CHAPTER 6: RESULTS AND DISCUSSION

6.1 INTRODUCTION

While some authors present their results first and then discuss these in a separate chapter, the author decided to combine the results and discussion into one comprehensive chapter.

6.2 SUBJECTS

Four hundred and forty four (n=444) South African males from a cross section of the different population groups in South Africa (Black, White, Coloured, Asian, etc.) were used as subjects. No mention was made regarding the different numbers of subjects in each of the race groups. They were all volunteers for becoming pilots in the South African National Defence Force (SANDF). All subjects that reported as volunteers were tested, provided that they were first examined and cleared for testing by the medical doctor. The physical testing took place over a three-year period, according to the regulations laid down by the South African Medical Services (SAMS), in conjunction with the Institute for Aviation Medicine of the SANDF, and the Biokinetics Centre of 1 Military Hospital.

The body composition of the sample group is summarized in Table 6.1. Their ages varied between 16 and 29 years, with the average age being 19.07 years (± 1.91). The average body mass of the subjects was 71.58 kg (± 9.06) and their average height/stature was 178.58 cm (± 5.54). Subjects displayed an average body fat percentage of 9.97% (± 3.21). This value places them in the *"ideal"* range for fat percentage of young adult men according to Carter (1982).

Roughly half the group (n=245) also underwent somatotype testing. These subjects displayed the following somatotype: an endomorphic component of 3.1, a mesomorphic component of 4.3, and an ectomorphic component of 3.2. Thus the average subject was a balanced mesomorph. This research study is the only one to the author's knowledge that reports on somatotype as well as on normative isokinetic strength values.

It may therefore be feasible to suggest that subjects that do not fit the average somatotype of this group (**3.1-4.3-3.2**) may not display similar isokinetic strength values. A possible solution to this problem may lie in comparing a subject's torque produced in Nm, divided by the subject's lean body mass (LBM) in kilograms. However, very few studies have determined their subject's LBM, thus it is suggested that the torque divided by the body mass value (Nm/kg or % BM) be used when comparing a subject's value to that of a normative data base.

Table 6.1: Body composition of subjects.

	Average	Maximum	Minimum	STD	N
Age (years)	19.06	24	17	1.86	439
Body mass (kg)	71.5	95	46	8.7	439
Stature (cm)	178.6	192	160	5.6	439
Percentage body fat (%)	9.9	22.3	5.6	3.04	436
Endomorphy	3.02	9.8	1.1	1.45	240
Mesomorphy	4.3	7.4	0.58	1.22	240
Ectomorphy	3.22	5.9	0.1	1.16	240
X-Component	0.2	4.36	-8.8	2.37	240
Y-Component	2.36	9.0	-6.18	3.04	240

6.3 INTERPRETATION OF TORQUE VALUES

When presenting the results of the present study, it will be compared to those of other researchers in the field. If values differ, the author may offer possible explanations to the phenomenon.

Although both absolute (Nm) and relative (Nm/kg BM) torque values will be presented in the results, the focus will fall on the relative values, especially when proposing normative scales for the given population of this study.

As far as **"normative scales"** are concerned, one should be very cautious. If, for example the object was to establish whether the knee extension torque value of a sedentary person was acceptable, the method would differ from that relating to establishing this same person's ability to partake in elite sport. The author suggests using one of the following methods: When evaluating a non-athlete, one could use the following values to determine whether the score is acceptable or not: **"sample mean plus/minus (±) one standard deviation (STD)** or values that fall between the **15th and 85th percentile.** However, if elite athletes are considered, one could use a variety of other methods, including the following: selecting only those individuals with **scores above** the **"sample mean plus one STD"** or those scores above the **85th percentile.**

To accommodate the above, the STD will be included with the mean torque values and a percentile table will be supplied for each movement pattern that was tested.

6.4 KNEE FLEXION AND EXTENSION

When one compares the knee joint torque results from the present study in Table 6.2 to that of other researchers one observes the following. Gross *et al.* (1989) used a Cybex II dynamometer in testing male subjects of approximately 30 years of age and reported an average knee extension (KE) torque of 240 Nm and 153 Nm for knee flexion (KF). Although they corrected for the effects of gravity, their values were very similar to that of the present study. When one compares the torque values expressed per kilograms body mass reported by Gross *et al.* (1989) to that of the present study, one also finds similar values (KE: 307% vs. 331%, and KF: 196% vs. 222%). A possible reason for the slightly lower relative values reported by Gross *et al.* (1989) could be that their subjects were 6.5 kg heavier on average than the subjects of the present study. They reported a knee flexion/extension ratio of 64% compared to 67.6% for the present study. Krüger *et al.* (1992) reported a knee extension torque value of 238 Nm (338% BM), 127 Nm (183% BM) for knee flexion, and a knee flexion/extension ratio of 54% (all values were corrected for gravity). The slightly lower values for knee flexion and flexion/extension ratio compared to the present study could possibly be attributed to two factors. Firstly, the torque values of Krüger *et al.* (1992) were corrected for gravity, which effectively decreases knee flexion scores. Secondly, Krüger *et al.* (1992) conducted their research on *"inactive"* male subjects (n=536); their subjects

might have displayed lower values for knee flexion (due to inactivity) compared to the mixed group of the present study.

Wyatt & Edwards (1981) studied 50 healthy male subjects with an average age of 29 years and they did not correct for the effects of gravity. They reported a knee extension torque value of 183 Nm (236% BM), a knee flexion value of 130 Nm (168% BM), and a knee flexion/extension ratio of 72%. The lower values reported by this study, compared to that of the present study, could also be attributed to the 6 kg difference in BM (77.6 kg versus 71.6 kg). It is also interesting to note the similarity between the knee flexion/extension ratio of Wyatt & Edwards (72%) and that of the present study (67.6%), since both studies did not correct for gravitational effects.

Ghena *et al.* (1991) used a **Biodex B-2000** to investigate concentric and eccentric knee flexion and extension at **60°/s** in **male, university athletes** (n=100). The dominant side was selected and values were **corrected for gravity**. The average age, height and weight were 20 years, 182 cm, and 76 kg, respectively. Their values were as follows: **concentric** knee flexion (142 Nm and 186% BM), knee extension (260 Nm and 340% BM), and knee flexion/extension (55%).

Schlinkman (1984) reported very similar values at **60°/s** compared to that of Krüger *et al.* (1992) and Ghena *et al.* (1991). Their values were 127 Nm and 179% BM for

knee flexion, 235 Nm and 338% BM for knee extension, and a flexion/extension ratio of 54%. They used a **Cybex II** dynamometer and **corrected for the effects of gravity**. Their subjects consisted of male, **high school football players** (n=342) with an average age of 16 years. Thus, it may seem that the subjects from the study of Krüger *et al.* (1992), although reported as inactive, compared favourably to these football players tested by Schlinkman (1984).

It is clear that the ratio of 72%, reported by Wyatt & Edwards (1981) and the 67.6% reported by the present study is much higher than that of the abovementioned researchers, who took the effects of gravity into consideration (Krüger *et al.*, 1992; Ghena *et al.*, 1991; Schlinkman, 1984). It was only the knee flexion/extension value (64%), reported by Gross *et al.* (1989), that did not agree with these low ratios (54% to 55%). When comparing the data of Krüger *et al.* (1992) and that of Gross *et al.* (1989), a possible explanation lies in the fact that the subjects of Krüger *et al.* (1992) displayed much higher knee extension torque values compared to Gross *et al.* (1989) (238 Nm vs. 198 Nm). Even when the torque values are expressed relative to percentage BM, the trend still holds (338% BM vs. 272% BM). Seen together with the fact that the knee flexion values are fairly similar (127 Nm vs. 134 Nm, and 183% BM vs. 184% BM), one might think that the subjects of Krüger *et al.* (1992) were more athletically inclined than those of Gross *et al.* (1989).

In conclusion, the present study's torque values and flexion/extension ratio are higher than most of the previously reported normative studies. A possible explanation for this may be the extremely high levels of motivation displayed by subjects in the present study (they were all competing for selection as Air Force pilots), and the fact that no corrections were made for gravity (which led to elevated knee flexion torque values and the high knee flexion/extension ratio).

Table 6.2: Knee flexion and extension torque at 60°/s (NGC).

Movement pattern	Average	Maximum	Minimum	STD	N
Knee flexion					
Peak torque (Nm)	158.5	256	91	26.1	438
Peak torque/BM (%)	222.5	321	145	29.4	438
Peak torque/LBM (%)	246.9	349	164	30.6	435
Knee extension					
Peak torque (Nm)	235.90	358.00	137.00	34.4	438
Peak torque/BM (%)	330.9	428	227	36.3	438
Peak torque/LBM (%)	367.4	493	255	37.4	435
Knee flexion/extension ratio (%)	67.6	103.68	44.56	8.8	438

Table 6.3: Percentile scores for knee flexion and extension at 60°/s

		Knee extension (Nm/kg BM)	Knee flexion (Nm/kg BM)
N	Valid	438	438
	Missing	1	1
Mean		330.9064	222.4909
Median		330	222
Mode		347	214
Percentiles	5	273	173.95
	10	288	185
	15	296.85	192
	20	301	196.8
	25	306.75	201.75
	30	310.7	207
	35	316	211
	40	320.6	214
	45	325	217
	50	330	222
	55	334.45	226
	60	339	230
	65	343	234
	70	347.3	238
	75	356	242.25
	80	361	247
	85	369.15	253
	90	380	259.1
	95	393.05	272.05
	100	428	321

Table 6.4: Percentile scores for knee flexion/extension ratio at 60°/s.

Statistics

		Knee flexion/extension (%)
N	Valid	438
	Missing	1
Mean		67.603
Median		67.175
Mode		66.67(a)
Percentiles	5	54.977
	10	57.474
	15	58.9355
	20	60.238
	25	61.2175
	30	62.294
	35	63.3595
	40	65.142
	45	66.1055
	50	67.175
	55	68.5935
	60	69.37
	65	70.35
	70	71.819
	75	72.6475
	80	73.686
	85	74.733
	90	77.335
	95	83.2855
	100	103.68

a Multiple modes exist. The smallest value is shown

6.5 ANKLE PLANTAR AND DORSIFLEXION

No research study fitting the **criteria** for a **normative database** was found in the literature for ankle plantar and dorsiflexion at 30°/s with the knee straight **(0° knee flexion).** However, Fugl-Meyer (1981) conducted some research on inactive subjects and competitive athletes. He reported the following values for **inactive**

subjects and **athletes**, respectively: ankle dorsiflexion (33 Nm & 47% BM vs. 35 Nm & 47%), plantar flexion (126 Nm & 180% BM vs. 184 Nm & 245% BM), and dorsi/plantar flexion (26% vs. 19%). The author's results (Table 6.3) compares well with that of the inactive population of Fugl-Meyer (1981): dorsiflexion (36 Nm & 52% BM), plantar flexion (131 Nm & 186% BM), and a dorsi/plantar flexion ratio of 29%.

Table 6.5: Ankle plantar and dorsiflexion torque at 30°/s (knee and hip straight) (NGC).

Movement pattern	Average	Maximum	Minimum	STD	N
Ankle dorsiflexion:					
Peak torque (Nm)	36.3	55	17	6.4	219
Peak torque/BM (%)	51.6	75	22	8.4	219
Peak torque/LBM (%)	57.3	82	31	8.9	219
Ankle plantar flexion:					
Peak torque (Nm)	131.2	229	57	27.5	219
Peak torque/BM (%)	186.3	280	61	34.4	219
Peak torque/LBM (%)	206.5	302	78	36.7	219
Ankle dorsi/plantar flexion ratio (%)	28.8	80.7	14.8	8.2	215

Table 6.6: Percentile scores for ankle dorsi and plantar flexion at 30°/s.

		Ankle plantar flexion (Nm/kg BM) 0° knee flexion	Ankle dorsi flexion (Nm/kg BM) 0° knee flexion
N	Valid	201	201
	Missing	238	238
Mean		186.6119	70.8607
Median		187	70
Mode		175.00(a)	48.00(a)
Percentiles	5	135.2	41.1
	10	144	44.4
	15	148.3	48
	20	159	49.4
	25	163	53
	30	168	57.6
	35	174	60
	40	177	62
	45	184	67
	50	187	70
	55	191.1	74.1
	60	194	77
	65	197	82
	70	200	84.4
	75	207.5	87.5
	80	214.6	91
	85	225.7	94
	90	237	98.8
	95	245.8	114
	100	280	129

Table 6.7: Percentile scores for ankle dorsi/plantar flexion ratio at 30°/s (knee and hip straight).

		Ankle dorsi/plantar flexion (%) 0° knee flexion
N	Valid	215
	Missing	224
Mean		28.8763
Median		28.14
Mode		23.03(a)
Percentiles	5	19.102
	10	20.352
	15	21.494
	20	22.736
	25	23.28
	30	24.124
	35	25.336
	40	26.094
	45	27.054
	50	28.14
	55	28.818
	60	29.44
	65	30.18
	70	30.862
	75	32.43
	80	33.848
	85	34.996
	90	38.406
	95	43.406
	100	80.7

Following the author's proposed method for determining the **"normality"** of a person's ankle dorsi- and plantar flexion torque values at 0° of knee and hip flexion, the following recommendations are made: ankle dorsiflexion torque relative to BM should be between 47% BM and 95% BM. Ankle plantar flexion should be between 152% BM and 221% BM, and the ankle dorsi/plantar flexion ratio should be between 21% and 37%.

6.6 ELBOW FLEXION AND EXTENSION

6.6.1 Ninety degree pronated handgrip-position (90°)

The present study utilized two different grip positions for elbow flexion and extension testing. The first grip position was with the forearm in 90° of pronation. No normative data was found for this grip position. Thus, the normative data from the present study (Table 6.5) may be a first step in establishing population-specific normative scales for elbow flexion and extension, using a 90°-pronated grip position.

Table 6.8: Elbow flexion and extension torque (NGC) at 60°/s (forearm pronated to 90°).

Movement pattern	Average	Maximum	Minimum	STD	N
Elbow flexion:					
Peak torque (Nm)	48.5	76	27	9.6	234
Peak torque/BM (%)	69.1	102	43	10.9	234
Peak torque/LBM (%)	76.7	110	48	11.8	234
Elbow extension:					
Peak torque (Nm)	60.6	110	33	14.2	234
Peak torque/BM (%)	86.0	133	46	15.9	234
Peak torque/LBM (%)	95.5	150	51	17.5	234
Elbow flexion/extension ratio (%)	81.8	134.3	50.8	14.0	234

Table 6.9: Percentile scores for elbow flexion and extension at 60°/s (90°-pronated handgrip).

		Elbow extension (Nm/kg) 90° pronated grip	Elbow flexion (Nm/kg) 90° pronated grip
N	Valid	234	234
	Missing	205	205
Mean		86.04	69.08
Median		85.135	68.966
Mode		86	70
Percentiles	5	61	51
	10	67	55
	15	70	58
	20	72	60
	25	75	62
	30	77	63
	35	79	65
	40	82	66
	45	83	67
	50	85	69
	55	87	70
	60	89	71
	65	91	73
	70	93	75
	75	96	77
	80	99	78
	85	101	80
	90	104	83
	95	117	87
	100	133	102

Table 6.10: Percentile scores for elbow flexion/extension ratio at 60°/s (90°-pronated handgrip).

		Elbow flexion/extension (%) 90° pronated grip
N	Valid	234
	Missing	205
Mean		81.8106
Median		80.7
Mode		100
Percentiles	5	60.68
	10	65.8
	15	67.305
	20	69.7
	25	71.335
	30	73.97
	35	76.185
	40	77.5
	45	79.17
	50	80.7
	55	82.155
	60	83.64
	65	86.0825
	70	87.8
	75	89.83
	80	92.73
	85	96
	90	100
	95	108.04
	100	134.29

Following the author's proposed method for determining the **"normality"** of a person's elbow flexion and extension torque values using a 90° pronated grip, the following recommendations are made: elbow flexion torque relative to BM should be between 58% BM and 80% BM. Elbow extension should be between 70% BM and 102% BM, and the elbow flexion/extension ratio should be between 68% and 96%.

6.6.2 Anatomical zero handgrip-position (AZ)

The second grip position for elbow testing was in the anatomical zero (AZ) position. Knapik & Ramos (1980) used a similar grip position and conducted research on 352 **infantry soldiers** at 0, **30, 90, and 180**°/s. They used a Cybex II dynamometer and **did not correct for the effects of gravity**. Their subjects (24 years, 176 cm, 74 kg) were all **males**. They reported that elbow flexion peak torque was 50 Nm (67% BM), extension peak torque was 44 Nm (59% BM), and the flexion/extension ratio was 114% (at 30°/s). The results of the present study (Table 6.6) for elbow flexion (56.5 Nm & 77.7% BM), elbow extension (48.4 Nm & 66.5% BM), and the flexion/extension ratio (119%) compare favourably to that of Knapik & Ramos (1980), and could thus be used as a normative scale for young adult men.

Table 6.11: Elbow flexion and extension torque (NGC) at 60°/s (forearm in anatomical zero position).

Movement pattern	Average	Maximum	Minimum	STD	N
Elbow flexion:					
Peak torque (Nm)	56.52	91.00	28.00	11.14	199
Peak torque/BM (%)	77.71	121.43	47.95	12.42	199
Peak torque/LBM (%)	86.4	131	55	13.2	196
Elbow extension:					
Peak torque (Nm)	48.38	84.00	24.00	10.85	199
Peak torque/BM (%)	66.47	110.00	39.13	12.48	199
Peak torque/LBM (%)	73.9	121	46	13.5	196
Elbow flexion/extension ratio (%)	119.02	178.57	77.03	19.82	199

Following the author's proposed method for determining the **"normality"** of a person's elbow flexion and extension torque values using an AZ-grip, the following recommendations are made: elbow flexion torque relative to BM should be between 65% BM and 90% BM. Elbow extension should be between 54% BM and 79% BM, and the elbow flexion/extension ratio should be between 99% and 139%.

Table 6.12: Percentile scores for elbow flexion and extension at 60°/s (AZ handgrip position).

		Elbow extension (Nm/kg BM) AZ grip	Elbow flexion (Nm/kg BM) AZ grip
N	Valid	199	199
	Missing	240	240
Mean		66.47	77.6935
Median		64.384	77.307
Mode		63	77.00(a)
Percentiles	5	49	58
	10	52	62
	15	55	66
	20	58	67
	25	59	69
	30	60.5	71
	35	61	73
	40	62	74
	45	63	76
	50	64	77
	55	66	79
	60	68	80
	65	70	82
	70	71	83
	75	73	85
	80	75	87
	85	76	90
	90	82	93
	95	92	99
	100	110	121

Table 6.13: Percentile scores for elbow flexion/extension ratio at 60°/s (AZ handgrip position).

		Elbow flexion/extension (%) AZ grip
N	Valid	199
	Missing	240
Mean		119.02%
Median		118.60%
Mode		100.00%
Percentiles	5	86.00%
	10	93.10%
	15	98.18%
	20	101.89%
	25	105.00%
	30	108.06%
	35	109.43%
	40	112.50%
	45	116.67%
	50	118.60%
	55	121.43%
	60	123.68%
	65	126.42%
	70	128.21%
	75	131.03%
	80	135.90%
	85	140.91%
	90	146.15%
	95	151.43%
	100	178.57%

6.7 FOREARM SUPINATION AND PRONATION

Very few researchers have studied isokinetics of the forearm movements, and no normative database could be found. However, Ellenbecker (1991) tested the forearms of 22 highly skilled adult tennis players at 90°/s, 210°/s, and 300°/s. He reported a forearm pronation torque of 11.9 Nm (19.4% BM), a forearm supination value of 11.7 Nm (19% BM), and a supination/pronation ratio of 98% for the non-dominant side at 90°/s. The average forearm pronation value of the present study of 18 Nm (25% BM), 13 Nm (18% BM) for supination, and 74% for the supination/pronation ratio at a velocity of 30°/s (Table 6.7) does not differ substantially from that of Ellenbecker (1991).

In the absence of other normative data on the forearm's supination and pronation torque (Perrin, 1993), the results of the present study may be used as a normative scale for young adult men.

Table 6.14: Forearm supination and pronation torque (NGC) at 30°/s.

Movement pattern	Average	Maximum	Minimum	STD	N
Forearm supination:					
Peak torque (Nm)	12.97	23.00	8.00	2.56	199
Peak torque/BM (%)	17.94	26.35	10.59	3.18	196
Peak torque/LBM (%)	19.9	29	12	3.5	196
Forearm pronation:					
Peak torque (Nm)	17.97	31.00	9.00	3.73	199
Peak torque/BM (%)	24.88	46.97	10.59	4.81	196
Peak torque/LBM (%)	27.6	51	13	5.1	196
Forearm supination/pronation ratio (%)	73.83	121.42	47.62	2.24	199

Table 6.15: Percentile scores for forearm supination and pronation at 30°/s.

		Forearm pronation (Nm/kg BM)	Forearm supination (Nm/kg BM)
N	Valid	199	199
	Missing	240	240
Mean		24.8392	17.9196
Median		25	18
Mode		21	18
Percentiles	5	18	13
	10	19	14
	15	20	15
	20	21	15
	25	21	16
	30	22	16
	35	23	16
	40	23	17
	45	24	17
	50	25	18
	55	25	18
	60	26	19
	65	26	19
	70	27	19
	75	28	20
	80	29	21
	85	30	21
	90	31	22
	95	33	24
	100	47	26

Table 6.16: Percentile scores for forearm supination/pronation ratio at 30°/s.

Statistics

		Forearm supination/pronation (%)
N	Valid	199
	Missing	240
Mean		73.82%
Median		71.43%
Mode		100.00%
Percentiles	5	52.63%
	10	56.52%
	15	58.82%
	20	60.87%
	25	62.50%
	30	63.16%
	35	66.67%
	40	68.42%
	45	70.00%
	50	71.43%
	55	75.00%
	60	75.00%
	65	76.47%
	70	80.00%
	75	83.33%
	80	85.71%
	85	92.86%
	90	100.00%
	95	100.00%
	100	121.43%

Following the author's proposed method for determining the **"normality"** of a person's forearm pronation and supination torque values, the following recommendations are made: forearm pronation torque relative to BM should be between 20% BM and 30% BM. Forearm supination should be between 15% BM and 21% BM, and the forearm supination/pronation ratio should be between 59% and 89%.

6.8 SHOULDER HORIZONTAL ABDUCTION AND ADDUCTION

Weir *et al.* (1992) conducted research on 104 **male high school wrestlers** between the ages of 16 and 18, using a **Cybex II** dynamometer. The dominant side was evaluated and the damp setting was two (gravity was not corrected for). Test speeds of 30, 180, and 300°/s were included. The resultant values for **30°/s** were as follows: concentric shoulder horizontal abduction: 68 Nm (100% BM), horizontal adduction: 74 Nm (106% BM), and a horizontal shoulder abduction/adduction ratio of 93%. The values of the present study (Table 6.8) were slightly higher in all respects: horizontal shoulder abduction was 93 Nm (131% BM), horizontal shoulder adduction was 92 Nm (129% BM), and the horizontal abduction/adduction ratio was 101%.

Taking into account that the test velocity was 60°/s for the present study, the values reported by Weir *et al.* (1992) at a test velocity of 30°/s, are very similar to those of the present study.

Table 6.17: Shoulder horizontal abduction and adduction torque at 60°/s (NGC).

Movement pattern	Average	Maximum	Minimum	STD	N
Shoulder horizontal abduction:					
Peak torque (Nm)	93.4	210	50	27.06	103
Peak torque/BM (%)	132	266	72	34.73	103
Peak torque/LBM (%)	145.5	286	80	236.9	103
Shoulder horizontal adduction:					
Peak torque (Nm)	91.8	184	40	23.46	103
Peak torque/BM (%)	129.5	261	73	27.87	103
Peak torque/LBM (%)	142.9	279	78	29.7	103
Shoulder abduction/adduction ratio (%)	101.3	186	53.4	21.9	103

Table 6.18: Percentile scores for shoulder abduction and adduction at 60°/s.

Statistics

		Shoulder horizontal adduction (Nm/kg BM)	Shoulder horizontal abduction (Nm/kg BM)
N	Valid	103	103
	Missing	336	336
Mean		129.466	131.9612
Median		126	126
Mode		95.00(a)	102
Percentiles	5	93.4	83.2
	10	95.4	97.4
	15	102.2	102
	20	104	104.8
	25	111	109
	30	114.4	113.2
	35	116.4	116.4
	40	120.6	118.6
	45	122.8	122
	50	126	126
	55	131	128
	60	133.4	131
	65	137	138.8
	70	140	144
	75	146	148
	80	153.2	150
	85	156	162
	90	162.8	178.6
	95	175.8	205.2
	100	261	266

a Multiple modes exist. The smallest value is shown

Table 6.19: Percentile scores for shoulder horizontal abduction/adduction ratio at 60°/s.

		Shoulder horizontal adduction/abduction (%)
N	Valid	103
	Missing	336
Mean		101.2836
Median		100
Mode		100
Percentiles	5	67.04
	10	76.672
	15	80.276
	20	85.632
	25	88.51
	30	91.022
	35	93.264
	40	95.75
	45	97.652
	50	100
	55	101.306
	60	102.522
	65	106.932
	70	109.322
	75	110.99
	80	114.364
	85	117.958
	90	129.94
	95	145
	100	185.96

Following the author's proposed method for determining the **"normality"** of a person's shoulder horizontal abduction and adduction torque values, the following recommendations are made: shoulder horizontal abduction torque relative to BM should be between 98% BM and 167% BM. Shoulder horizontal adduction should

be between 102% BM and 157% BM, and the shoulder horizontal adduction/abduction ratio should be between 79% and 123%.

6.9 SHOULDER FLEXION AND EXTENSION

At **60°/s concentric** shoulder flexion and torques varied from 65 Nm (Cahalan *et al.*, 1991), to 62 Nm (Ivey *et al.*, 1985), and extension values from 80 Nm (Ivey *et al.*, 1985), to 122 Nm (Cahalan *et al.*, 1991). Torque relative to bodyweight (BM) varied between 80% (Cahalan *et al.*, 1991) and 76% (Ivey *et al.*, 1985) for shoulder flexion, and between 97% (Ivey *et al.*, 1985) and 150% (Cahalan *et al.*, 1991) for shoulder extension. These two authors reported flexion/extension ratios of between 53% (Cahalan *et al.*, 1991) and 77% (Ivey *et al.*, 1985). Both these researchers used a **Cybex II** dynamometer, **did not correct for gravity**, used **healthy males** between the ages of 21 and 50 years, and their sample consisted of 36 (Ivey *et al.*, 1985) and 26 (Cahalan *et al.*, 1991) subjects. When the author pooled (n=62) the data, the following values were obtained: shoulder flexion 64 Nm (78% BM), shoulder extension 101 Nm (123% BM), and a flexion/extension ratio of 65%. These values correspond closely to those reported by Freedson *et al.* (1993) on males between the ages of 21 and 30 years: shoulder flexion: 62 Nm, shoulder extension: 98 Nm, and flexion/extension ratio: 63%. Shklar & Dvir (1995) reported the following values at 60°/s: a shoulder flexion value of 61 Nm, a shoulder extension value of 85 Nm, and a flexion/extension ratio of 72%.

The author's shoulder flexion peak torque of 81 Nm (113.5% BM) is higher (Table 6.9) than that reported previously in the literature, while the 87.5 Nm (123% BM) for shoulder extension compares favourably. The flexion/extension ratio (94%) of the present study is also higher than that of previous studies (Ivey *et al.*, 1985; Calahan *et al.*, 1991; Freedson *et al.*, 1993; Shklar & Dvir, 1995). The reason for this finding is unclear and warrants further investigation.

Table 6.20: Shoulder flexion and extension torque (NGC) at 60°/s (90° pronated grip).

Movement pattern	Average	Maximum	Minimum	STD	N
Shoulder flexion:					
Peak torque (Nm)	80.5	137	44	19.0	116
Peak torque/BM (%)	113.9	191	79	21.8	116
Peak torque/LBM (%)	125.9	204	85	123.5	116
Shoulder extension:					
Peak torque (Nm)	87.2	138	40	19.8	116
Peak torque/BM (%)	123.3	182	53	21.1	116
Peak torque/LBM (%)	136.3	205	61	22.6	116
Shoulder flexion/extension ratio (%)	93.9	230	59	20.0	116

Table 6.21: Percentile scores for shoulder flexion and extension at 60°/s.

Statistics

		Shoulder flexion (Nm/kg BM) 90° pronated grip	Shoulder extension (Nm/kg BM) 90° pronated grip
N	Valid	116	116
	Missing	323	323
Mean		113.8534	123.2845
Median		112.5	120
Mode		94.00(a)	109
Percentiles	5	84.85	89.55
	10	88	99.4
	15	93.55	104.55
	20	94.4	109
	25	97	109
	30	100.1	111.2
	35	103.95	114
	40	105	116.8
	45	109	119
	50	112.5	120
	55	113.35	123
	60	118	126
	65	120	128
	70	122	130.9
	75	126	135.75
	80	130	139
	85	133.45	145.35
	90	143.3	155
	95	157.15	163.3
	100	191	182

a Multiple modes exist. The smallest value is shown

Table 6.22: Percentile scores for shoulder flexion/extension ratio at 60°/s.

		Shoulder flexion/extension (%)
N	Valid	116
	Missing	323
Mean		93.8557
Median		93.1
Mode		100
Percentiles	5	69.747
	10	75.305
	15	77.1845
	20	78.242
	25	80.625
	30	83.205
	35	85.652
	40	89.222
	45	90.7525
	50	93.1
	55	93.977
	60	95.152
	65	96.6385
	70	100
	75	101.385
	80	104.49
	85	107.5
	90	111.217
	95	123.7715
	100	230

Following the author's proposed method for determining the **"normality"** of a person's shoulder flexion and extension torque values using a 90° pronated grip, the following recommendations are made: shoulder flexion torque relative to BM should be between 92% BM and 136% BM. Shoulder extension should be

between 102% BM and 144% BM, and the shoulder flexion/extension ratio should be between 74% and 114%.

6.10 SHOULDER INTERNAL AND EXTERNAL ROTATION

Ivey *et al.* (1985), Connelly Maddux *et al.* (1989), and Cahalan *et al.* (1991) conducted research at **60°/s** using the **Cybex II** dynamometer. They **did not correct for the effects of gravity** and their subjects were **males** between the ages of 21 and 50 years. The subjects were positioned with their shoulders in 90° of abduction. They reported the values for concentric shoulder internal rotation between 46 Nm and 53 Nm (57-66% BM), between 26 Nm and 33 Nm (32-39% BM) for shoulder external rotation, with external/internal rotation values between 57% and 65%.

The author's shoulder external rotation torque values are higher than those reported previously (Ivey *et al.* (1985); Connelly Maddux *et al.* (1989); Cahalan *et al.* (1991), but the internal rotation values are very similar. Due to the higher external rotation values, the shoulder external/internal rotation ratio of the present study is also higher: 80% (see Table 6.10).

Table 6.23: Shoulder internal and external rotation torque at 60°/s (90°-abducted shoulder position) (NGC).

Movement pattern	Average	Maximum	Minimum	STD	N
Shoulder external rotation:					
Peak torque (Nm)	39.3	80	20	9.3	239
Peak torque/BM (%)	55.7	85	34	10.6	239
Peak torque/LBM (%)	61.7	97	37	11.4	237
Shoulder internal rotation:					
Peak torque (Nm)	50.6	88	27	12.7	239
Peak torque/BM (%)	71.6	114	40	14.9	239
Peak torque/LBM (%)	79.4	124	43	16.3	237
Shoulder external/internal rotation ratio (%)	79.6	187.9	48.9	18.1	239

Table 6.24: Percentile scores for shoulder external and internal rotation at 60°/s.

		Shoulder external rotation (Nm/kg BM) 90° abducted pos.	Shoulder internal rotation (Nm/kg BM) 90° abducted pos.
N	Valid	239	239
	Missing	200	200
Mean		55.7029	71.7573
Median		55	72
Mode		57	72.00(a)
Percentiles	5	39	48
	10	42	52
	15	44	56
	20	47	59
	25	49	61
	30	50	63
	35	51	65
	40	53	68
	45	54	70
	50	55	72
	55	57	73
	60	58	75
	65	59	76
	70	61	79
	75	62	82
	80	64	85
	85	67	88
	90	70	91
	95	75	96
	100	85	114

Table 6.25: Percentile scores for shoulder external/internal rotation at 60°/s.

Statistics

		Shoulder external/internal rotation (%) 90° abducted pos.
N	Valid	239
	Missing	200
Mean		79.629
Median		77.14
Mode		66.67(a)
Percentiles	5	58.46
	10	61.36
	15	64.18
	20	66.67
	25	68.42
	30	69.74
	35	71.74
	40	73.08
	45	75
	50	77.14
	55	78.57
	60	81.13
	65	82.61
	70	84.38
	75	87.01
	80	89.47
	85	92.11
	90	98.04
	95	107.55
	100	187.88

a Multiple modes exist. The smallest value is shown

Following the author's proposed method for determining the **"normality"** of a person's shoulder external and internal rotation torque values using an AZ-grip position, the following recommendations are made: shoulder external rotation torque relative to BM should be between 45% BM and 66% BM. Shoulder internal

rotation should be between 57% BM and 87% BM, and the shoulder external/internal rotation ratio should be between 62% and 98%.

6.11 SUMMARY OF NORMATIVE VALUES

To present the results in a normative fashion, the following tables have been constructed for the different movement patterns that were tested.

Table 6.26: Normative values for knee flexion and extension torque at 60°/s (NGC).

Knee flexion & extension	AVG (%BM)	AVG ±1STD	15th %tile	85th %tile
Knee flexion (Nm/kg)	223	193-251	192	253
Knee extension (Nm/kg)	331	294-366	297	369
Knee flexion/extension ratio (%)	68	59-76	59	75

As is very clear from the above table, the average plus/minus one STD values correspond very closely to that of the 15th and 85th percentiles. The author thus decided to omit the percentile values from the summary tables. The percentile tables of each joint are available in the discussion above.

Thus, the subsequent tables present normative values in two ways:

- as the sample mean or average value **(AVG)**; and
- as the mean ± one standard deviation **(± 1STD)**.

The inclusion of the **AVG ± 1STD notation** was the result of each movement pattern having a **"normal distribution"**. This was tested statistically before reporting on each movement pattern; since all results of the movement patterns were normally distributed, the author decided to use this notation for the establishment of the relevant isokinetic norms or normal values in this population.

Table 6.27: Normative values for ankle dorsi and plantar flexion torque at 30°/s.

Ankle dorsi & plantar flexion	AVG (%BM)	AVG ±1STD
Ankle dorsiflexion (Nm/kg)	36	47–95
Ankle plantar flexion (Nm/kg)	131	152–221
Ankle dorsi/plantar flexion (%)	29	21–37

Table 6.28: Normative values for elbow flexion and extension torque at 60°/s using the (1) 90°-pronated and (2) AZ-handgrip.

Elbow flexion & extension	AVG (%BM)	AVG ±1STD
(1) 90°-pronated handgrip		
Elbow flexion (Nm/kg)	69	58-80
Elbow extension (Nm/kg)	86	70-102
Elbow flexion/extension ratio (%)	82	68-96
(2) AZ-handgrip		
Elbow flexion (Nm/kg)	78	65-90
Elbow extension (Nm/kg)	67	54-79
Elbow flexion/extension ratio (%)	119	99-139

Table 6.29: Normative values for forearm supination and pronation torque at 30°/s.

Forearm supination & pronation	AVG (%BM)	AVG ±1STD
Forearm supination (Nm/kg)	13	20-30
Forearm pronation (Nm/kg)	18	15-21
Forearm supination/pronation ratio (%)	74	59-89

Table 6.30: Normative values for shoulder horizontal abduction and adduction torque at 60°/s (NGC).

Shoulder horizontal abduction & adduction	AVG (%BM)	AVG ±1STD
Shoulder horizontal abduction (Nm/kg)	132	98-167
Shoulder horizontal adduction (Nm/kg)	130	102-157
Shoulder horizontal abduction/adduction ratio (%)	101	79-123

Table 6.31: Normative values for shoulder flexion and extension torque at 60°/s (NGC).

Shoulder flexion & extension	AVG (%BM)	AVG ±1STD
Shoulder flexion (Nm/kg)	114	92-136
Shoulder extension (Nm/kg)	123	102-144
Shoulder flexion/extension ratio (%)	94	74-114

Table 6.32: Normative values for shoulder external and internal rotation torque at 60°/s (90°-abducted shoulder position).

Shoulder external & internal rotation	AVG (%BM)	AVG ±1STD
Shoulder external rotation (Nm/kg)	56	45-66
Shoulder internal rotation (Nm/kg)	72	57-87
Shoulder external/internal rotation ratio (%)	80	62-98

6.12 Summary

The purpose of the present study was to establish normative isokinetic torque values for young South African men. The shoulder, elbow, forearm, knee, and ankle joints were investigated. This was done by testing 444 young South African men from a cross-section of the different race groups in the country. Although some of the normative values were different to those proposed by other researchers, one should bear in mind that norms are population- and method-specific. To offer conclusive reasons for the differences observed between the torque values of the present study and that of previous studies, would be inappropriate, but clinicians are cautioned that norms are always established for a certain sector of the population and should not be extrapolated to include subjects that fall outside this sub-group or population. In addition, methodological differences like gravity correction, subject positioning, visual feedback, etc., may have a large influence on the eventual results of isokinetic testing.

The author proposes that the established isokinetic norms, will serve to guide biokineticists, physiotherapists, orthopaedic surgeons and other exercise scientists in setting objective and realistic goals for orthopaedic rehabilitation programmes. Furthermore, these normative values may be useful when conducting sport-specific strength screening of young South African men. These norms may then be used as a guideline when evaluating elite or high performance athletes. These norms

may even be used to identify athletes with superior peak torque producing capabilities (i.e. above the 85th percentile). Other applications may include screening workers for job-specific strength demands (for example, operators of heavy tools or machinery).