscle fibres.

4.2 MUSCLE STRENGTH AND ENDURANCE

4.2.1 Results of the analysis of the comparison of the two groups on various measurements:

The Mann-Whitney U-tests were used to determine whether statistically significant differences existed between the experimental and control groups on various variables measured. Since this statistical technique is based on mean rank, the mean rank scores will be shown in all figures. Statistically significant differences on the 5% level of significance will be graphically presented.

Statistically significant differences were found at the 5% level of significance between the control and experimental groups for 1RM bench press at T3 and maximum number of push-ups in 1 minute at T2 and T3. The results are summarized **in Figure 50.**

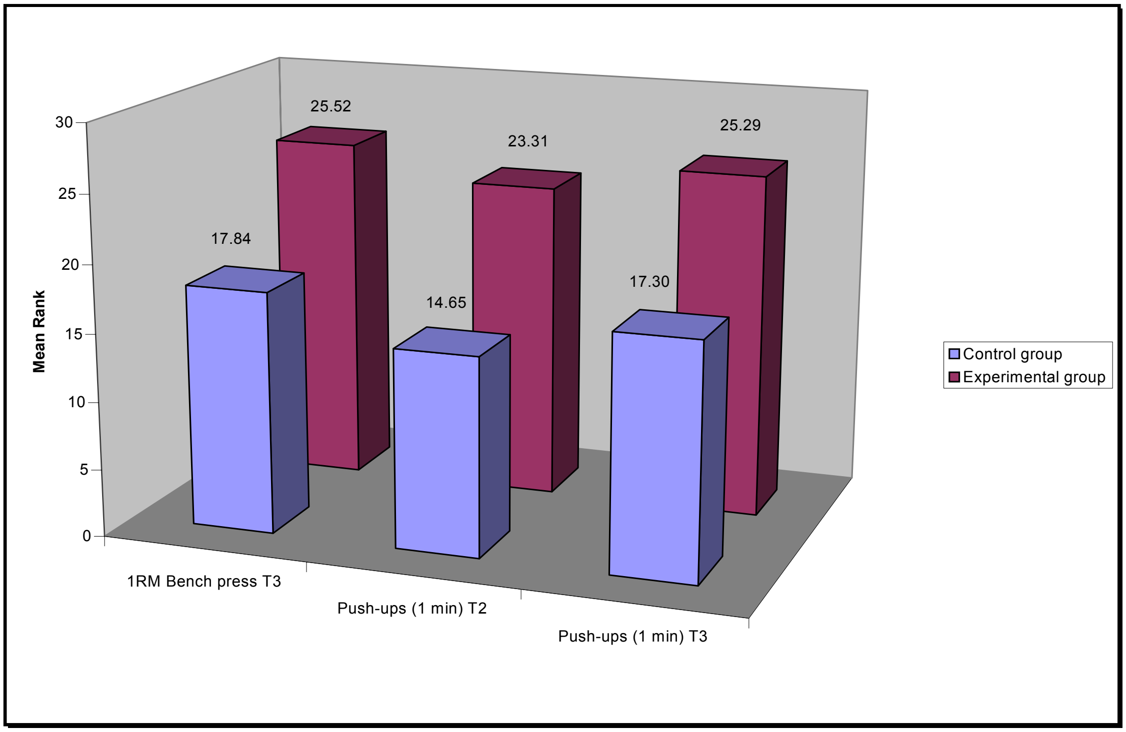

Figure 50: Statistically significant difference between groups: Muscle strength and endurance.

*Results in **Figure 50** can be interpreted as follows:*

1RM bench press measurements at T3 are lower for the control group than for the experimental group. This is also true for the maximum number of push-ups in 1 minute at T2 and T3. The control group therefore had lower 1RM bench press measurements at T3 than the experimental group. The control group also had a lower maximum number of push-ups in 1 minute at both T2 and T3 than the experimental group.

4.2.2 Results of the analysis of the comparison of measurements taken at T1 and T3 of the same group across various variables:

The Wilcoxon Signed Ranks test was used to determine whether statistically significant changes took place between measurements taken at T1 and at T3, within the same group regarding the various variables.

The following significant differences in distribution on the 5% level of significance were found between the results at T1 and T3 in the *control* and *experimental groups.*

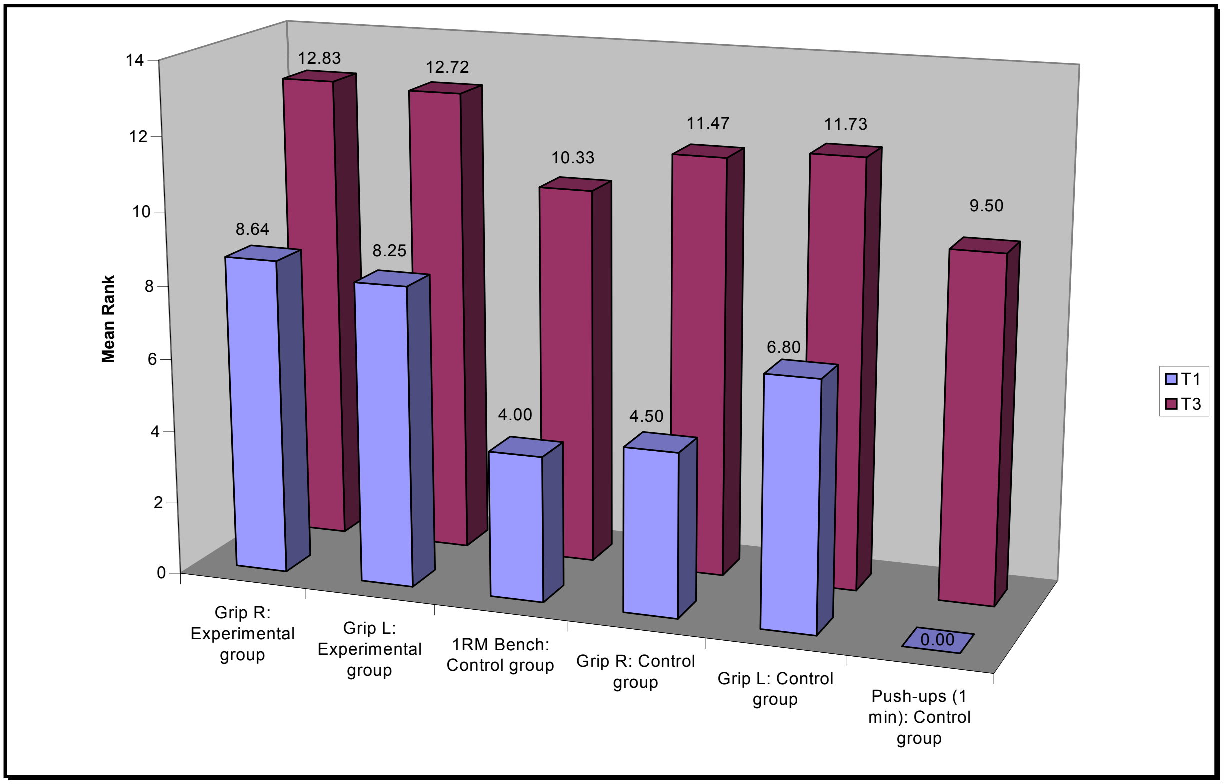

Figure 51: Statistically significant difference within groups: Isokinetic muscle strength (T1 and T3).

*The results of **Figure 51** indicate the following:*

a. The distribution of the 1RM bench press at T1 is significantly different from the distribution of the 1RM bench press at T3 in the *experimental group*. The 1RM bench press at T1 was therefore lower than the 1RM bench press at T3 in the *experimental group*.

b. The distribution of the grip strength of the dominant hand at T1 is significantly different from the distribution of the grip strength of the dominant hand at T3 in the e*xperimental group.* Thus, the grip strength of the dominant hand at T1 was therefore lower than the grip strength of the dominant hand at T3 in the e*xperimental group*.

c. The distribution of the grip strength of the non-dominant hand at T1 is significantly different from the distribution of the grip strength of the non-dominant hand at T3 in the e*xperimental group.* Thus, the grip strength of the non-dominant hand at T1 was therefore lower than the grip strength of the non-dominant hand at T3 in the e*xperimental group*.

d. The distribution of the maximum push-ups in 1 minute at T1 is significantly different from the distribution of the maximum push-ups in 1 minute, at T3 in the e*xperimental group.* Thus, the maximum push-ups in 1 minute at T1 were therefore lower than the maximum push-ups at 1 minute at T3 in the e*xperimental group*.

e. The distribution of the grip strength of the dominant hand at T1 is significantly different from the distribution of the grip strength of the dominant hand at T3 in the *control group.* Thus, the grip strength of the dominant hand at T1 was therefore lower than the grip strength of the dominant hand at T3 in the *control group.*

f. The distribution of the grip strength of the non-dominant hand at T1 is significantly different from the distribution of the grip strength of the non-dominant hand at T3 in the *control group.* Thus, the grip strength of the non-dominant hand at T1 was therefore lower than the grip strength of the non-dominant hand at T3 in the *control group.*

4.2.3 Results of the analysis of the comparison of the same group across various measurements at different time intervals:

Friedman tests were used to determine whether statistically significant changes took place within the same group across the measurements taken at different time intervals. The results can be summarized as follows:

Statistically significant differences were found on the 5% level of significance for the experimental group regarding the 1RM bench press, grip strength of the dominant and non-dominant hands, and maximum push-ups in 1 minute. A statistically significant difference, on the 5% level of significance, was found for the control group for grip strength of the non-dominant hand. The results of the above analysis are presented in Figures 52 and 53 that follow.

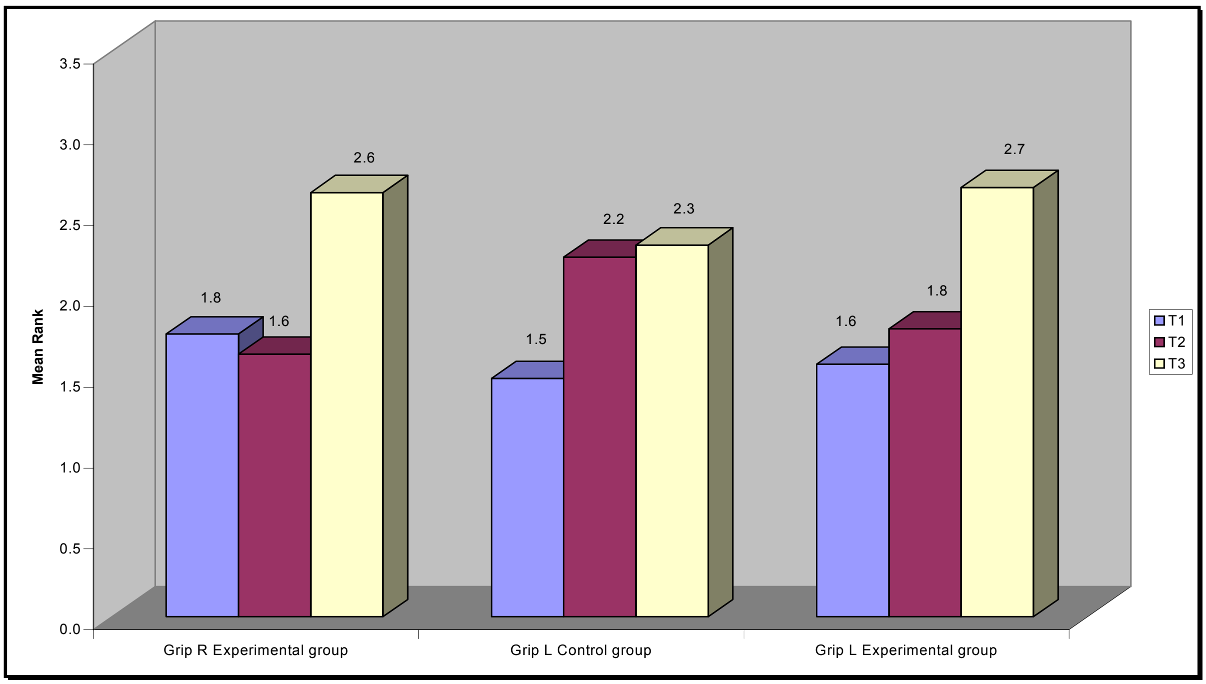

Figure 52: Statistically significant difference for Muscle Strength and Endurance between T1, T2 and T3.

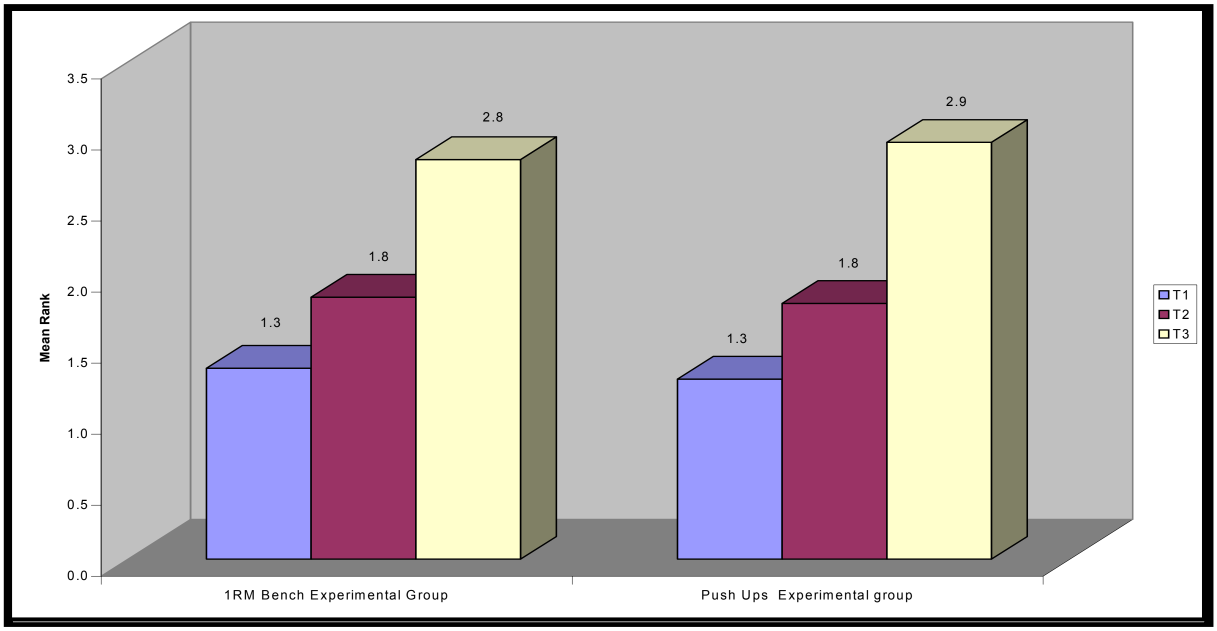

Figure 53: Statistical significant differences for Muscle Strength and Endurance between T1, T2 and T3 (continue).

*The results of **Figures 52** and **53** indicate the following:*

a. For the *experimental group*, the 1RM bench press showed a significant increase from T1 to T3, peaking at T3.

b. For the *experimental gro*up, the grip strength of the dominant as well as the grip strength of the non-dominant hands showed a significant increase from T1 to T3.

c. For the *experimental group*, the maximum push-ups in 1 minute showed a significant increase from T1 to T3.

d. For the *control group*, the grip strength of the non-dominant hand showed a significant increase from T1 to T2, from where it showed a slight increase to T3.

Discussion:

The weight- training programme that was followed by the experimental group, was based on the principle of "progressive overload". In order to raise the level of strength and stamina, the body had to be subjected to an increased resistance through heavier weights, higher repetitions and longer or more frequent training sessions (Kirkley & Goodbody, 1986; Kraemer *et al*., 2003). According to research done by Anderson & Kearney (1992) and Kraemer *et al*. (2003) individuals that were exposed to heavier loads during training experienced greater improvements in maximal strength performance. Due to the importance of muscular power in tennis, resistance training, and therefore muscular strength, became a very important training tool to optimize the neuromuscular performance factors related to the primary strokes in tennis (Kraemer *et al*. 2003). The exercise programmes that were followed, were specifically designed to meet the demands of tennis (Costill & Fox, 1969; Matveyev, 1981; Kirkley & Goodbody, 1986; Kraemer *et al*., 2003; Roetert, 2003). The inclusion of weights in the training programme helped to improve explosive speed on the court, muscle strength as well as muscle endurance (Kirkley & Goodbody, 1986; Roetert, 2003; Salisbury *et al*., 2003).

4.3. ISOKINETIC MUSCLE STRENGTH

4.3.1 Results of the analysis of the comparison of the two groups on various measurements:

As indicated previously, Mann-Whitney U-tests were used to determine whether statistically significant differences existed between the experimental and control groups on various variables measured.

A statistically significant difference was found on the 5% level of significance between the *control* and *experimental group*s for the strength of the internal rotators of the non-dominant shoulder at T3. Thus, the *control* and *experimental groups* differed significantly with regard to the strength of the internal rotators of the non-dominant shoulder at T3. Results can be found in **Figure 54** below.

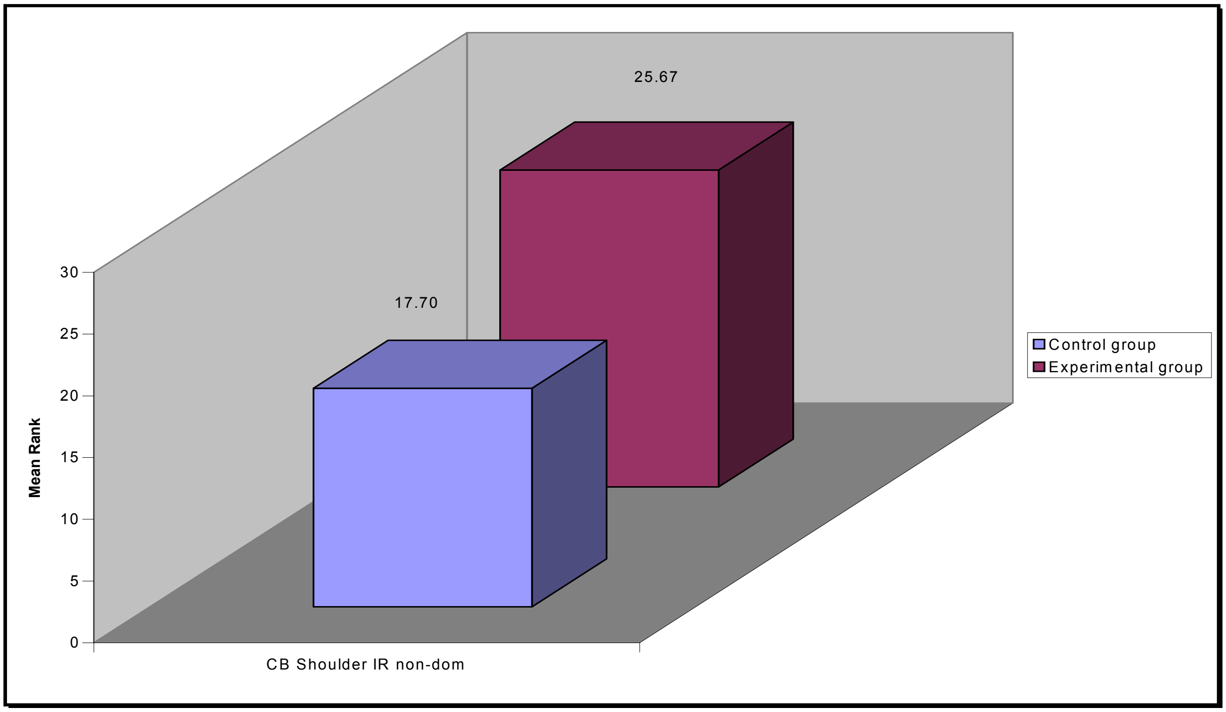

Figure 54: Statistically significant differences between groups: Isokinetic Muscle Strength (T3).

From the results in Figure 54 it can be seen that the strength of the internal rotators of the non-dominant shoulder at T3 was significantly lower for the *control group* than for the *experimental group*.

4.3.2 Results of the analysis of the comparison of measurements taken at T1 and T3 of the same group across various variables:

The Wilcoxon Signed Ranks test was used to determine whether statistically significant changes took place between measurements taken at T1 and at T3, within the same group regarding the various variables.

The following significant differences in distribution on the 5% level of significance were found between the results at T1 and T3 in the *control* and *experimental group.* The results are summarized in Figures 55 and 56.

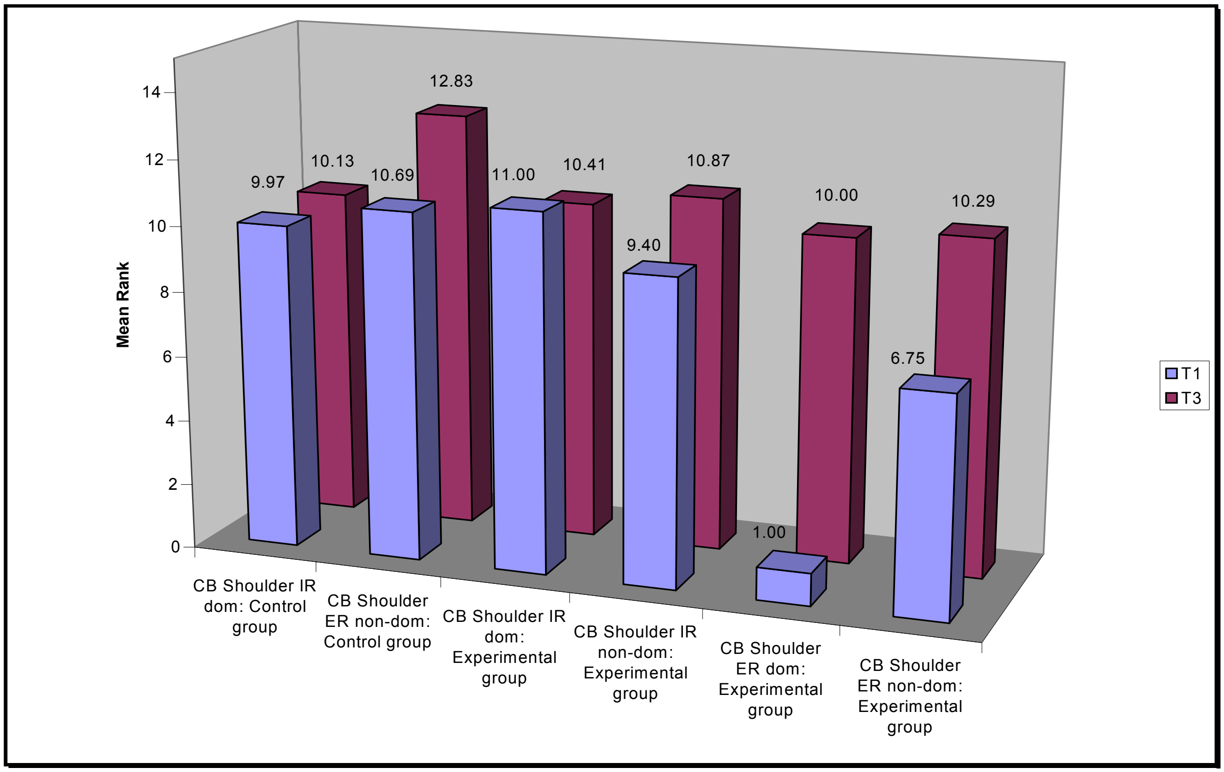

Figure 55: Statistically significant differences within groups: Isokinetic Muscle Strength (T1 and T3).

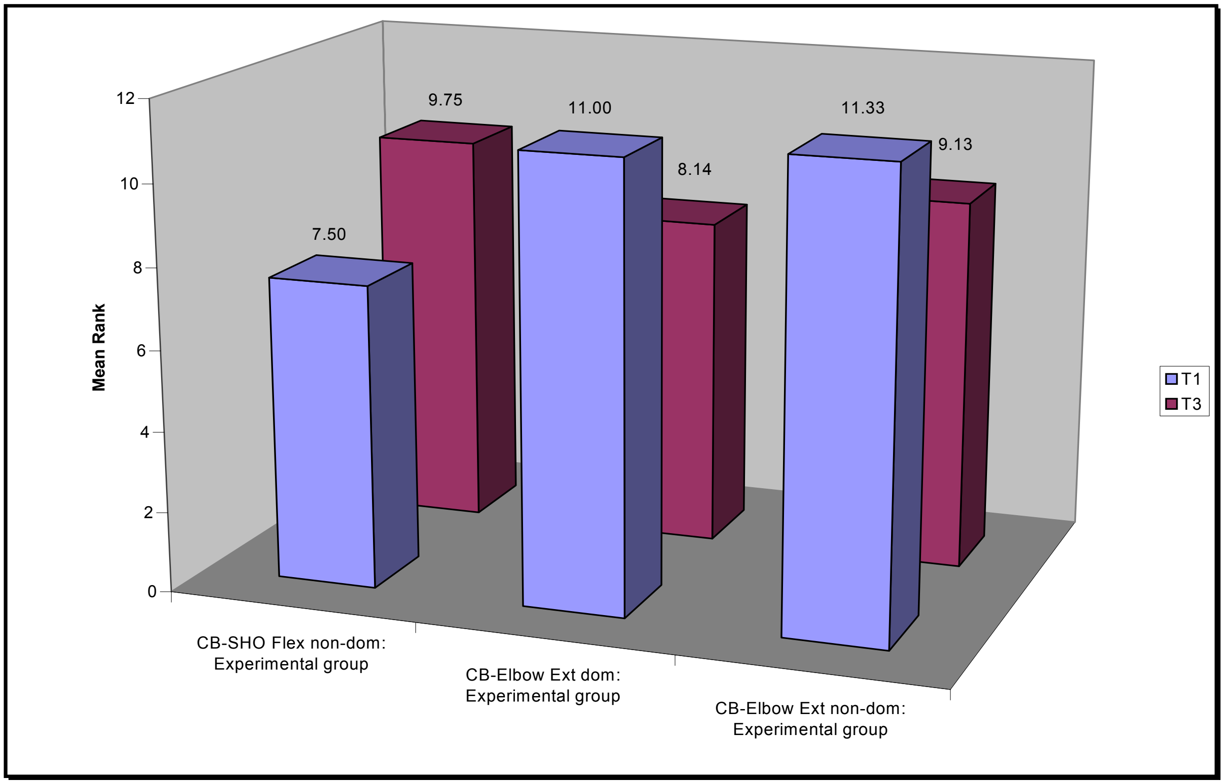

Figure 56: Statistically significant differences within groups: Isokinetic Muscle Strength (continue) (T1 and T3).

The results of Figures 55 and 56 indicate the following:

a. The distribution of the strength of the internal rotators of the dominant shoulder at T1 is significantly different from the distribution of the strength of the internal rotators of the dominant shoulder at T3 in the *experimental group*. The strength of the internal rotators of the dominant shoulder at T1 was therefore lower than the strength of the internal rotators of the dominant shoulder at T3 in the *experimental group*.

b. The distribution of the strength of the internal rotators of the non-dominant shoulder at T1 is significantly different from the distribution of the strength of the internal rotators of the non-dominant shoulder at T3 in the *experimental group*. The strength of the internal rotators of the non-dominant shoulder at T1 was therefore lower than the strength of the internal rotators of the non-dominant shoulder at T3 in the *experimental group*.

c. The distribution of the strength of the external rotators of the dominant shoulder at T1 is significantly different from the distribution of the strength of the external rotators of the dominant shoulder at T3 in the *experimental group*. The strength of the external rotators of the dominant shoulder at T1 was therefore lower than the strength of the external rotators of the dominant shoulder at T3 in the e*xperimental group*.

d. The distribution of the strength of the external rotators of the non-dominant shoulder at T1 is significantly different from the distribution of the strength of the external rotators of the non-dominant shoulder at T3 in the e*xperimental group*. The strength of the external rotators of the non-dominant shoulder at T1 was therefore lower than the strength of the external rotators of the non-dominant shoulder at T3 in the e*xperimental group*.

e. The distribution of the strength of the flexor muscles for the non-dominant shoulder at T1 is significantly different from the distribution of the strength of the flexor muscles for the non-dominant shoulder at T3 in the *experimental group*. The strength of the flexor muscles for the non-dominant shoulder at T1 was therefore lower than the strength of the flexor muscles for non-dominant shoulder at T3 in the e*xperimental group*.

f. The distribution of the strength of the elbow extensors for the dominant elbow at T1 is significantly different from the distribution of the strength of the elbow extensors for the dominant elbow at T3 in the *experimental group*. The strength of the elbow extensors for the dominant elbow at T1 was therefore lower than the strength of the elbow extensors for dominant elbow at T3 in the *experimental group*.

g. The distribution of the strength of the elbow extensors for the non-dominant elbow at T1 is significantly different from the distribution of the strength of the elbow extensors for the non-dominant elbow at T3 in the *experimental group*. The strength of the elbow extensors for the non-dominant elbow at T1 was therefore lower than the strength of the elbow extensors for non-dominant elbow at T3 in the *experimental group*.

h. The distribution of the internal rotators of the non-dominant shoulders at T1 is significantly different from the distribution of the internal rotators of the non-dominant shoulders at T3 in the *experimental group*. The internal rotators of the non-dominant shoulders at T1 were therefore lower than the internal rotators of the non-dominant shoulders at T3 in the *experimental group*.

i. The distribution of the external rotators of the dominant shoulders at T1 is significantly different from the distribution of the external rotators of the dominant shoulders at T3 in the *experimental group*. The external rotators of the dominant shoulders at T1 were therefore lower than the external rotators of the dominant shoulders at T3 in the *experimental group*.

j. The distribution of the external rotators of the non-dominant shoulders at T1 is significantly different from the distribution of the external rotators of the non-dominant shoulders at T3 in the *experimental group*. The external rotators of the non-dominant shoulders at T1 were therefore lower than the external rotators of the non-dominant shoulders at T3 in the e*xperimental group*.

Discussion:

According to Costill & Fox (1969), Matveyev (1981), Kirkley & Goodbody (1986), Kraemer *et al*. (2003) and Roetert (2003) the importance of specificity of training cannot be stressed enough. One thing that strongly emerges, is the fact that training has to be geared to the specific sport that the athlete is training for (Fleck, 1999; Kraemer *et al*., 2003). Most injuries in tennis are typical *overuse* injuries (Priest & Nagel, 1976; Schmidt-Wiethoff *et al*., 2000; Roetert, 2003), resulting from repetitive stresses and minor traumatic events, as well as muscle imbalances (Reece *et al*., 1986; Roetert & Ellenbecker, 1998; Meister, 2000). Typically in tennis, the anterior muscles of the shoulder and the chest (pectoralis and anterior deltoids) are stronger than the rotator cuff and the upper back muscles that support the scapula (Roetert & Ellenbecker, 1998). The programme of the experimental group focused on strengthening of the rotator cuff muscles on the dominant and non-dominant side as well as the internal rotators of the non-dominant arm that plays a key role in the double-handed backhand. Other muscles used in the double-handed backhand include the latissimus dorsi, clavicular pectoralis, sternocostal pectoralis and the anterior deltoid (Hay & Reid, 1999; Gokeler *et al*., 2001; Martini *et al*. 2001; Schmidt-Wiethoff *et al*., 2003).

4.4 FLEXIBILITY

4.4.1 Results of the analysis of the comparison of measurements taken at T1 and T3 of the same group across various variables:

The Wilcoxon Signed Ranks test was used to determine whether statistically significant changes took place between measurements taken at T1 and at T3, within the same group regarding the various variables.

The following significant differences in distribution on the 5% level of significance were found between the results at T1 and T3 in the *control* and *experimental groups.* The results are summarized in Figure 57 that follows.

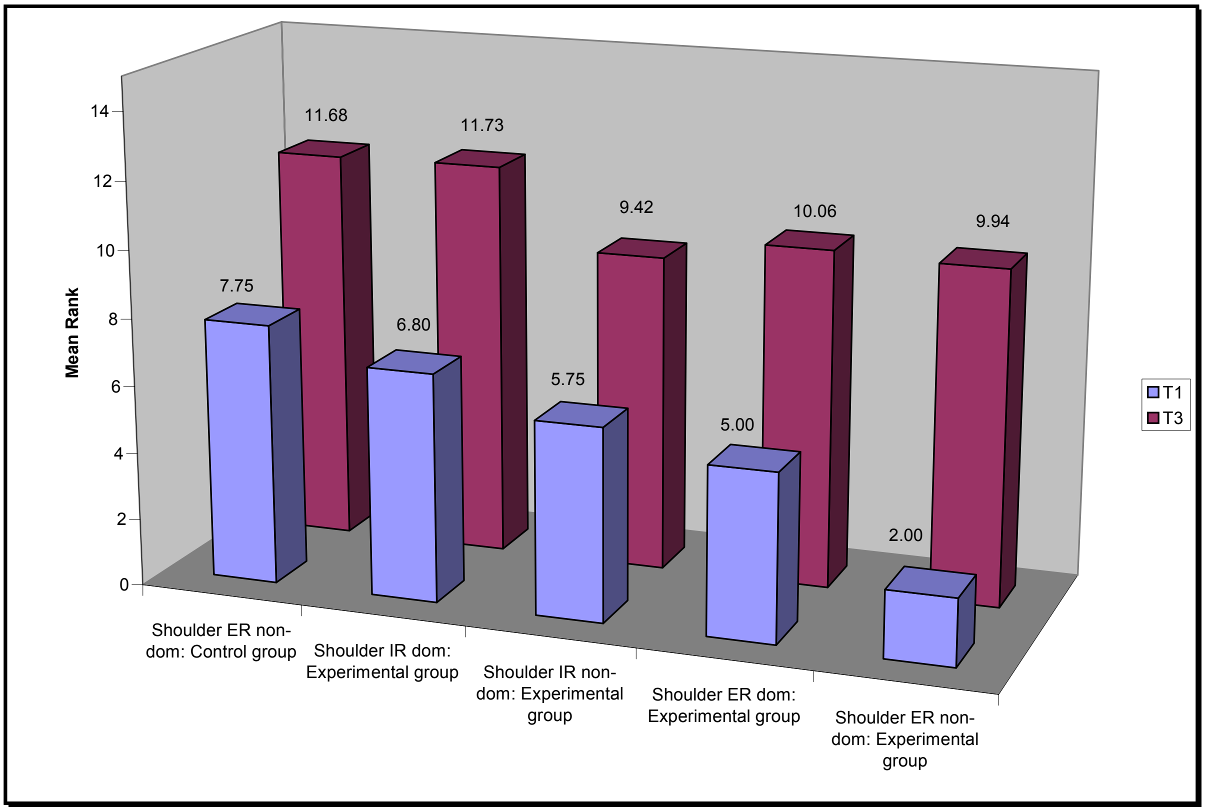

Figure 57: Statistically significant differences within groups: Flexibility (T1 and T3).

The results of Figure 57 indicate the following:

a. The distribution of the internal rotators of the dominant shoulders at T1 is significantly different from the distribution of the internal rotators of the dominant shoulders at T3 in the e*xperimental group*. The internal rotators of the dominant shoulder at T1 were therefore lower than the internal rotators of the dominant shoulder at T3 in the *experimental group*.

b. The distribution of the internal rotators of the non-dominant shoulders at T1 is significantly different from the distribution of the Internal rotators of the non-dominant shoulders at T3 in the *experimental group*. The internal rotators of the non-dominant shoulder at T1 were therefore lower than the internal rotators of the non-dominant shoulder at T3 in the *experimental group*.

c. The distribution of the external rotators of the dominant shoulders at T1 is significantly different from the distribution of the external rotators of the dominant shoulders at T3 in the *experimental group*. The external rotators of the dominant shoulder at T1 were therefore lower than the external rotators of the dominant shoulder at T3 in the *experimental group*.

d. The distribution of the external rotators of the non-dominant shoulders at T1 is significantly different from the distribution of the external rotators of the non-dominant shoulders at T3 in the *experimental group*. The external rotators of the non-dominant shoulder at T1 were therefore lower than the external rotators of the non-dominant shoulder at T3 in the *experimental group*.

e. The distribution of the external rotators of the non-dominant shoulders at T1 is significantly different from the distribution of the external rotators of the non-dominant shoulders at T3 in the *control group*. The external rotators of the non-dominant shoulder at T1 were therefore lower than the external rotators of the non-dominant shoulder at T3 in the *control group*.

Discussion:

According to the results, the experimental group showed an improvement in the flexibility of the internal and external rotators in both the dominant and the non-dominant shoulders, where the control group only improved on the external rotators of the non-dominant shoulder. According to Roetert & Ellenbecker (1998) an important factor contributing to overuse injuries in the shoulder is muscle imbalance (Muller *et al*., 2000). It is therefore important that the exercise programme allows for the improvement of muscle imbalances both in strength and flexibility (Kirshblum *et al*., 1997, Gokeler *et al*., 2001). Most tennis players are flexible in the external shoulder rotation due to the serving action, but have limited internal rotation on their tennis playing side (Roy *et al*., 1995; Kirshblum *et al*., 1997). Specific flexibility exercises help to overcome imbalances created by tennis and other daily activities and they lighten the intensity of work of the opposing muscle groups by providing less restricted motion (Roy *et al*., 1995; Roetert & Ellenbecker, 1998). Flexibility can be defined as the degree in which the muscles, tendons and connective tissues around the joints can elongate and bend (Burnham *et al*., 1993; Roy *et al*., 1995; Kirshblum *et al*., 1997, Salisbury *et al*., 2003). In tennis a player is required to make shots that places his body parts in extreme ranges of motion. If the player can maintain strength throughout a flexible, unrestricted range of motion it will help prevent injuries and enhance performance (Roy *et al*., 1995; Salisbury *et al*., 2003). Static flexibility was used as an indication of the amount of motion that the player has around a joint or series of joints while at rest (Kirshblum *et al*., 1997; Burnham *et al*., 1993; Kirshblum *et al*., 1997; Salisbury *et al*., 2003). Dynamic flexibility is very important in tennis, for it describes the active range of motion about the joints and represents the amount of movement the player has available for executing serves, groundstrokes and volleys (Roy *et al*., 1995; Roetert & Ellenbecker, 1998; Salisbury *et al*., 2003). The joint structure's resistance to motion limits dynamic flexibility, as well as the ability of the soft tissue (muscles and tendons) to deform and the neuromuscular components of the body, including the nerves (Roy *et al*., 1995; Salisbury *et al*., 2003). Heat increases the elongation and bending properties of soft tissue in the body. Warming up before stretching raises the body's core temperature and provides greater gains in flexibility with less micro trauma to the tissues being stretched (Roetert & Ellenbecker, 1998; Salisbury *et al*., 2003). Also when a muscle is stretched quickly, the muscle spindle sends a message to the central nervous system to contract the muscle (Burnham *et al*., 1993; Schmidt-Wiethoff *et al*., 2000). This stretch reflex causes the muscle to shorten and contract, therefore hindering the stretching process (Burnham *et al*., 1993; Roetert & Ellenbecker, 1998).

4.5 POSTURE MEASURES

4.5.1 Scoliosis

Use was made of frequency tables to determine the percentage of players with scoliosis within each group (experimental and control) for T1 compared to T3. A player is said to have scoliosis when his posture is either convex to the dominant side or convex to the non-dominant side. Use was also made of the same frequency tables to determine the percentage of players within each group that are convex to the dominant side and convex to the non-dominant side for T1 compared to T3. Results for this analysis can be found in Tables 18 and 19 that follow.

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

Group			Frequency	Percent	Valid %	Cumulative %
Control Group	Valid	Cv	9	40.	40.	40.
		Level	13	59.	59.	100.
		Total	22	100.	100.	
Experimental Group	Valid	cv	5	25.	25.	25.
		cv	1	5.0	5.0	30.
		nor	14	70.	70.	100.
		Total	20	100.	100.	

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

			Frequency	Percent	Valid Percent	Cumulative %
Control Group	**Valid**	Cv	1	4.5	4.5	54.
		Cv	10	45.	45.	
		Leve	22	100.	100.	100.
		Total	5	25.	25.	
Experimental Group	**Valid**	Cv	1	5.0	5.0	50.
		Cv	5	25.	25.	55.
		cv nor	4	20.	20.	25.
		No	5	25.	25.	75.
		Total	20	100.	100.	100

From results in Tables 18 and 19 the following can be seen:

a. For the *control group*, 54.5% of players had scoliosis at T1, compared to 55% of the *experimental group*.
b. For the *control group* at T3, 40.9% of players had scoliosis compared to the 30% in the *experimental group*.
c. Although the percentage of players with scoliosis in both the *control* and *experimental groups* showed a decrease from T1 to T3, the players in the

experimental group showed a larger decrease than those in the *control group.*

d. Fifty percent (50%) of players in the *control group* were convex to the non-dominant side at T1, compared to the 4.5% that was convex to the dominant side. At T3, 40.9% of players in the *control group* were convex to the non-dominant side with none of the players being convex to the dominant side.

e. The players in the *experimental group* showed a similar trend than those in the *control group* at T1. Fifty percent (50%) of players in the *experimental group* were convex to the non-dominant side compared to the 5% that was convex to the dominant side. At T3, 25% of players in the *control group* were convex to the non-dominant side with 5% still being convex to the dominant side.

4.5.2 Shoulder height

Use was made of frequency tables to determine the shoulder height of players in both the control and experimental groups at T1 and T3. A summary of the analysis can be found in Tables 20 and 21 that follow:

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

Group			Frequency	Percent	Valid Percent	Cumulative Percent
Control Group	Valid	ND	14	63.	63.	63.
		Leve	8	36.	36.	100.
		Total	22	100.	100.	
Experimental Group	Valid	ND	10	50.	50.	50.
		level	9	45.	45.	95.
		D	1	5.0	5.0	100.
		Total	20	100.	100.	

Table 21: Frequency tables for the control and experimental groups for shoulder height at T3.

Group			Frequency	Percent	Valid Percent	Cumulative Percent
Control Group	Valid	ND	9	40.	40.	40.
		Leve	13	59.	59.	100.
		Total	22	100.	100.	
Experimental Group	Valid	ND	5	25.	25.	25.
		level	14	70.	70.	95.
		D	1	5.0	5.0	100.
		Total	20	100.	100.	

From results in Tables 20 and 21 the following can be seen:

a. For the *control group* at T1, 63.6% of players' shoulder heights were not level. For the *experimental group* at T1, 55% of the players' shoulder heights were not level.
b. At T3, 40.9% of *control group* players' shoulder heights were not level, compared to 30% in the *experimental group*.
c. At both T1 and T3, the percentage of players with shoulder heights not level in the control group, was higher than that in the *experimental group*. In both the *control* and *experimental groups*, the percentage of players with shoulder heights not level, decreased from T1 to T3.
d. 63.6% of players in the *control group's* non-dominant shoulder were higher than the dominant shoulder at T1, compared to the 40.9% of players at T3. There were no players in the *control group* with the dominant shoulder higher than the non-dominant one.
e. For the players 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, at T3. Those with the non-dominant shoulder being higher at T1 therefore showed a decrease to T3.

4.5.3 CM Bend

The CM bend was used to determine whether scoliosis was present. According to Shrober's test scoliosis is present when the CM bend is less than 5 cm (Becker, 1986).

A cross-tabulation was run to determine in what percentage of players, CM bend was less than 5 in T1 and became greater than 5 in T2. This was done for both the control and experimental groups. A summary of results can be found in Table 22 below.

Table 22: Cross-tabulation of CM Bend at T1 with CM Bend at T3 for both the control and experimental groups.

Group				CM Bend		Total
				<5	>5	
Experimental Group	CM T1	<5	Coun	8	5	13
			% within CM Bend	61.5%	38.5%	100.0
		>5	Coun		9	9
			% within CM Bend		100.0	100.0
	Total		Coun	8	14	22
			% within CM Bend	36.4%	63.6%	100.0
Control Group	CM T1	<5	Coun	8	2	10
			% within CM Bend	80.0%	20.0%	100.0
		>5	Coun		10	10
			% within CM Bend		100.0	100.0
	Total		Coun	8	12	20
			% within CM Bend	40.0%	60.0%	100.0

From the results in Table 22 the following can be seen:

a. In 38.5% of cases, in the experimental group, CM bend was less than five in T1 and became more than five in T3.
b. In 20% of cases, in the control group, CM bend was less than five in T1 and became greater than five in T3.

4.5.4 Higher hip

Use was made of frequency tables to determine the percentage of players within each group (control and experimental), with hips that were not level. It was also used to determine the percentage of players with the left hip higher than the right hip, and the right hip higher than the left hip. This was also done for both groups. A summary of results can be found in Tables 23 and 24 that follow.

Table 23: Frequency table for the control and experimental groups for Hip Height at T1.

Group			Frequency	Percent	Valid	Cumulative Percent
Control Group	Valid	Leve	8	36.	36.	36.
		D	14	63.	63.	100.
		Total	22	100.	100.	
Experimental Group	Valid	Leve	9	45.	45.	50.
		D	10	50.	50.	100.
		ND	1	5.0	5.0	5.0
		Total	20	100.	100.	

Table 24: Frequency tables for the control and experimental groups for Hip Height at T3.

Group			Frequency	Percent	Valid	Cumulative Percent
Control Group	Valid	Leve	13	59.	59.	59.
		D	9	40.	40.	100.
		Total	22	100.	100.	
Experimental Group	Valid	Leve	14	70.	70.	75.
		D	5	25.	25.	100.
		ND	1	5.0	5.0	5.0
		Total	20	100.	100.	

From the results in Tables 23 and 24 it can be seen that:

a. In the *control group* at T1, 63.6% of the group's hips were not level, compared to 40.9% at T3.

b. For the *experimental group* at T1, 55% of the group's hips were not level, compared to 30% at T3.
c. For the *control group* at T1, 63.6% of players' dominant hip was higher than the non-dominant, with none with the non-dominant hip higher than the dominant. At T3, the percentage with a higher dominant hip decreased to 40.9%.
d. In the *experimental group* at T1, 50% of players had a higher dominant hip and 5% a higher non-dominant hip. At T3, the percentage with the higher dominant hip decreased to 25% with the percentage with a higher non-dominant hip staying stable at 5%.

Due to the small sample size, any relationship that might exist between scoliosis and hip height could not be determined by using cross-tabulation with Chi-square analysis.

4.5.5 Kyphosis

Frequency tables were used to determine the percentage of players with kyphosis in both the control and experimental groups at T1 and T3. Results are summarized in Figure 58 below.

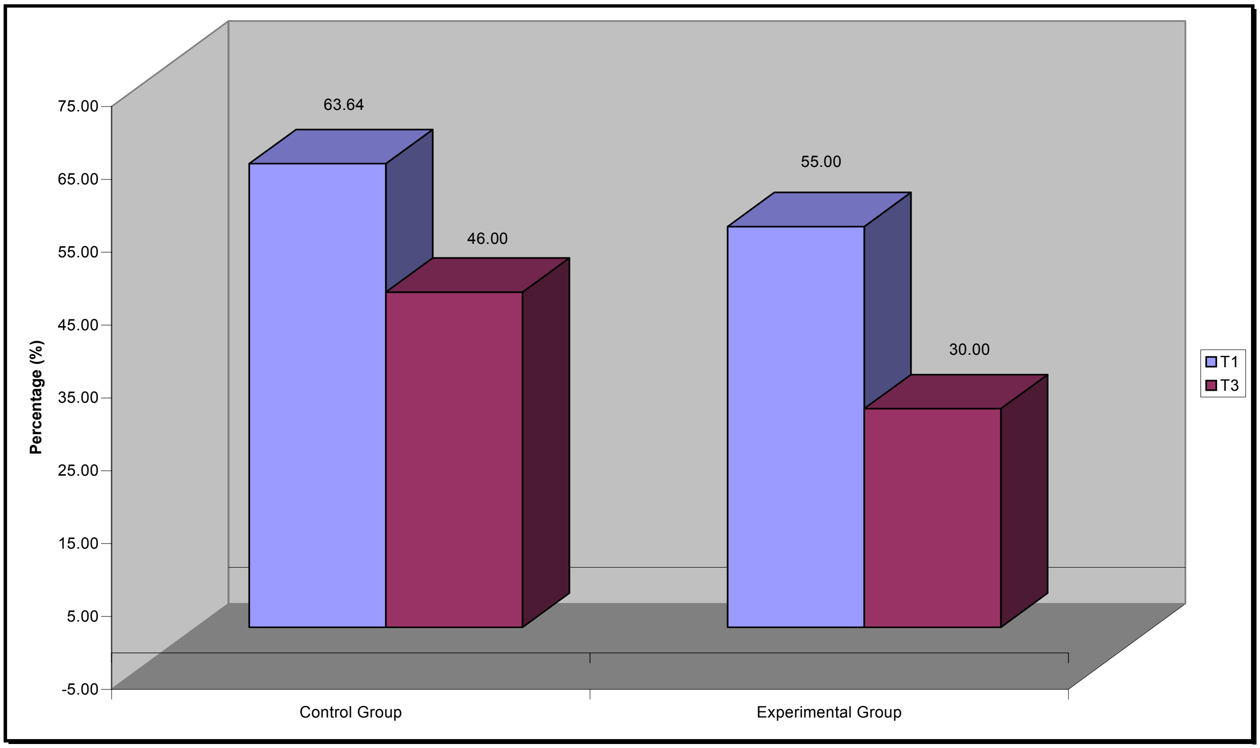

Figure 58: Percentage of players within each group with kyphosis at T1 and **T3.**

From the results in **Figure 58** it can be seen that the percentage of players with kyphosis in both the *control* and *experimental* groups decreased from T1 to T3:

a. In the *control group*, the percentage of players with kyphosis decreased from 63.64% at T1 to 46% at T3.
b. In the *experimental group*, the percentage of players with kyphosis decreased from 55% at T1 to 30% at T3.
c. The percentage of players with kyphosis was higher for the *control group* than for the *experimental group* at both T1 and T3.

4.5.6 Lordosis

Frequency tables were used to determine the percentage of players with lordosis in both the *control* and *experimental* groups at T1 and T3. Results are summarized in **Figure 59** below.

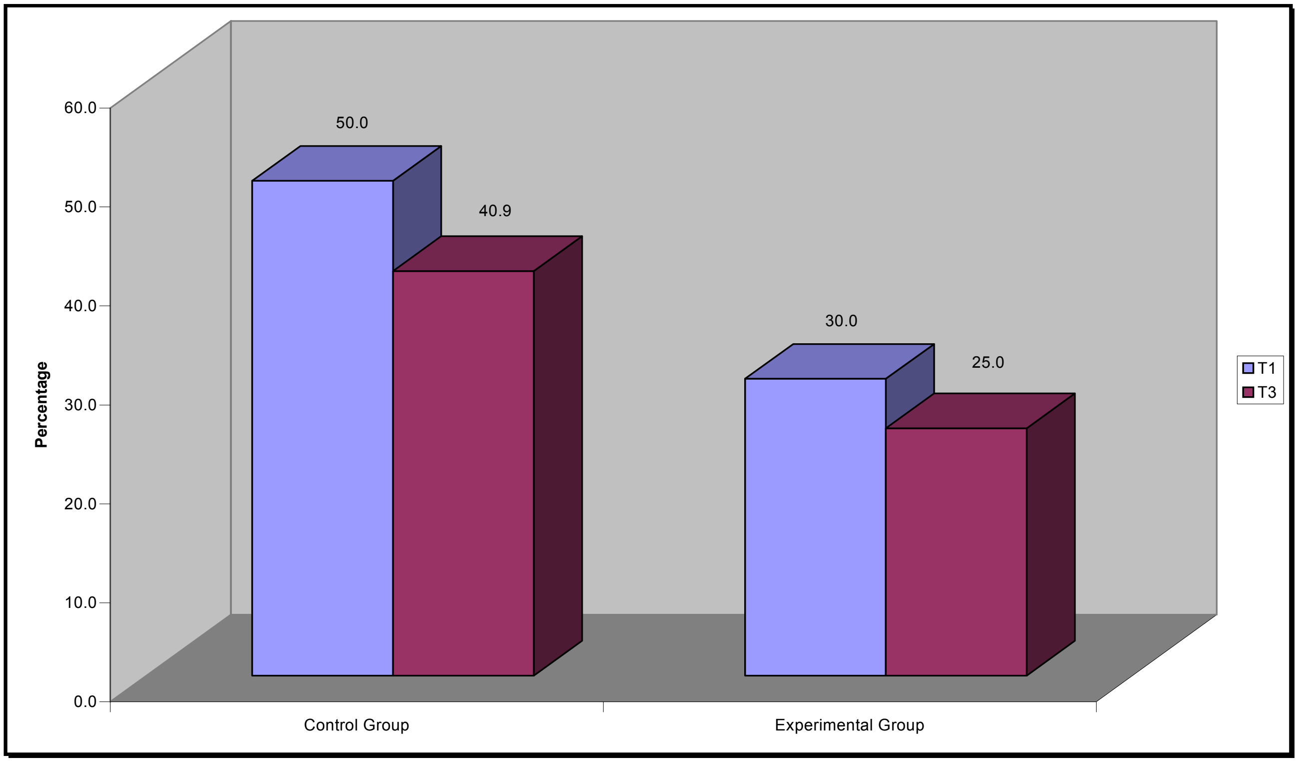

Figure 59: Percentage of players with Lordosis in both groups at T1 and T3.

From **Figure 59,** it can be seen that the percentage of players with lordosis in both the *control* and *experimental groups* decreased from T1 to T3:

a. In the *control group*, the percentage of players with lordosis decreased from 50.0% at T1 to 40.7% at T3.
b. In the *experimental group*, the percentage of players with lordosis decreased from 30% at T1 to 25% at T3.

The percentage of players with lordosis was higher for the *control group* than for the *experimental group* at both T1 and T3.

Discussion:

As mentioned by Skrez (2003) children are involved in competitive sport from an early childhood. The various types of stresses to which they are exposed can effect the growth and the development of their maturing musculoskeletal systems and it could disrupt the normal growth pattern (Skrez, 2003; Walker, 2003). The most serious of all the growth disorders is scoliosis, due to the fact that the body may disform and then inhibit normal bodily organ function (Becker, 1986; Walker, 2003). Katz (2003) and Milan (2003) found that side - bending exercises, as well as trunk rotation exercises could improve the condition of scoliosis. The exercise programme also focused on strengthening of the back in order to perform up to the demands of tennis. This produced an increase in all the normal curves of the spine (Hauser, 1937; Carlson, 2003; Skrzek, 2003). Another aspect taken care of in the programme, is “poor posture”, which is the result of imbalances between the anterior and posterior structures of the back (Katz, 2003). A strong back can withstand the demands made on the back, such as overload (Skrzek, 2003). The programme further focused on strengthening of the non-dominant side of the back and stretching of the dominant side in order to restore normal back curvature. Research done by Becker (1986) and Skrzek (2003) showed that the curvature is usually convex to the dominant arm, due to muscle imbalances (Becker, 1986; Skrzek, 2003).

4.6 GRADES OF INJURIES

Injuries were graded as follows:

a. Grade 1: Old injury – shoulder pain but player kept on playing.
b. Grade 2: New injury – shoulder pain but player kept on playing.
c. Grade 3: Old injury – shoulder injury where player has to stop playing.
d. Grade 4: New injury – shoulder injury where player has to stop playing
e. Grade 5: Old injury – serious shoulder injury where player needs an operation.

f. Grade 6: New injury – serious shoulder injury where player needs an operation.

Frequency tables were used to determine how many injuries (per grade of injury) occurred at each measurement (T1, T2 and T3). A summary of results can be found in Figures 60 and 61 that follow.

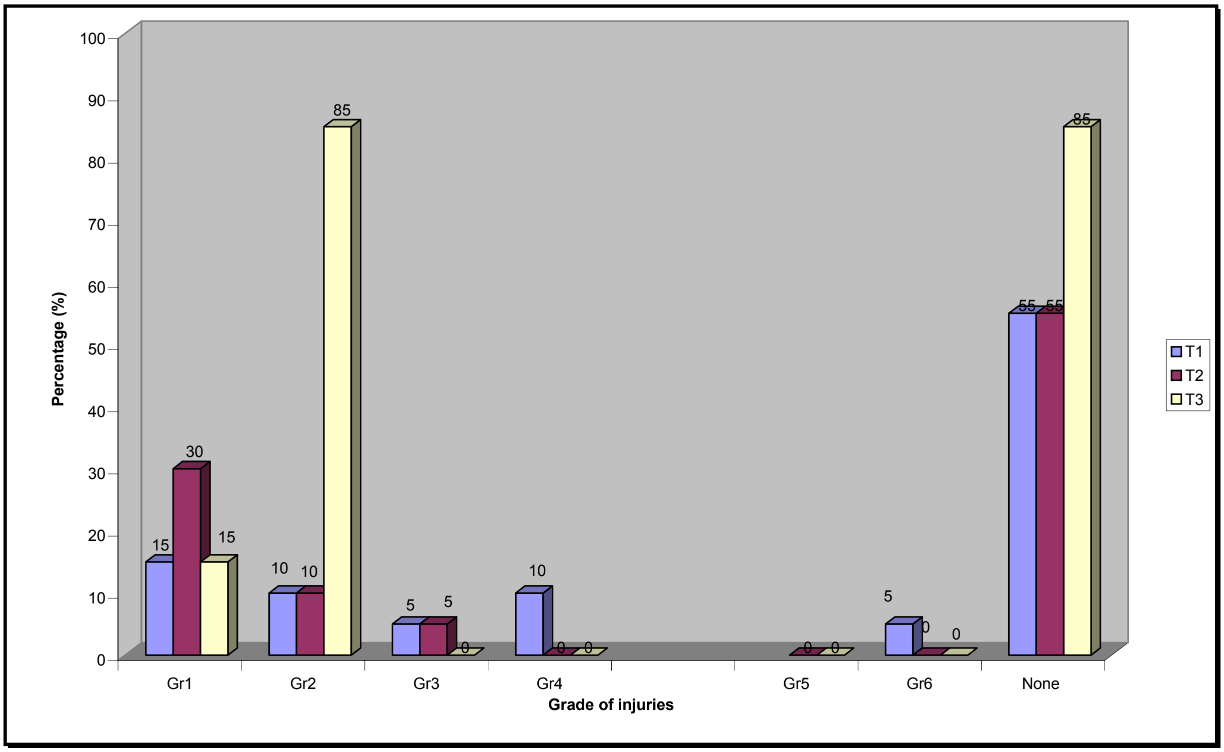

Figure 60: Control group: Grades of shoulder injuries (T1, T2 and T3).

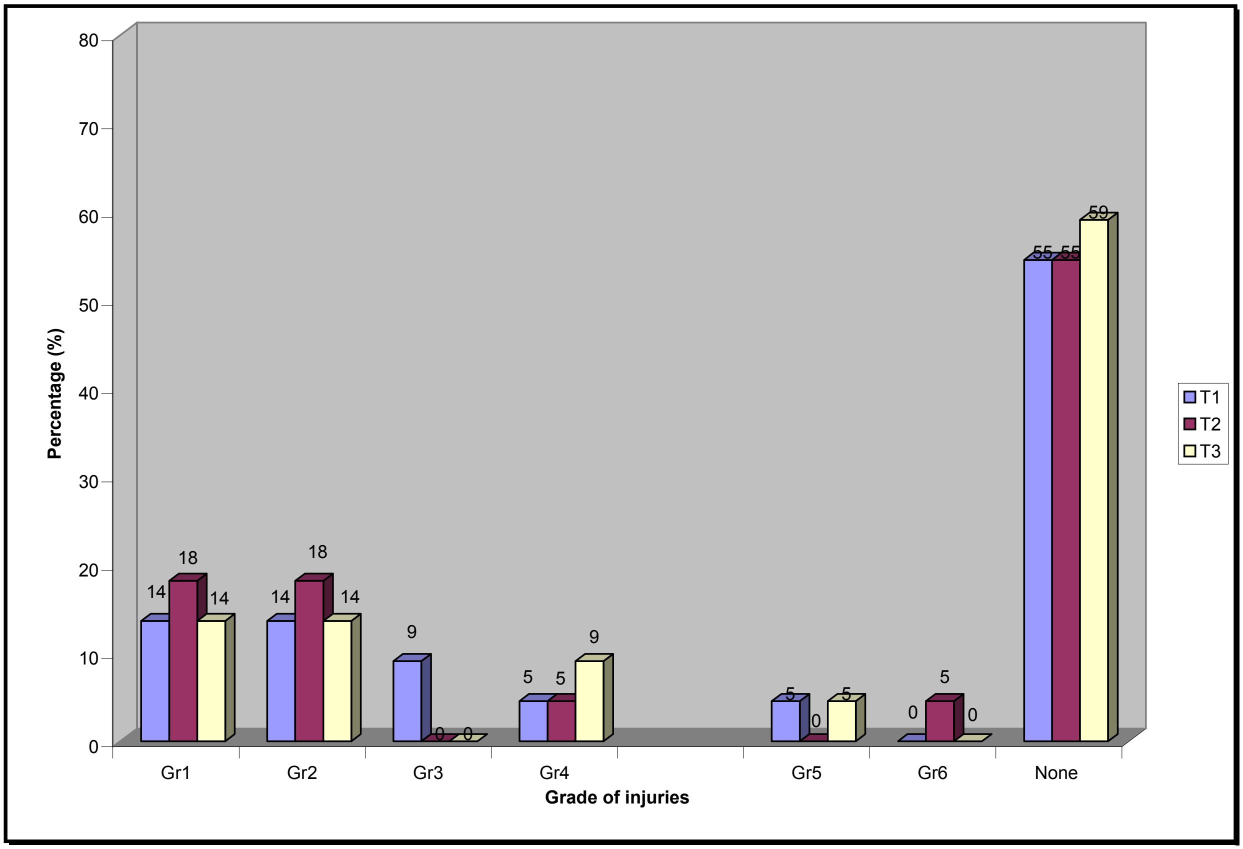

Figure 61: Experimental group: Grades of shoulder injuries (T1,T2 and T3).

The results in Figures 60 and 61 show the following:

a. No injuries:

In the ***control group*****:**

- the players with no injuries stayed stable from T1 (54.5%) to T2 (54.5%) where after it increased to 59.1% at T3;

In the ***experimental group***:

- the players with no injuries stayed stable from T1 (55.0%) to T2 (55.0%) where after it increased to 85% at T3.

Discussion:

Both the control and the experimental group showed a decrease in injuries towards T3, with the experimental group showing a much greater improvement with fewer injuries occurring. According to Reece *et al*. (1986), Kibler *et al*. (1988), Lehman (1988), Schmidt-Wiethoff *et al*., (2000); and Roetert (2003), 80% of all tennis injuries are caused by overuse. Intensive research done by Ellenbecker (1995), Roetert & Ellenbecker (1998) and Muller *et al*. (2000) found that there are two major factors leading to overuse injuries in the shoulder of tennis players:

- weak rotator cuff muscles; and
- muscle imbalances.

The training programme of the experimental group focused on sport specific strengthening exercises of the shoulder and rotator cuff muscles. The rotator cuff exercises that were used are described in Chapter 2.7.1. It was recommended that the athletes use low-resistance, high-repetition exercises in strengthening the rotator cuff muscles in order to prevent the body using the larger muscle groups, such as the trapezius and the deltoid (Roetert & Ellenbecker, 1998; Schmidt-Wiethoff *et al*., 2000; Roetert, 2003).

The programme of the experimental group was designed to improve muscle imbalances (Schmidt-Wiethoff *et al*., 2000; Schmidt-Wiethoff *et al*., 2003). Typically in tennis, the anterior muscles of the shoulder and the chest (pectoralis and the anterior deltoids) are stronger than the rotator cuff and the upper back muscles that support the scapula (Roetert & Ellenbecker, 1998). Studies done by Miyashita *et al*. (1980), Yoshizawa *et al*. (1987), Rhu *et al*. (1988) and Ellenbecker *et al*. (2002) show a relative silence of electrical activity in the acceleration muscles during impact with peak activity occurring just prior to impact. The *infraspinatus*, part of the rotator cuff muscles, is the only muscle that remains active during impact while stabilizing the shoulder. According to the analysis done of the shoulder muscles in tennis-specific movements in Chapter 2.4, it is clear that a clinically applicable premise regarding the importance of the rotator cuff and the scapular stabilizers (serratus anterior) can be formulated (Ellenbecker, 1995; Schmidt-Wiethoff *et al*., 2000; Roetert, 2003).

b. Grade 1 and Grade 2:

In the **control group:**

- For both grades 1 and 2 injuries, the percentage of players with these types of injuries was 13.6% at T1, increased to 18.2% at T2, and decreased to 13.6% at T3.

In the **experimental group:**

- 15% of the players 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 players with Grade 2 injuries remained stable at 10.0% from T1 to T2. None of the players had grade 2 injuries at T3.

c. Grade 3:

In the **control group:**

- 9% of players had grade 3 injuries at T1, with none having them at T2 and T3.

In the **experimental group:**

- The percentage of players with Grade 4 injuries remained stable at 5.0% from T1 to T2. None of the players had grade 3 injuries at T3.

d. Grade 4:

In the control group:

- 4.5% of players 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% of players had grade 4 injuries at T1. None of the players had grade 4 injuries at either T2 or T3.

Discussion:

The injured players of the experimental group followed a comprehensive rehabilitation programme that mainly focused on the upper extremity kinetic chain, served to restore normalized joint arthrokinematics and enabled a full return to the repetitive musculoskeletal demands of tennis (Ellenbecker, 1995; Meister, 2000; Ellenbecker *et al*., 2002). These players also had a thorough evaluation of the injured shoulder. This evaluation was complete and specific about the primary diagnosis and the secondary problems that it could cause (Rubin & Kibler, 2002). According to Kibler & Livingston (2001) the goal of a functional rehabilitation programme is to restore normal function. The majority of the rehabilitation exercises were done in the upright position with the feet on the ground in order to restore normal physiology and proprioseption (Rubin & Kibler, 2002; Schmidt-Wiethoff *et al*., 2003). After proximal stability was regained, rehabilitation of the scapula was incorporated, including scapular retraction and depression. Only after the scapular movements were normal, glenohumeral rehabilitation proceeded (Rubin & Kibler, 2002). This included restoration of scapular mobility and rotator cuff activation to restore normal compression. As soon as the player was able to isolate the rotator cuff muscles, rehabilitation was further integrated into the context of the kinetic chain by using closed-chain exercise protocols. In the final phase of rehabilitation plyometric exercises were incorporated in the exercise programme (Ellenbecker *et al*., 2002; Rubin & Kibler, 2002; Schmidt-Wiethoff *et al*., 2003).

e. Grade 5:

In the **control group:**

- 4.5% of players 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 players had grade 5 injuries at T1, T2 or T3.

f. Grade 6:

In the **control group:**

- Both at T1 and at T3, none of the players had Grade 6 injuries. At T2, however, 4.6% of players had grade 6 injuries.

In the **experimental group:**

- 5.0% of players had a grade 6 injury at T1 and none of the players had this type of injury at T2 or T3.

Discussion:

Effective and thorough post-operative rehabilitation is vital for the successful re-entering of the tennis court (Rubin, 2000; Kibler & Livingston, 2001). The recovery period was divided into four phases:

a. The acute phase included the first three weeks of recovery. The main objectives were to control the pain, clear soft tissue restrictions, begin muscle re-education as well as active and active-assisted range of motion exercises (Rubin, 2000; Kibler & Livingston, 2001).
b. The early recovery phase lasted from week 3 to week 6 postoperatively. The goals were to increase range of movement, flexibility, strength, control and endurance as well as to restore the normal kinematics (Rubin, 2000; Sonnery-Cottet *et al*., 2002).
c. The late recovery phase extended from weeks 6 to 12 postoperatively. The objectives were to restore the full range of motion and flexibility, further increase strength, power and endurance through exercises that stress the core-based muscle synergy, and advanced eccentric and concentric scapular stabilization (Sullivan, 2001; Rubin & Kibler, 2002).
d. The functional phase began 3 months post-operatively in conjunction with the coaches' and trainers' sport-specific progressions. The goals were to restore the sport and work specific

kinematics, increase strength, power and endurance to a functional level of play and to restore the required activity specific coordination, speed and agility (Burkhart & Tehrany, 2002; Rubin & Kibler, 2002).